HOW TO

NOTES

How to Include the Effects of Rising Temperatures in Long-Term GDP Projections

Samuele Centorrino, Emanuele Massetti, Mehdi Raissi, and Filippos Tagklis

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How to Include the Effects of Rising Temperatures in Long-Term GDP Projections

Samuele Centorrino, Emanuele Massetti, Mehdi Raissi, and Filippos Tagklis
November 2025

Climate change threatens macroeconomic and financial stability through rising temperatures, shifting precipitation patterns, sea level rise, and more frequent and intense extreme weather, in addition to other factors. To better assess vulnerabilities and future risks, climate change effects should be integrated in long-term macroeconomic projections. This note shows how to include the effect of rising temperatures into long-term GDP projections using a three-step method: (1) estimating macroeconomic effects of rising temperatures from historical data, (2) building temperature change scenarios from climate model simulations, and (3) integrating impacts into long-term GDP projections. The methodology addresses key empirical challenges and can be leveraged to assess the effects of temperature increases on fiscal variables, including public debt. Impact assessments for 171 countries are available in an online Data Appendix.

Introduction

Climate change impacts can affect both the supply and demand side of economies in several significant ways. On the supply side, higher temperatures can lead to a decrease in output by reducing agricultural crop yields, diminishing labor productivity due to impaired physical and cognitive performance, and increasing rates of mortality and morbidity, for example. More severe droughts are a drag on the economy, especially on agriculture and hydropower electricity generation. More frequent and intense extreme weather events may accelerate capital depreciation and slow capital accumulation. Sea level rise impairs coastal infrastructure and eventually leads to permanent inundation of coastal land. On the demand side, climate change has the potential to change consumption and investment decisions. Higher temperatures might increase energy demand for cooling needs. Higher uncertainty will impact investment decisions of businesses. Overall, the combined effect of all these factors on economic growth could be significant in the long term.

To effectively assess vulnerabilities and future risks, it is crucial to incorporate climate change effects into long-term macroeconomic projections.[1] Overlooking long-term losses from climate change may create an optimistic backdrop for macroeconomic projections and planning. For example, debt sustainability analysis may project optimistic debt-to-GDP ratios and underestimate debt risks. This could happen if climate change reduces future economic output, increases debt, or, most likely, both.

A substantial body of literature has examined the potential effect of climate change on individual economic sectors or on aggregate economic output; however, a broader analysis of macroeconomic risks remains underexplored. Recently, econometric methods have been used to establish connections between various weather indicators and GDP (for example, Dell, Jones, and Olken 2012; Burke, Hsiang, and Miguel 2015; Kalkuhl and Wenz 2020; Kahn and others 2021; Tol 2021; Kotz, Levermann, and Wenz 2024; Akyapi, Bellon,

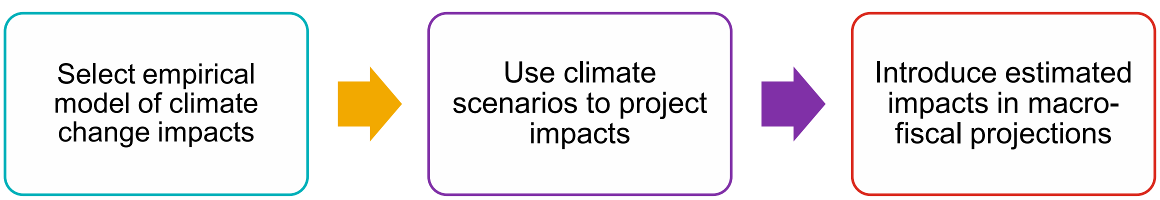
[1] Most macroeconomic forecasts have a 1-to-5-year time horizon, much shorter than the long-term view taken in this analysis. This Note shows how to include the impacts of slow-moving temperature increases into "long-term macroeconomic projections," hereafter referred to as "macroeconomic projections" for brevity.

and Massetti 2025).[2] This relationship is used to project climate change impacts into the distant future using climate scenarios developed by scientists. There is considerably less work on evaluating the effects of climate change on macroeconomic risks and variables beyond GDP, such as government revenue, expenditure, financial conditions, and debt ratios.

Climate change impacts can be integrated into macroeconomic projections by "shocking" GDP or other macroeconomic variables, drawing from estimates in the empirical literature under alternative climate scenarios. For example, one can use the GDP impact associated with each unit of temperature increase, as documented in existing studies, in conjunction with temperature scenarios to adjust GDP projections. The percent deviations of GDP from the baseline, or the "shock," can prompt adjustments to other variables within a macroeconomic framework. A key distinction is that long-term macroeconomic analyses must focus on *climate change*, which is a "change in the state of the climate that can be identified (for example, by using statistical tests) by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer (IPCC, 2021, Annex VII)," rather than on weather.[3] Unlike climate change impacts, which manifest gradually and lead to a continuous decline in macroeconomic conditions, weather shocks produce immediate and potentially large consequences, although the economy typically returns to its equilibrium state over time. In contrast, climate change fundamentally alters this equilibrium path in the long run.

The global nature, uncertainties, and complexity of climate change present challenges that must be carefully considered when integrating its impacts into macroeconomic projections. Estimating the long-run impact of climate change is particularly complex due to its unprecedented nature. Future effects must be inferred from weather observations or climatic conditions across regions or temporal climate shifts, both of which raise numerous empirical challenges. Simulating the response of the economy to future climate changes is also fraught with complications. As a result, seemingly minor differences in methods and data can lead to dramatically different impact estimates in the literature (Mitra and others 2025; Morris and others 2025). However, as research progresses, methods continue to be refined, allowing for the exclusion of implausible results and enhancing the reliability of impact assessments.

Figure 1. A Three-Step Approach to Include Climate Impacts in Macroeconomic Frameworks



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This note adopts a practical approach to incorporating the impact of temperature increases in macroeconomic projections while following the latest advancements in the literature to address several methodological and

[2] The literature, including methods presented in this Note, estimates the impact of climate change on GDP per capita rather than on GDP levels to remove population dynamics from the empirical analysis. As the changes in the level of GDP are equivalent to changes in GDP per capita if the population figure is the same with and without the climate damage, in this Note we use GDP impacts instead of GDP per capita impacts for simplicity.

[3] *Weather* refers to atmospheric conditions over short periods of time (for example, temperature and precipitation). *Climate* is the long-term (30 years) average and variability of weather (World Meteorological Organization).

empirical challenges. The following sections outline three key steps for integrating the impact of rising temperatures into macroeconomic projections (Figure 1).

- The first step involves selecting a robust method for estimating the macroeconomic impact of slow-moving temperature increases. This note adopts the methodology of Kahn and others (2021) as it is grounded in growth theory and effectively addresses several key econometric challenges. The approach highlights the role of adaptation in mitigating climate change impacts. While the estimated empirical relationship between a trend rise in temperature and economic growth remains consistent with Kahn and others (2021), this note enhances its findings by (1) leveraging the latest climate scenarios, (2) calculating confidence intervals for all impact projections to display statistical uncertainty, and (3) adding a scenario with very slow adaptation.
- The second step involves selecting a set of climate scenarios for long-term GDP impact assessments. Given the uncertainty surrounding future greenhouse gas emissions, multiple scenarios are necessary. This note uses the latest warming scenarios, drawn from dozens of climate models prepared for the Sixth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) (AR6).
- The third step consists of modifying the existing long-term macroeconomic projections for the impact of temperature increases under the chosen climate scenarios. The note includes an illustrative example demonstrating how to adjust a GDP series for impacts of rising temperatures in country-level macroeconomic analysis. The note also shows how this information can be used in a simple macro-fiscal framework to project changes in public debt. Time series data on GDP impacts for three climate scenarios and a special high-warming scenario, under four alternative assumptions about adaptation, are available with empirical confidence intervals in the online Data Appendix for each year until 2100, for 171 countries.[4]

The note emphasizes the significance of rising temperatures, but this is only one dimension of climate change. Rising temperatures deserve close scrutiny because of their potentially large long-term macroeconomic implications, particularly as the upward trend in temperatures is anticipated to persist and potentially intensify for decades to come. However, changes in precipitation, more frequent and intense extreme weather events, changes in tropical cyclones, and sea level rise, present important macroeconomic risks that need to be integrated into country-level macroeconomic analysis, where relevant. The note also abstracts from catastrophic risks arising from passing global climate thresholds due to substantial uncertainty in how to quantify these risks. The same three-step process described in this note can be applied to evaluate the effects of several of these more complex dimensions of climate change whenever robust empirical evidence and future scenarios are available. Macroeconomic implications of mitigation policy and transition risks are outside the scope of this note.

The Empirical Literature on the Macroeconomic Impact of Rising Temperatures

A growing literature uses panel data models to estimate the effect of temperature increases on macroeconomic variables. This approach is attractive because it directly estimates the net impact of temperature increases on macroeconomic variables (for example, GDP), without having to model sectoral impacts and complex interdependencies (Dell, Jones and Olken, 2012; Burke, Hsiang, and Miguel 2015; Kalkuhl and Wenz 2020; Kahn and others 2021; Tol 2021). For simplicity, we refer to temperatures herein, but the literature has also studied the effects of precipitation changes and other climate variables (for example, Kotz, Leverman, and Wenz 2024; Akyapi, Bellon, and Massetti 2025).

After linking temperature shocks to macroeconomic variables, the relationship is used to predict long-term effects of increasing temperatures. For example, many studies find that temperature increases are associated with lower real GDP. This relationship is then extrapolated to predict the impact of permanently higher temperatures on GDP. One strand of the literature argues that temperature increases affect GDP levels but do not affect long-term GDP growth (Tol 2024). If the empirical analysis finds that a 1°C temperature shock reduces GDP by 0.5 percent, the result is linearly extrapolated to predict that a 2°C permanent increase in temperature

[4] Climate models project temperature until December 31, 2099, and all climate change impacts are calculated using this data. In this Note, for simplicity, we refer to the end of the century as the year 2100.

reduces GDP by 1 percent below its reference level. Another strand of the literature argues that temperature shocks affect the growth rate of the economy permanently. In this case, if the analysis finds that a 1°C temperature shock reduces GDP growth by 0.1 percentage points, a permanent 2°C increase in temperature reduces growth by 0.2 percentage points. The exact mechanism through which climate affects the economy (for example, lower agricultural output or reduced labor productivity in the construction sector) is unknown, but this simplified econometric method can still lead to useful insights on the macroeconomic effects of increasing temperatures.

The literature also focuses on other approaches to quantify the macroeconomic impacts of climate change. Climate data permitting, the empirical implementation of econometric methods is relatively straightforward. Although preparing climate data can be challenging, an increasing number of ready-to-use data sets are available as part of Data Appendixes to published studies and by climate research centers (for example, Harris and others 2020). In contrast, calibrating sector-by-sector physical damages from climate change and integrating their outputs into large computable general equilibrium models to evaluate their macroeconomic effects is much more complex and requires large multidisciplinary teams. The relative simplicity of the econometric approach explains the large expansion of academic literature and many policy applications of these methods. For example, the Network for Greening the Financial System (NGFS) uses the econometrically estimated relationship between GDP growth and several weather variables in Kotz, Leverman, and Wenz (2024) to predict the economic costs of climate change. The IMF's Quantitative Climate Risk Fiscal Tool, or Q-CRAFT for short (Tjeerd and Rahman 2024), relies on results presented in this note and available in the Data Appendix to predict how increasing temperatures affect the fiscal accounts and debt-to-GDP dynamics in the long run.

A mechanical implementation of econometric methods conceals significant challenges in identifying and projecting the long-term macroeconomic effect of slow-moving increases in temperatures. First, identification of the causal effects of temperature increases on macroeconomic variables is complicated by many empirical obstacles. If there are reasons to doubt that the estimated effect of temperature increases on GDP does not equal its "true" effect, projections are intrinsically flawed. Second, the relationship between temperature and the macroeconomy is estimated using random temperature shocks (or anomalies), but results are used to project the effect of a permanent shift in temperature (for example, climate change). Most empirical models typically assume that the sensitivity of GDP to year-to-year variations in temperature is equal to the response of GDP to a permanent increase in temperature. However, behavioral, technological, and institutional responses to predictable and persistent changes in temperature will shape the actual macroeconomic outcomes. In other words, adaptation to climate change can attenuate the long-term losses but are largely overlooked in this literature.

These empirical challenges and the use of different methodologies lead to vastly different estimates of global warming impacts on the macroeconomy. Models that relate temperature to GDP levels tend to yield income loss estimates that are smaller than models that relate temperature to GDP growth (Newell, Prest, and Sexton 2021). Models that include gradual adaptation to slow-onset climate change yield much smaller losses than models that derive climate change costs from weather shocks with little or no adaptation (Massetti and Mendelsohn 2018). Different ways to calculate losses and differences in emissions scenarios further widen the range of results. Considering its scope, this note relies on Kahn and others (2021) as a solid empirical foundation for its estimates. Carleton and others (2024), Mitra and others (2025) and Morris and others (2025) conduct broader literature reviews.

Unbiased Macroeconomic Estimates of Trend Temperature Increases

Many papers in the literature directly regress GDP growth on temperature across countries. In its most basic form, this approach involves regressing GDP growth rates for each country ($r_{i,t}$) on a country-specific fixed effect (α_i) that captures unobserved time-invariant country characteristics (for example, geography), macroregional drivers of growth that change from year to year ($\theta_{r,t}$), and the level of temperature observed each year in the country $T_{i,t}$, while $\varepsilon_{i,t}$ represents the error term:

$$r_{i,t} = \alpha_i + \theta_{r,t} + \beta T_{i,t} + \varepsilon_{i,t}. \quad (1)$$

The effect of temperature on growth is measured by β. For example, if the estimated value of β is equal to -0.2 and the average temperature is equal to 20°C, in a year in which the temperature is equal to 20.5°C, growth will be lower by 0.1 percentage points ($-0.2 \times (20.5 - 20) = -0.1$). This is the approach taken, for instance, in Dell, Jones, and Olken (2012) and in Burke, Hsiang, and Miguel (2015), where $r_{i,t}$ is taken as in equation (1) with an additional quadratic time trend, and the square of temperatures.

By using temperature scenarios developed by climate scientists, it is possible to project the future growth impact of higher temperatures. For example, if the temperature in 2050 is projected to be on average 2°C higher than during the past thirty years, average annual growth is projected to be 0.4 percentage points lower than what it would have been if temperature had not increased ($-0.2 \times (22 - 20) = -0.4$). Growth declines as temperature increases and the difference between reference GDP (calculated using the previously projected growth rates) and GDP in a warmer world becomes exponentially larger over time.

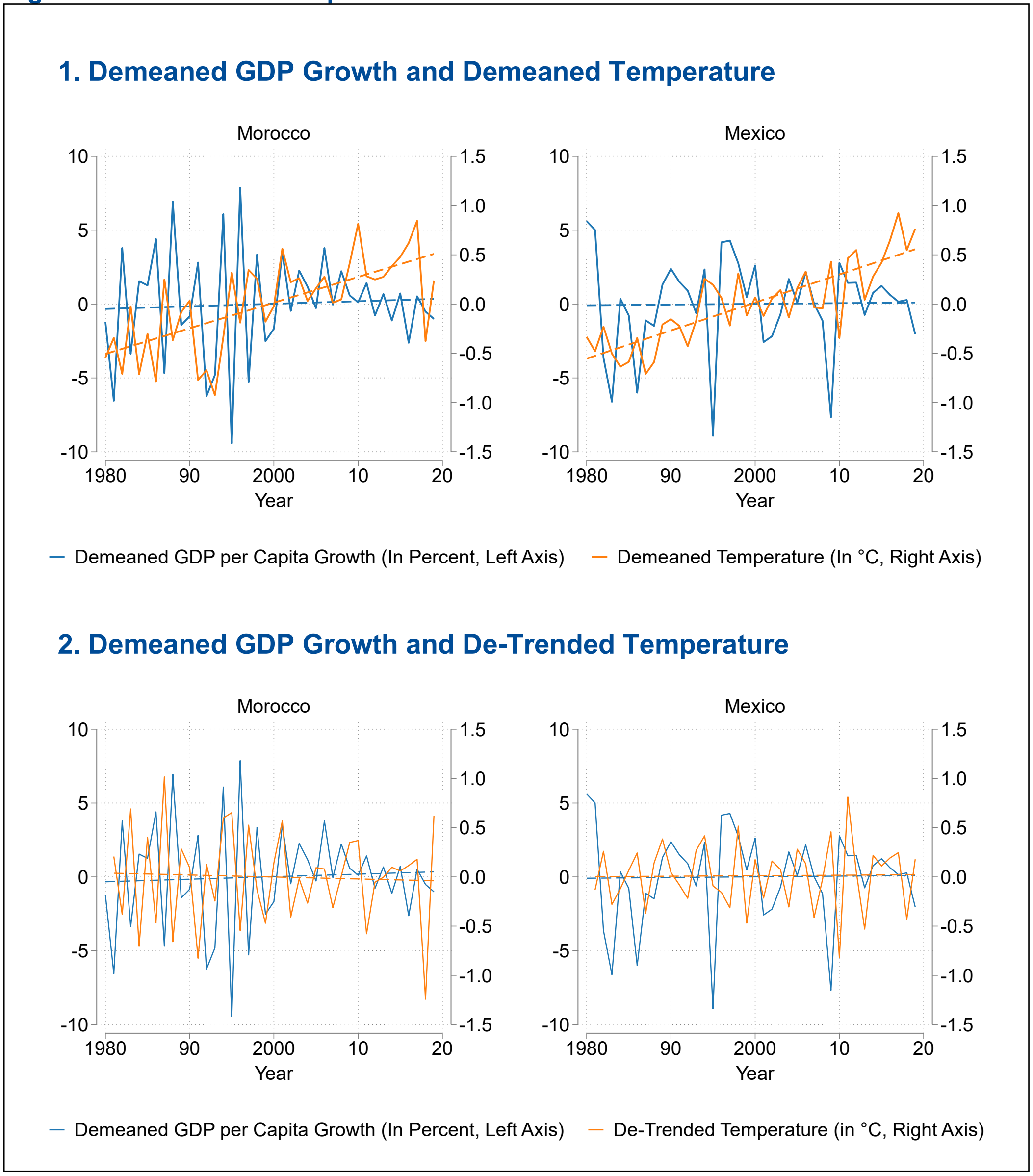
However, regressing GDP growth on temperature levels leads to biased estimates because GDP growth is stationary while temperature is positively trended due to global warming. Without additional restrictions,[5] the trend increase in temperature implies that mean output growth will be non-stationary, which contradicts economic growth theory and empirical evidence.[6] To see this more clearly, consider the time series of temperature and GDP per capita growth illustrated in Figure 2. While variations of GDP growth from its average over the sample period are centered around zero, temperature deviations from its sample average are increasing over time.[7] As a result, a correct estimation of the effect of temperature on GDP growth is possible only if the linear or quadratic country time trends that are often included in these models exactly cancel the trend temperature increase (Dell, Jones, and Olken 2012; Burke, Hsiang, and Miguel 2015). As these time trends account for multiple other time-varying variables, it would be an unlikely coincidence if they perfectly captured the trend temperature increase (linearly or quadratically).

[5] For example, one would need to assume the existence of a country-by-country productivity trend making the economy increasingly more productive. The two effects offset each other, and the result is stationary growth. Without climate change, economic growth would have been not only on average higher but accelerating. This is at odds with both empirical evidence and economic growth theory (Appendix A.2 in Kahn and others 2021).

[6] Burke, Hsiang, and Miquel (2015) consider a panel specification with quadratic climate variables in regressions and find that GDP growth peaks at an annual average temperature of 13°C and then declines as temperatures rise further. This means that a one-off permanent increase in temperature can create a long-lasting divergence in cross-country economic growth globally, with hot countries growing ever poorer and cold countries experiencing faster growth as they warm. The hypothesis that a one-off rise in temperature would affect the growth rate of the economy is theoretically inconsistent and empirically void (see Appendix A.2 in Kahn and others 2021; Nath, Ramey, and Klenow 2024; Tol 2024).

[7] Figure 2 shows deviations of growth and temperature from their averages because the fixed effect α_i in equation (1) captures average growth and temperature. In practice, equation (1) is estimated by regressing deviations of growth and temperature from their country-level averages.

Figure 2. Growth and Temperature



Source: Authors.

Notes: The top row shows deviations of GDP per capita growth and temperature from their 1980–2019 average time horizon. In the bottom row, temperature shocks are defined as temperature realization in each year minus its long-term average over the previous 30 years as in Kahn and others (2021). Note that temperature shocks are no longer significantly trended in the bottom row. Countries chosen for illustrative purposes.

To address the serial correlation and the non-stationarity of GDP, the regression can be specified in first differences with lags of both the dependent and independent variables included. As GDP is measured in logs, this Auto-Regressive Distributed-Lags (ARDL) model relates the rate of growth of GDP and long-run exogenous determinants of growth, lagged growth over several years, and both contemporaneous and lagged first differences of deviations of temperature from their averages. Thereby, growth is not affected by the level of temperature, avoiding the econometric pitfalls of linking stationary and trended variables discussed above. This note follows the specification of this ARDL model adopted by Kahn and others (2021).[8] For more details see the Appendix.

Empirical evidence suggests that a persistent deviation of temperature from its long-term average causes cumulative GDP losses. Using a panel of 174 countries from 1960 to 2014, Kahn and others (2021) employed an ARDL specification of GDP growth as a function of deviations of annual temperature from its moving average during the previous thirty years.[9] Results show that persistently higher temperatures above their long-term averages lead to cumulatively lower GDP levels. Warming reduces GDP levels in rich as well as in poor countries and in hot as well as in cold countries.[10]

The negative effect of long-term warming on GDP growth is persistent but not permanent. These dynamics emerge because the benchmark for measuring temperature shocks is a moving average temperature (for example, calculated over the thirty years preceding each observation). This implies that the critical factor in determining cumulative income losses is not the absolute level of temperature but rather changes in its trend. Such a change should ideally be compared to a "baseline" in which temperature continues to increase according to its historical trend (the gray bar in Figure 3). If the temperature trend stays constant compared to this baseline (approximately, the green scenario in Figure 3), economic growth remains unaffected despite increases in temperature. Conversely, if the trend accelerates, growth declines further (the yellow and red scenarios in Figure 3). A deceleration in the trend leads to faster economic growth as the end-century temperature level will be lower than the baseline (the blue scenario in Figure 3), and if temperatures stabilize, growth returns to its baseline rate.

The choice of the benchmark for measuring the impacts of future temperature scenarios significantly affects the estimated GDP losses. Prior research projects the GDP impact of rising temperature assuming a "no further warming" counterfactual (for example, Burke, Hsiang, and Miquel 2015; Kalkuhl and Wenz 2020; Kotz, Levermann, and Wenz 2024). Given that the planet has already warmed by approximately 1.2°C compared to pre-industrial averages, its impact on GDP (alongside past adaptation) is already reflected in historical growth observations. Continuation of the historical increase into the future will imply implicit income losses when compared to a scenario with "no further warming." However, since there are no pathways to a scenario in which baseline temperatures remain constant, we follow Kahn and others (2021) in comparing the GDP impact of temperature increases under different climate scenarios to a baseline under which temperature in each country rises according to its historical trend of 1960–2014. Mohaddes and Raissi (2025) conducted an additional exercise in which GDP losses from temperature increases based on the 1960–2014 trends are compared to a counterfactual without climate change (for example, with "no further warming"). They found an implicit GDP loss of about 1.5 percent by the end of the century.

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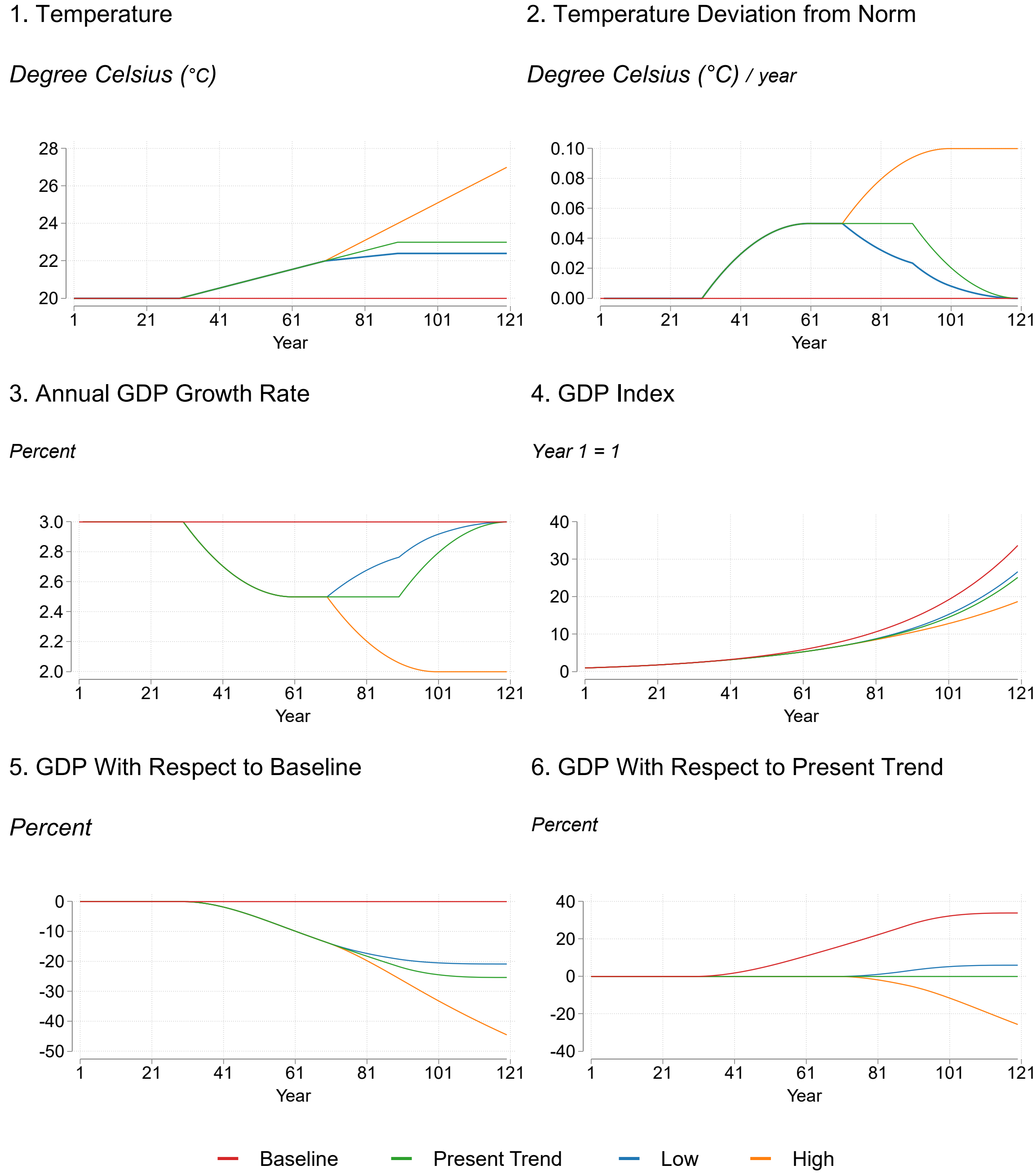
[8] The econometric strategy of Kahn and others (2021) is appealing for several reasons. First, it enables one to formulate the regression equation in level terms, while estimating the long-term macroeconomic impact of persistent increases in temperature through the Half-Panel Jackknife Fixed Effects estimator to correct for the small sample bias. Second, it facilitates the implicit modeling of adaptation by varying the speed with which historical norms are formed. Third, it accounts for state-specific and time-varying climate thresholds—a subtle form of nonlinearity. Lastly, it allows one to circumvent the econometric pitfalls associated with the use of trended variables, such as temperature, in output growth equations.

[9] As in most papers in the literature, the effect of total annual precipitation on economic activity is not statistically significant. This may be due to loss of information when precipitation data is averaged at the country level, especially in geographically diverse countries. For simplicity, precipitation is omitted from the analysis.

[10] While the level of temperature should not be included in growth regressions for empirical and theoretical reasons, the marginal impact of temperature shocks can be shown to vary across different temperature (climates) or income levels. Measuring the heterogeneous impact of weather shocks across climates and socio-economic conditions is a promising and still developing area of research.

Box 1. A Schematic Description



Source: Authors.

The Figure provides a schematic representation of how illustrative temperature trajectories (panel a) affect the deviation of temperature from its 30-year moving average (b), GDP growth (c), and GDP levels (d). A slow-moving rise in temperature reduces GDP growth persistently below its Baseline (no warming) counterfactual (which is set at 3% per year for illustration). The size and sign of GDP losses depends on the counterfactual scenario (panels e and f).

Under the Present Trend scenario, temperature continues to increase before stabilizing at 23°C (a). This would result in an annual 0.05°C deviation of temperature from its long-term moving average before this deviation gradually starts declining when the temperature stabilizes. Growth stabilizes at a lower rate of 2.5%

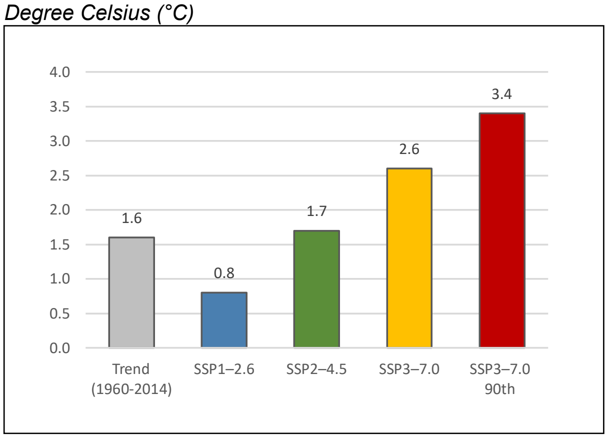
per year and persists at this level over time. As the deviation of temperature from its long-term moving average shrinks with temperature stabilization at 23°C, the growth rate of the economy increases from 2.5% towards the previous baseline of 3% (c). In this new growth equilibrium, GDP is permanently lower relative to the Baseline scenario (d), but income losses eventually stabilize at about 25 percent of the baseline GDP (e).

Consider now two alternative temperature scenarios. In the *High* scenario, 40 years after the onset of the temperature increase, the warming rate accelerates and temperature does not stabilize (a). After a brief period of stability at 2.5%, the GDP growth rate starts declining again for 30 years, before converging to the value implied by the temperature trend (2%). GDP losses are larger than in the Present Trend scenarios and continue increasing in proportion to the baseline GDP, because temperature never stabilizes. In the *Low* scenario, temperature stabilizes at 22.4°C instead of 23°C, and the decline in warming rate starts earlier than in the Present Trend scenario. As a result, the growth rate of the economy converges to its baseline 3% equilibrium faster than in the Present Trend scenario. At the new equilibrium, GDP is lower than its baseline level, but higher than in the other temperature scenarios discussed above (panel f).

As global temperatures have been increasing steadily during the past four to five decades, observed growth rates already plausibly reflect the impact of past warming. If the goal of the analysis is to include warming impacts in macroeconomic projections, it is more logical to use the Present Trend scenario as a reference because existing GDP growth projections are largely made based on past observations and implicitly assume a continuation of existing temperature trends. If GDP losses are measured with respect to this Present Trend scenario, no further adjustments to GDP are necessary. However, GDP will be higher than projected if the temperature trend slows down and will be lower than projected if the temperature trend increases (panel f). This explains why countries for which temperature projections indicate a slower warming rate than in the past are projected to have higher GDP. However, all scenarios indicate that global warming permanently reduces GDP levels with respect to a no warming baseline. This framework reconciles long-term climate change losses with stable long-term growth dynamics.

Figure 3: Additional Global Temperature Increase Under Different Scenarios (2014–2100)

Degree Celsius (°C)



Source: Calculations in Mohaddes and Raissi (2025) based on IPCC AR6 Physical Science Report.
Notes: Reports temperature increases relative to the 2014 average global surface temperature. At the time of the Paris Agreement's adoption in 2015, global temperatures were estimated to be 0.98°C above pre-industrial levels, with the agreement aiming to limit warming to well below 2°C, and pursue efforts to limit it to 1.5°C. SSP3-7.0 (yellow) is a high emission scenario (pessimistic scenario). SSP1-2.6 scenario (blue) is in line with the Paris Agreement goal to keep global mean temperature increase below 2ºC with respect to pre-industrial times (optimistic scenario). SSP2-4.5 (green) is a middle-of-the-road scenario that can be used to illustrate continuation of present trends (Present Trend scenario). SSP3-7.0 90th shows the 90th percentile of the distribution of temperature anomalies from the model ensemble. Please see Bellon and Massetti (2022), Mitra and others (2025) for more details on the use of climate scenarios for macroeconomic analysis and O'Neill and others (2014, 2017) and Riahi and others (2017) for a comprehensive discussion of socio-economic and energy assumptions in the scenarios, and Lee and others (2021) for a summary of climate change projections.

The choice of the time horizon for establishing temperature norms determines how fast the growth rate diverges from and subsequently returns to its baseline. This is also crucial for GDP loss estimates and can be interpreted as the speed of adaptation. The longer the period, the slower is the convergence between expected and observed temperature, the slower adaptation, and the larger the impact on growth. For example, using forty or fifty years to calculate climate norms leads to more lasting impacts of changes in the trend of temperature on growth than using thirty years. The latter is the reference time window that aligns with the IPCC and World Meteorological Organization's recommended 30-year standard for climatological normals. Using twenty years implies faster adaptation and leads to a quicker response to changes in temperature trends. Adaptation does not imply that GDP losses caused by climate change will be eliminated. More narrowly, it means that the economy, after some delay, catches up with contemporaneous temperature trends. Losses with respect to a no climate change scenario and losses suffered during the adjustment period are never recovered (see Box 1).

Projections of GDP impacts of slow-moving temperature increases can be informed by warming scenarios from climate model runs.[11] Climate models provide gridded data on temperature levels from 1850 to 2100 under alternative emissions scenarios starting from 2015. By comparing future and historical trends in each model, for each emissions scenario, it is possible to project the change in growth and calculate the effect on GDP levels compared to a scenario in which temperature continues to rise as in the past. By repeating this exercise using multiple models, it is possible to show the distribution of projected changes for each emissions scenario. Calculating the full cost of climate change relative to a hypothetical world in which climate remained as in pre-industrial times requires building a counterfactual scenario of growth without any trend temperature increase.

Impacts of Trend Temperature Increase on GDP Using Climate Scenarios

This note projects country-specific impacts of rising temperatures on GDP using a new set of climate scenarios. The econometric estimate of temperature effects on GDP is the same as in Kahn and others (2021), but the projection of the impact of changes in temperature trends on GDP is recalculated for all countries using the newest vintage of emission scenarios—the Shared Socio-Economic Pathways (SSPs), introduced in 2017—and new climate model data from CMIP6, released since 2019. SSPs replace the earlier projections based on the Representative Concentration Pathways (RCPs) and the CMIP5 models used in the IPCC Fifth Assessment Report. CMIP6 is the largest and most authoritative international collaboration effort among all major climate research centers in the world and this data set was used by the IPCC in its most recent Assessment Report.

The new climate scenarios consider a plausible range of future emissions.[12] Kahn and others (2021) relied on RCP8.5, an extremely high emissions scenario, and RCP2.6, an emissions scenario in line with the goal of keeping the global average temperature increase below 2°C. This note uses SSP1-2.6, SSP2-4.5, and SSP3-7.0. With the SSP1-2.6 scenario, emissions decline at a rapid pace, the warming trend slows down, and global mean temperature stabilizes around 2°C. Emissions in the SSP2-4.5 scenario grow in line with the observed trends and current policies, but eventually decline. Global mean temperature increases by approximately 2.7°C in 2100, with respect to its pre-industrial average level. SSP3-7.0 is a high emissions scenario. Warming accelerates and temperature increases by 3.6°C in 2100, with respect to its pre-industrial average level. We use the 90th percentile of the SSP3-7.0 model ensemble to include a high-emission high-warming sensitivity case.

[11] Specifically, for different emission scenarios, the historical trend observed in each country is perturbed assuming a constant annual acceleration (or deceleration) that delivers the median temperature change from 2015 to 2100 projected by an ensemble of climate models.

[12] Please see Bellon and Massetti (2022) and Mitra and others (2025) for more details on the use climate scenarios for macroeconomic analysis. O'Neill and others (2014, 2017) and Riahi and others (2017) have a comprehensive discussion of socio-economic and energy assumptions in the scenarios. Lee and others (2021) is a summary of climate change projections prepared for the Sixth Assessment Report of the IPCC.

Global temperature with this pessimistic case increases by approximately 4.4°C with respect to its pre-industrial average level by the end of the century.[13]

For each emissions scenario, consensus temperature projections are calculated using data from multiple climate models. Finally, following best practices, all climate models that provide data on temperature projections with each emission scenario are used to calculate the median warming trajectory (see Massetti and Tagklis 2024).[14]

Figure 4 shows median temperature projections for the three core climate scenarios and the pessimistic scenario for a randomly selected country. Temperature has a clear positive trend and is projected to continue increasing in all scenarios until mid-century. After mid-century temperature stabilizes in the SSP1-2.6 scenario but keeps increasing in the other scenarios. Warming is particularly fast in the SSP3-7.0 90th percentile scenario, which shows a distinct trajectory from the beginning of the simulation period. It is always useful to start the analysis of climate change impacts on the macroeconomy by showing temperature trends and projections for the country of interest.

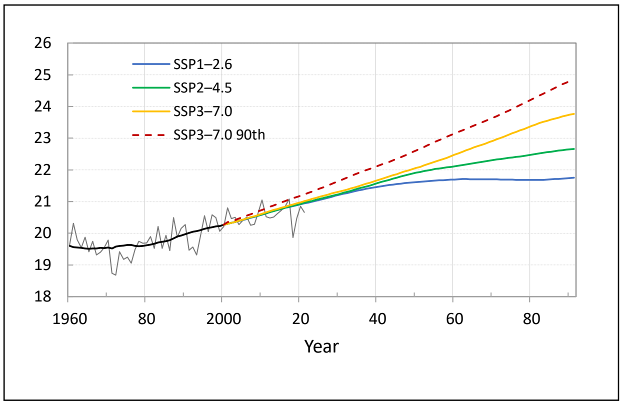
GDP losses from trend temperature increases differ across climate scenarios and depend on the time it takes for climate norms to form (for example, adaptation). Impacts on per capita GDP growth can be translated to cumulative losses in the level of real GDP, as shown in Figure 5. Impacts have a positive sign—GDP increases—when using the SSP1-2.6 scenario because temperature stabilizes, and the warming trend is smaller than what was observed in the past decades. The model does not calculate the impact of warming with respect to a hypothetical no climate change scenario. Positive impacts should then be interpreted as a reduction of the damage caused by climate change due to slower trend temperature increases under the Paris Agreement compared to historical trends. The additional growth under the SSP1-2.6 scenario is possible only thanks to sharp emissions reductions. This positive effect can be used to estimate the benefits of mitigation. The SSP2-4.5 scenario displays temperature trends like those observed in the past and thus has almost no impact on GDP. GDP growth in this scenario is largely consistent with baseline macroeconomic projections.

[13] This warming level is similar to the ensemble median warming level under RCP8.5 and SSP5-8.5 emission scenarios, which are considered unlikely and internally inconsistent by a growing literature (Hausfather and Peters 2020; Pielke and Ritchie 2021; Bellon and Massetti 2022; Meinshausen and others 2024).

[14] Data from each model-scenario combination are processed with a 31-year moving average filter to smooth out weather-related variability. Anomalies relative to the 1985–2014 average are calculated for each scenario to describe warming trends. For GDP impact calculations, the median anomaly scenario is used to estimate the projected warming trends between 2015 and future years, as detailed in Appendix 1. Since temperature projections conclude in 2099, from 2084 onward the 31-year moving average uses repeated temperature values from 2099 for all subsequent missing years. This approach may result in underestimation of positive or negative trends. GDP impacts for 2100 are based on 2099 climate data. Those concerned about these methodological approximations may choose to restrict analysis to the year 2084.

Figure 4. Temperature Scenarios in a Randomly Chosen Country

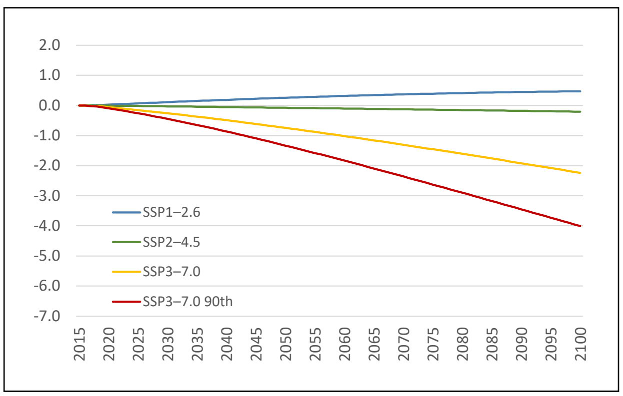
Degree Celsius (°C)



Sources: FADCP Climate Dataset (Massetti and Tagklis, 2024), using CRU data (Harris and others 2020), and CMIP6 data (Copernicus Climate Change Service, Climate Data Store 2021).
Notes: The gray line describes historical mean annual temperature in a randomly chosen country based on observations (CRU). The black line describes the 31-year moving average of historical data centered around each year. Colored lines represent the median of 31-year moving averages of CMIP6 ensemble temperature anomalies added to the CRU value (black line in the year 2000). Country-level temperatures are calculated by averaging temperatures in CRU grid cells that are within the country boundaries, excluding sea, using area weights.

Figure 5. Impact of Warming Trends on Real GDP in a Randomly Chosen Country Using 30-Year Historical Norms

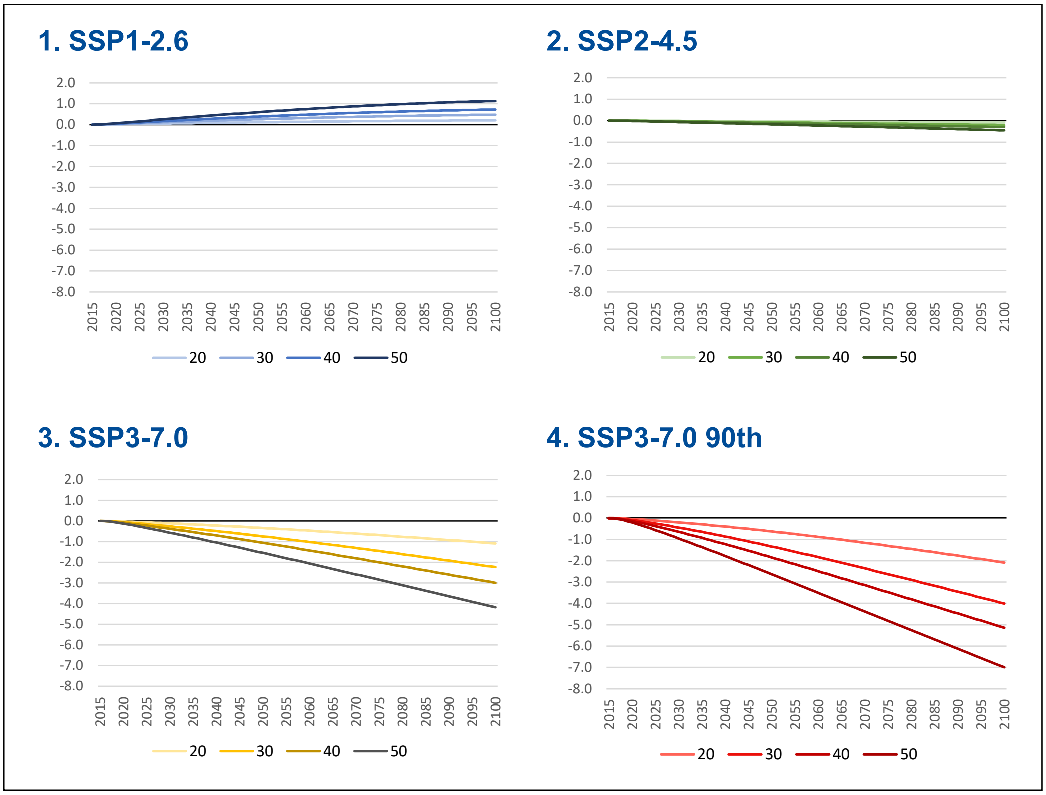
Percent Deviation from the Reference Scenario



Sources: Authors using Kahn and others (2021), and CMIP6 data (Copernicus Climate Change Service, Climate Data Store 2021) processed by Massetti and Tagklis (2024).
Notes: The impact of the warming trend for each scenario in a randomly chosen country is estimated using Kahn and others (2021) under the assumption that adaptation can offset impacts after 30 years. Impacts are measured as percentage deviations of real GDP relative to a reference scenario in which the warming trend follows the historical pattern. For a description of climate scenarios, see notes to Figure 3.

Figure 6. Impact of Warming Trends on Real GDP for Different Levels of Adaptation in a Randomly Chosen Country

Percent Deviation from the Reference Scenario

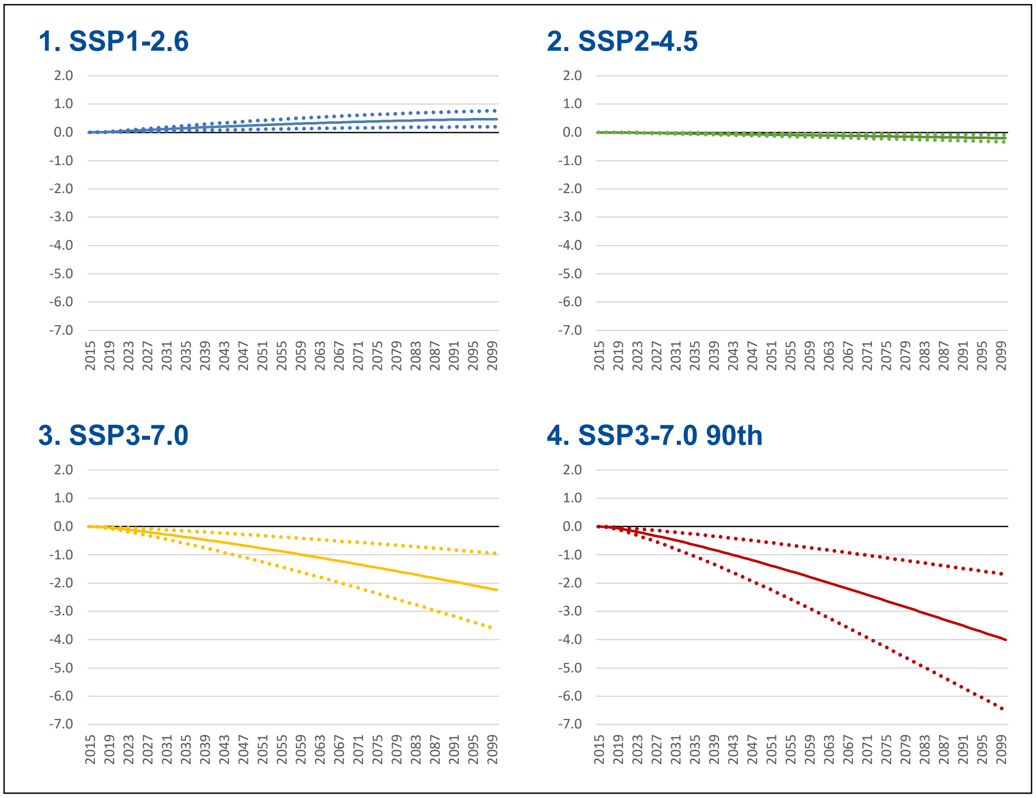


Sources: Authors using Kahn and others (2021), and CMIP6 data (Copernicus Climate Change Service, Climate Data Store 2021) processed by Massetti and Tagklis (2024).

Notes: The impact of the warming trend for each scenario in a randomly chosen country is estimated using Kahn and others (2021) under the assumption that adaptation can offset the warming trend after 20, 30, 40, or 50 years. Impacts are measured as percentage deviations of real GDP relative to a reference scenario in which the warming trend follows the historical pattern. For a description of climate scenarios, see notes to Figure 3.

Figure 7. Impact of Warming Trends on Real GDP in a Randomly Chosen Country Using 30-Year Historical Norms, with Confidence Intervals

Percent Deviation from the Reference Scenario



Sources: Authors using Kahn and others (2021), and CMIP6 data (Copernicus Climate Change Service, Climate Data Store 2021) processed by Massetti and Tagklis (2024).

Notes: The impact of the warming trend for each scenario in a randomly chosen country is estimated using Kahn and others (2021) under the assumption that adaptation can offset the warming trend after 30 years. Dotted lines indicate 95 percent bootstrap confidence intervals. Impacts are measured as percentage deviations of real GDP relative to a reference scenario in which the warming trend follows the historical pattern. For a description of climate scenarios, see notes to Figure 3.

The role of adaptation can be examined further by changing the duration of temperature norms. The results of these different assumptions are shown in Figure 6 and can be used as an input in macroeconomic projections. Here the impact of warming trends varies depending on the speed of adaptation. The slower the response to a change in the temperature trend, the larger the impact on GDP. If projected warming is slower than in the historical period, slower adaptation leads to larger positive impacts because expectations are updated with longer delay, leading to more pessimistic projections.

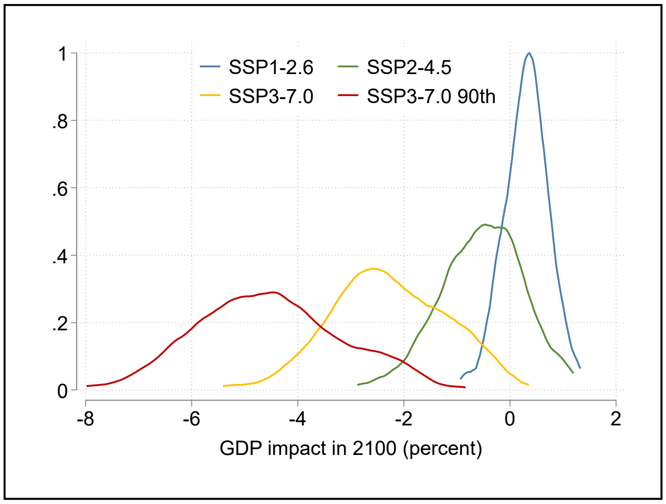
Statistical parameter uncertainty can be shown through confidence intervals of the projected impacts. Kahn and others (2021) do not calculate these confidence intervals. We add information on the statistical uncertainty around central estimates by calculating 95 percent bootstrapped confidence intervals. While this provides a richer picture of parameter uncertainty, it nonetheless concentrates on the median warming scenarios. The SSP3-7.0 90th percentile of climate model runs is an exception, because we use the 90th percentile of the range across models as an independent extreme scenario, for which we calculate its own confidence intervals. The upper bound of the confidence interval for this extreme scenario provides a worst-emission, worst-warming, worst-vulnerability case. As illustrated in Figure 7, in the country that was randomly selected to prepare these figures, impacts are significant, except for the period up to mid-century in the SSP2-4.5 scenario. Uncertainty grows over time and becomes large at the end of the century for the fast-warming scenarios with slow adaptation. This is the result of uncertainty compounding over time. A worst-case scenario can be built by assuming very high emissions (SSP3-7.0), very fast warming (90th percentile), very slow adaptation (50 years), and the lower bound of the confidence intervals.

In this empirical setting, impacts vary across countries depending on their local warming trends. All countries are negatively affected by an acceleration in their warming trend. Conversely, all countries are positively affected by a reduction in their warming trend. This is a key difference with respect to other studies that postulate a globally optimal temperature such that warming has a positive impact for cold countries and a negative impact for temperate or hot countries (for example, Burke, Hsiang, and Miguel 2015). The key insight is that impacts on GDP are caused by deviations from expected temperatures in this model, not from a globally optimal temperature level. Cold countries suffer more than temperate or hot countries only if they warm faster. The long-run steady state growth level is however unaffected and long-term GDP projections primarily depend on technological progress and other drivers of growth. To illustrate the geographic heterogeneity of impacts, Figure 8 shows a density function of impacts on GDP in 2100 across all countries using the reference adaptation assumption and all four warming scenarios. Table 1 reports key statistics of these density functions. For virtually all countries in the case of the two fastest warming scenarios, and for most countries in the case of the SSP2-4.5 scenario, warming trends are projected to accelerate, and thus 2100 GDP is projected to be lower than what it would have been under the continuation of past trend increases in temperatures. With strong mitigation (SSP1-2.6), most (but not all) countries are projected to benefit from a reduction in their warming trend, and thus they are projected to have larger GDP in 2100 than what they would have under the continuation of past temperature trends. Considering that global warming is projected to accelerate under various IPCC climate scenarios, its impact on the economy will be more detrimental than in the past almost everywhere, unless countries close the mitigation ambition and policy implementation gaps that are needed to abide by the Paris Agreement goals. The likelihood that countries' future warming outpaces the past trends is very high in the SSP3-7.0 scenario almost everywhere, but lower in the SSP1-2.6 scenario. When compared to a hypothetical world without climate change (in which temperatures had remained at the pre-industrial levels), all countries in all scenarios would have experienced macroeconomic losses.

The data used for all the charts is available for all countries in a companion data set. While key statistics are available in the Data Appendix, all the data used for this note is available at this link. This data includes, for all years until 2099 and all 171 countries, temperature scenarios, temperature impacts on GDP growth and GDP levels, statistical confidence intervals, key statistics of the distribution of temperature change across climate models (10th, 50th, and 90th percentiles), and different assumptions on the speed of adaptation (20, 30, 40, and 50 years). This data can be used to include climate change effects in macro-fiscal projections, as is done, for example, in the Q-CRAFT tool (Tim and Rahman 2024). This exercise involves subtracting the percentage loss projected in each year from baseline projections, as discussed in the next Section.

Figure 8. Impact of Warming Trends on Real GDP in 2100 Across Countries

Density



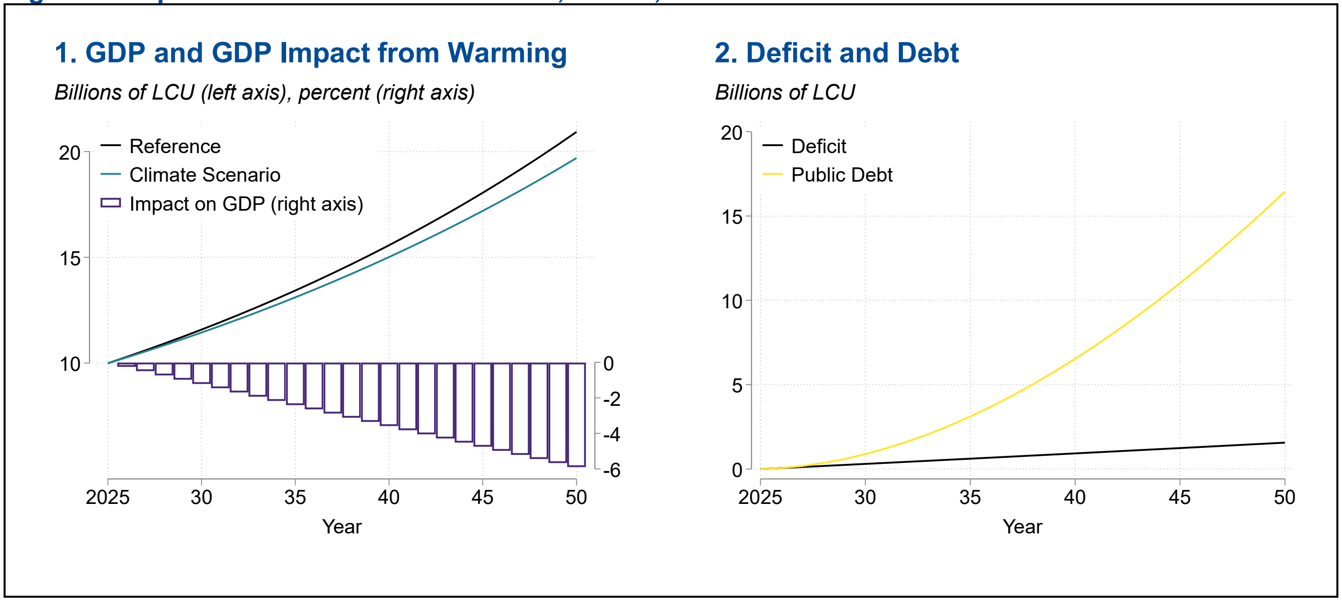
Sources: Authors using Kahn and others (2021), and CMIP6 data (Copernicus Climate Change Service, Climate Data Store 2021) processed by Massetti and Tagklis (2024).
Notes: Kernel density functions showing the distribution of impacts across countries using four temperature scenarios. The impact of the warming trend for each scenario is estimated using Kahn and others (2021) under the assumption that adaptation can offset the warming trend after 30 years. Impacts are measured as percentage deviations of real GDP relative to a reference scenario in which the warming trend follows the historical pattern. For a description of climate scenarios, see notes to Figure 3.

Table 1. Key Statistics for the Distribution Across Countries of Impacts of Warming Trends on Real GDP in 2100

	Years					**Years**			
	2030	**2050**	**2075**	**2100**		**2030**	**2050**	**2075**	**2100**
SSP1-2.6					SSP3-7.0				
Min	-0.04	-0.16	-0.49	-0.93	Min	-0.5	-1.6	-3.4	-5.4
p25	0.01	0.02	0.04	0.06	p25	-0.3	-0.9	-1.9	-3.0
Median	0.07	0.17	0.27	0.33	Median	-0.2	-0.7	-1.5	-2.3
p75	0.15	0.34	0.50	0.58	p75	-0.2	-0.5	-1.0	-1.5
Max	0.45	1.01	1.38	1.33	Max	0.1	0.1	0.3	0.4
SSP2-4.5					SSP3-7.0 90th				
Min	-0.22	-0.67	-1.67	-2.88	Min	-0.9	-2.4	-5.1	-8.0
p25	-0.10	-0.31	-0.64	-1.00	p25	-0.6	-1.8	-3.7	-5.5
Median	-0.05	-0.16	-0.30	-0.46	Median	-0.5	-1.5	-3.0	-4.6
p75	0.00	0.00	-0.01	-0.01	p75	-0.4	-1.2	-2.5	-3.8
Max	0.24	0.58	0.94	1.20	Max	-0.1	-0.3	-0.6	-0.8

Sources: Authors using Kahn and others (2021), and CMIP6 data (Copernicus Climate Change Service, Climate Data Store 2021) processed by Massetti and Tagklis (2024).
Notes: The impact of the warming trend for each scenario is estimated using Kahn and others (2021) under the assumption that adaptation can offset the warming trend after 30 years. Impacts are measured as percentage deviations of real GDP relative to a reference scenario in which the warming trend follows the historical pattern. For a description of climate scenarios, see notes to Figure 3.

Figure 9. Representative Scenarios for GDP, Deficit, and Debt



Source: Authors.
Notes: Illustrative scenarios of GDP (left), and deficit and public debt (right). The reference scenarios depict macroeconomic projections assuming no alterations to climate trends. The purple bars in the left panel show the percentage difference between GDP projections that account for the impacts of climate change. LCU = Local Currency Unit.

Introducing the Impacts of Trend Temperature Increases in Macroeconomic Projections

By using the estimated impact of future trend temperature increases under different climate scenarios, it is possible to "shock" GDP projections as needed. The starting point is a reference scenario in which GDP in country i grows following its long-term historical path. The exact way to include the climate shock in GDP projections varies based on the impact model, but in most cases, it is possible to calculate GDP projections with climate change starting from a reference scenario:

$$Y_{i,t,s}^{1} = (1 + \alpha_{i,t,s}/100)Y_{i,t}^{0} \quad (2)$$

where $Y_{i,t,s}^{1}$ is GDP with "climate change" in country i at time t, using scenario s; $Y_{i,t}^{0}$ is "reference" GDP, and $\alpha_{i,s}$ is the percentage impact of scenario s on GDP.[15] As discussed above, when using empirical estimates from Kahn and others (2021), the "reference" scenario is not a "no climate change" scenario but a reference scenario in which temperatures continue to increase according to their 1960–2014 historical trends. $\alpha_{i,t,s}$ has a negative value if the warming trend is larger than in the historical period using scenario s, and has a positive sign if the warming trend decelerates. Figure 9 shows an example for a country in which GDP starts from 10 Billion LCU in 2025 and grows at a constant rate equal to 3 percent until 2050 in the reference scenario. GDP declines due to

[15] Analogously, the "reference" growth rate $r_{i,t}$ can be altered as follows:

$$Y_{i,t+1,s}^{1} = (1 + r_{i,t} + \eta_{i,t,s})Y_{i,t}^{1}$$

where $\eta_{i,t,s}$ is a parameter that measures the impact of scenario s on the GDP growth rate measured in percentage points.

an acceleration of warming and, in 2050, is approximately 6 percent lower than what it would have been if the temperature trend had not changed.[16]

GDP projections under alternative temperature scenarios can be used in country-level macroeconomic projections to highlight fiscal risks. Consider the case of the country discussed above. Assume that the country runs a balanced budget and has no public debt. Government expenditure and fiscal revenues are equal to 25 percent of GDP. As GDP grows, expenditure and revenue grow along a balanced path. Assume that the government commits to long-term spending plans by counting on projected fiscal revenue in the "reference" scenario. If the government does not consider the possibility of larger future climate impacts, revenue projections may be optimistically high. As a result of the gradual increases in temperatures, the debt-to-GDP ratio rises owing to lower GDP (which worsens the denominator of the debt-to-GDP ratio), lower revenue (as the revenue-to-GDP ratio path remains unchanged while GDP falls), rigid expenditure, and continued compounding interest on a growing debt stock (the debt snowball effect). In the example above, public debt grows from zero to approximately 15 percent of (climate adjusted) GDP in 2050 (Figure 9), without considering the potentially higher interest rates. The full extent of long-term fiscal implications of GDP losses can be explored using existing macro-fiscal frameworks or other macroeconomic models. The IMF Q-CRAFT tool is an elaborate framework to build long-term climate change fiscal risk scenarios using methods and data illustrated in this note (Tim and Rahman 2024).[17] Q-CRAFT is already being used in many countries, including Armenia (Harris and others 2022a), Azerbaijan, Georgia (Harris and others 2022b), Jamaica, Jordan, Kenya, Morocco, The Netherlands, Rwanda, Seychelles, and Uganda—demonstrating the steadily growing global demand for climate-risk-informed fiscal analysis.

This type of analysis helps governments identify slow-building fiscal pressures/risks that might not be apparent in short- or medium-term budgets. By assessing the macroeconomic impact of different climate scenarios on public finances, it helps in developing resilience-building policies and supports earlier, smoother policy interventions (for example, by gradually building fiscal buffers or reducing spending rigidities). The analysis also helps governments integrate climate risks into their longer-term fiscal planning and strategy development, complementing other tools at their disposal.

Conclusion

This note shows how to estimate the GDP effects of slow-moving temperature increases and how to incorporate them into macroeconomic projections for long-term climate risk assessments. The emphasis is on a practical method that relies on the best available empirical foundations. Data on temperature scenarios and GDP impacts is provided for all countries in the online companion data set and can be used to integrate the impact of rising temperatures in existing macroeconomic projections. This can be the first step to assess long-term climate risks, but it is essential to acknowledge the uncertainties and limitations involved.

Significant uncertainty regarding the potential magnitude of climate change impacts on the economy warrants caution. Our focus is on a recent econometric specification that addresses shortcomings in previous literature,

[16] If the analysis starts from GDP per capita levels, a scenario of total GDP can be developed by multiplying both sides of equation (2) by total population in country i at time t ($L_{i,t}$): $y^1_{i,t}L_{i,t} = (1 + \alpha_{i,s})y^0_{i,t}L_{i,t}$. The United Nations provide long-term population projections under alternative scenarios for each country in case official country projections are not available (United Nations World Population Prospects, available at: https://population.un.org/wpp/).

[17] The median estimates of warming impacts on growth from this Note are used in Q-CRAFT and the scenarios are identical. The data set that accompanies this Note enables country teams to go beyond Q-CRAFT in analyzing GDP losses under different climate scenarios, each with 90 percent confidence intervals—capturing two sources of uncertainty: parameter and warming sensitivity in different climate models. This Note describes theory and empirical methods used for estimating temperature impacts used in Q-CRAFT and shows how to use this data in other macroeconomic frameworks.

yet the scientific debate is not settled. Spillover effects through trade, financial flows, and migration are not included. Inference about future damages based on past data is also fraught with difficulty and uncertainty.

Loss estimates presented in this note are likely conservative because many potential impacts of climate change are not included. Econometric models cannot account for global climate tipping points (for example, collapse of the Greenland and West Antarctica Ice Sheets; abrupt thawing of the permafrost; dieback of the Amazon rainforest; death of all tropical coral reef systems; and collapse of the Atlantic Meridional Overturning Circulation–AMOC), societal tipping points (for example, prolonged conflicts and institutional failure), non-market damages (for example, biodiversity loss; mortality), sea-level rise, and ocean acidification.[18] The econometric literature is making progress in estimating the impact of extreme weather events beyond changes in temperature (for example, Akyapi, Bellon and Massetti 2025).

Despite its unavoidable limitations, the method outlined in this note provides a blueprint for more accurate analysis. Extensions of the empirical method to account for heterogeneity in impacts and spillover effects would strengthen the analysis. Furthermore, climate change may directly affect fiscal variables such as revenue and expenditure, beyond the indirect GDP effects, as shown by Akyapi, Bellon, and Massetti (2025). If available, macroeconomic losses from other aspects of climate change can be added to the impact from rising temperatures. Climate policies, both mitigation and adaptation, also have complex direct and indirect macroeconomic impacts that are beyond the scope of this analysis. This necessitates more complex transformations in existing macroeconomic projections along the lines illustrated in this note.

[18] For a discussion of global climate tipping points, see Kemp and others(2022).

Appendix 1. Model Specification

In its simplest form Dell, Jones, and Olken (2012) estimate the following model using panel Fixed Effects (FE):

$$r_{i,t} = \Delta \ln(y_{i,t}) = \alpha_i + \theta_{r,t} + \beta T_{i,t} + \varepsilon_{i,t} \tag{1}$$

Where $\ln(y_{i,t})$ is the natural logarithm of real GDP per capita,[19] $r_{i,t}$ is GDP per-capita growth in country *i* at time *t*, α_i controls time-invariant country characteristics, $\theta_{r,t}$ is a regional time fixed effect, and $T_{i,t}$ is average annual temperature in country *i*. $\varepsilon_{i,t}$ is a random disturbance.

Due to global warming, temperature is positively trended in virtually all countries. It is thus possible to write $T_{i,t} = \delta_{i,t} + \nu_{i,t}$, where $\nu_{i,t}$ is an iid, normally distributed random shock with mean zero and variance equal to σ_i^2, and $\delta_{i,t} = \delta_{0,i} + \delta_{1,i}t$ is the amount of warming observed at time *t* with respect to the previous long-run equilibrium temperature.

While $\nu_{i,t}$ is a random shock for country *i*, $\delta_{1,i}$ is deterministic and affected by geography. For example, temperature trends are positively correlated with latitude, and thus inversely correlated with average temperature.

Rewriting (1) by separating the deterministic trend from random weather variation yields:

$$\begin{aligned} \Delta\, ln(y_{i,t}) &= \alpha_i + \theta_{\mathrm{r,t}} + \beta(\delta_{0,i} + \delta_{1,i}t + \nu_{i,t}) + \varepsilon_{i,t} \\ &= \alpha_i + \theta_{r,t} + \beta\delta_{0,i_i} + \beta\delta_{1,i}t + \beta\nu_{i,t} + \varepsilon_{i,t} \end{aligned} \tag{2}$$

Kahn et al. (2021) show that, unless the model is estimated under the restriction $\theta_{r,t} + \beta\delta_{1,i}t = 0$, it necessarily leads to non-stationary growth, which is not supported by empirical evidence. Even if growth can be non-stationary over an extended period, residual temperature trends likely lead to biased estimates. The specifications used by Burke, Hsiang, and Miguel (2015), and Kalkuhl and Wenz (2020), are subject to similar problems as shown by Kahn and others (2021).

The starting point of Kahn et al. (2021) is a model of GDP per capita that can be simplified as follows:

$$\ln(y_{i,t}) = y_{i,0} + \alpha_i t + \beta\left(\frac{2}{m+1}\left|T_{i,t} - \frac{1}{m}\sum_{l=1}^{m} T_{i,t-l}\right|\right) + \varepsilon_{i,t} \tag{3}$$

where $y_{i,0}$ is a function of the initial technological endowment, the steady state value of capital, and the climate. α_i is the exogenous rate of growth of technology, $T_{i,t} - \frac{1}{m}\sum_{l=1}^{m} T_{i,t-l}$ is a temperature shock defined as the deviation of temperature in year *t* from its average during the previous *m* years. $\varepsilon_{i,t}$ captures all other shocks. Variations of $ln(y_{i,t})$ around its trend $g_i t$ are determined only by technology and weather shocks. In the main specification, weather shocks enter in absolute value, implying that what matters is the deviation from expected conditions. Kahn et al. (2021) also consider potential asymmetrical effects of weather shocks but cannot reject the null hypothesis of symmetrical effects. As precipitations never have a significant effect on GDP per capita, they are omitted for simplicity.

[19] The main text of this Note discusses GDP impacts for simplicity, but the literature works with data on GDP per capita to remove population trends. As the notation in this section closely follows the literature, the dependent variable is real GDP per capita.

For both contemporaneous and lagged variables, it is possible to write the absolute change in temperature from its historical average as follows:

$$\left|T_{i,t} - \frac{1}{m}\sum_{l=1}^{m} T_{i,t-l}\right| = \left|\delta_{1,i}\left(t - \frac{1}{m}\sum_{l=1}^{m}(t-l)\right) + \nu_{i,t-j} - \frac{1}{m}\sum_{l=1}^{m}\nu_{i,t-l}\right| \\ = \left|\delta_{1,i}\frac{m+1}{2} + \left(\nu_{i,t} - \frac{1}{m}\sum_{l=1}^{m}\nu_{i,t-l}\right)\right| \quad (4)$$

Assuming $\beta < 0$ and positively trended temperature, real GDP per capita (in levels) is lowered by (1) the positive warming trend that pushes temperature up, and by (2) weather shocks.[20] Note that the amount of warming that damages the economy is relative to a moving climate average. The longer the reference period (the larger m), the larger the negative impact on the economy is. The model thus includes adaptation to higher temperatures. If temperature stabilizes ($\delta_{1,i} = 0$), GDP per capita eventually converges to its reference level, with historical volatility but no temperature trend.

To address serial-correlation and the fact that GDP levels are non-stationary the model is transformed using first differences and becomes a standard ARDL equation for growth:

$$\Delta \ln(y_{i,t}) = \alpha_i + \sum_{j=1}^{p}\varphi_j \Delta \ln(y_{i,t-j}) + \beta\left(\frac{2}{m+1}\Delta\left|T_{i,t} - \frac{1}{m}\sum_{l=1}^{m} T_{i,t-l}\right|\right) + \Delta\varepsilon_{i,t} \quad (5)$$

The growth rate of real GDP per capita time t is affected by long-run determinants of growth like technical progress (α_i), variations of the intensity of weather shocks, measured as absolute deviations of temperature from their average during the previous *m* years and other shocks captured by the error term. A set of lagged values of the growth rate of per capita GDP is included to deal with dynamic effects. Lagged values of temperature shocks capture effects of temperature anomalies in previous years. The level of temperature does not play any role in explaining growth, but its trend and random temperature variations do impact growth.

Under the additional assumption that $\nu_{i,t}$ is normally distributed we can write the contemporaneous weather shock, and similarly all lagged temperature variables, as follows:

$$E\left|T_{i,t} - \frac{1}{m}\sum_{l=1}^{m} T_{i,t-l}\right| \\ = \delta_{1,i}\frac{m+1}{2}\left[\Phi\left(\frac{\delta_{1,i}}{2\sigma_i}\sqrt{\frac{m+1}{m}}\right) - \Phi\left(-\frac{\delta_{1,i}}{2\sigma_i}\sqrt{\frac{m+1}{m}}\right)\right] \\ + 2\sigma_i\sqrt{1+\frac{1}{m}}\,\phi\left(\frac{\delta_{1,i}}{2\sigma_i}\sqrt{\frac{m+1}{m}}\right) \quad (6)$$

Where ϕ and Φ are the pdf and cdf of a standard normal distribution, respectively. In the last equation, the absolute change of temperatures from their historical trend does not depend on t, which implies that the

[20] Notice that the ARDL model in equation (5) can be estimated “as is" if all variables are stationary. However, it is possible that the growth rate, $g_{i,t}$ and the first differences of temperature from its norm are cointegrated (for example, a long-run equilibrium relationships between these variables may exist), and therefore Kahn and others (2021) estimate an error correction version of this model (see Pesaran 2015, p. 526).

expected difference in the absolute change of temperatures is equal to zero in equation (6). In steady state, using the fact that $\Delta\, ln(y_{i,t})$ is a stationary process, we have

$$E[\Delta \ln(y_{i,t})] = \frac{\alpha_i}{1 - \sum_{j=1}^{p} \varphi_j} \tag{7}$$

Hence, in steady state, growth is not affected by weather shocks. The long-run effect of a permanent increase in the trend can be calculated using

$$\frac{\sum_{j=1}^{p} \beta_j}{1 - \sum_{j=1}^{p} \varphi_j} \tag{8}$$

If (8) is negative, an acceleration of warming (a positive trend change) reduces growth, and a deceleration of warming (a negative trend change) increases growth above its counterfactual case which already includes the harmful negative effect of the historical trend. To calculate the impact of future warming scenarios, the following steps are followed for each country:

1. The median ensemble projection for a given emission scenario is used to calculate the change of temperature in the country, from 2015 to 2100.
2. To avoid an abrupt change of the trend in 2016, a counterfactual trend is calculated assuming constant acceleration (or deceleration) of temperature from the historical trend to achieve the warming level implied by the selected scenario.
3. The impact of the difference between projected and historical trend on growth is calculated for each year from 2015 to 2100 using (8).

Specifically, defining with T and H the beginning of and the number of years in the period over which climate change impacts are calculated (for a period that goes from 2015 to 2099, $T = 2015$ and H=85), the slope of the linear trend with climate change is

$$\delta_{1,i}^{1} = \frac{T_{i,T+H} - T_{i,T}}{H} \tag{9}$$

The path of warming during the century however is better described by a smooth acceleration or deceleration of the present trend than by assuming a linear trend. To achieve this effect Kahn et al. (2021) assume that the slope of the linear trend increases constantly by an amount equal to d_i each of the j years from T to T+H:

$$\delta_{1,i,j}^{1} = \delta_{1,i} + j d_i \tag{10}$$

As using either $\delta_{1,i}^{1}$ or $\delta_{1,i,j}^{1}$ must yield the same temperature increase at time H:

$$\begin{aligned} \delta_{1,i}^{1} H &= \sum_{j=1}^{H} (\delta_{1,i} + j d_i) \\ \delta_{1,i}^{1} H &= \delta_{1,i} H + H \frac{(1+H)}{2} d_i \\ d_i &= \frac{2(\delta_{1,i}^{1} - \delta_{1,i})}{(1+H)} \end{aligned} \tag{11}$$

For example, assume that temperature increases following the historical trend at a constant rate equal to $\delta_{1,i} = 0.01$ °C per year. From 2015 to 2099 this yields a temperature increase equal to 0.85 °C. Using a climate scenario that predicts a temperature increase equal to 1.7 °C from 2015 to 2099 we calculate $\delta_{1,i}^{1} = 0.02$. Then d_i =0.000233. $\delta_{1,i,2015}^{1}$ =0.010233, $\delta_{1,i,2057}^{1}$ =0.02, and $\delta_{1,i,2099}^{1}$=0.0298.

The impact on growth is then calculated using (5) and (8). m governs the speed at which the economy adapts to the change in the trend and the magnitude of the impact on GDP.

Appendix 2. Data on Temperature Scenarios and Their Impacts on GDP in All Countries

All data on temperature scenarios and their impact on GDP in all years until 2100, all countries, under alternative assumptions on the speed of adaptation is available in an Excel file at this link. The following table provides a summary of results for 2050 and 2100 in the case in which adaptation can offset any negative climate impacts after 30 years (m=30). Brackets show 95 percent bootstrap confidence intervals.

		SSP1-2.6		SSP2-4.5		SSP3-7.0		SSP3-7.0 90th p.	
Country	**ISO3**	**2050**	**2100**	**2050**	**2100**	**2050**	**2100**	**2050**	**2100**
Afghanistan	AFG	0.86 [0.36 1.39]	1.13 [0.48 1.82]	0.51 [0.21 0.82]	1.02 [0.43 1.65]	-0.34 [-0.56 -0.14]	-0.91 [-1.48 -0.39]	-1.19 [-1.93 -0.5]	-3.32 [-5.39 -1.41]
Albania	ALB	0.27 [0.11 0.44]	0.53 [0.23 0.86]	-0.15 [-0.25 -0.06]	-0.41 [-0.66 -0.17]	-0.8 [-1.3 -0.33]	-2.35 [-3.82 -0.99]	-1.37 [-2.22 -0.57]	-4.02 [-6.52 -1.7]
Algeria	DZA	0.58 [0.24 0.94]	0.94 [0.4 1.53]	0.17 [0.07 0.28]	0.41 [0.17 0.66]	-0.82 [-1.33 -0.34]	-2.24 [-3.64 -0.95]	-1.71 [-2.78 -0.71]	-4.65 [-7.55 -1.97]
Angola	AGO	0.25 [0.11 0.41]	0.49 [0.21 0.79]	-0.2 [-0.32 -0.08]	-0.53 [-0.86 -0.22]	-0.91 [-1.48 -0.38]	-2.62 [-4.26 -1.11]	-2.18 [-3.53 -0.91]	-5.99 [-9.73 -2.54]
Argentina	ARG	-0.04 [-0.06 -0.02]	-0.1 [-0.17 -0.04]	-0.34 [-0.56 -0.14]	-1.2 [-1.96 -0.51]	-0.89 [-1.44 -0.37]	-3.02 [-4.9 -1.27]	-1.51 [-2.44 -0.62]	-4.77 [-7.74 -2.02]
Armenia	ARM	0.02 [0.01 0.03]	0.04 [0.02 0.07]	-0.24 [-0.4 -0.1]	-0.83 [-1.35 -0.35]	-0.72 [-1.16 -0.3]	-2.73 [-4.44 -1.15]	-1.21 [-1.97 -0.5]	-4.64 [-7.53 -1.96]
Australia	AUS	-0.03 [-0.05 -0.01]	-0.08 [-0.13 -0.03]	-0.4 [-0.66 -0.17]	-1.38 [-2.24 -0.58]	-1.08 [-1.75 -0.45]	-3.59 [-5.83 -1.52]	-1.98 [-3.21 -0.82]	-6.11 [-9.92 -2.58]
Austria	AUT	0.05 [0.02 0.08]	0.11 [0.05 0.19]	-0.31 [-0.5 -0.13]	-0.95 [-1.55 -0.4]	-0.84 [-1.37 -0.35]	-2.78 [-4.52 -1.17]	-1.76 [-2.86 -0.73]	-5.68 [-9.23 -2.4]
Azerbaijan	AZE	0.13 [0.06 0.22]	0.25 [0.11 0.41]	-0.16 [-0.26 -0.07]	-0.46 [-0.75 -0.19]	-0.71 [-1.15 -0.29]	-2.35 [-3.81 -0.99]	-1.27 [-2.07 -0.53]	-4.29 [-6.97 -1.81]
Bangladesh	BGD	-0.16 [-0.25 -0.06]	-0.93 [-1.52 -0.39]	-0.51 [-0.82 -0.21]	-2.43 [-3.96 -1.03]	-1.08 [-1.75 -0.45]	-4.28 [-6.95 -1.81]	-1.91 [-3.11 -0.79]	-6.53 [-10.61 -2.76]
Belarus	BLR	0.33 [0.14 0.54]	0.58 [0.25 0.95]	0.07 [0.03 0.11]	0.17 [0.07 0.27]	-0.29 [-0.46 -0.12]	-0.8 [-1.3 -0.34]	-1.32 [-2.14 -0.55]	-4.15 [-6.74 -1.75]
Belgium	BEL	0.33 [0.14 0.54]	0.53 [0.22 0.86]	0.13 [0.05 0.2]	0.28 [0.12 0.46]	-0.19 [-0.3 -0.08]	-0.51 [-0.83 -0.22]	-0.76 [-1.24 -0.32]	-2.32 [-3.77 -0.98]
Belize	BLZ	0.03 [0.01 0.05]	0.07 [0.03 0.11]	-0.37 [-0.6 -0.15]	-1.12 [-1.82 -0.47]	-0.85 [-1.38 -0.35]	-2.58 [-4.2 -1.09]	-1.82 [-2.95 -0.76]	-5.21 [-8.46 -2.2]
Benin	BEN	0.31 [0.13 0.5]	0.58 [0.25 0.94]	-0.21 [-0.33 -0.09]	-0.54 [-0.88 -0.23]	-0.97 [-1.57 -0.4]	-2.61 [-4.24 -1.1]	-1.95 [-3.16 -0.81]	-5.12 [-8.31 -2.17]
Bhutan	BTN	0.05 [0.02 0.09]	0.12 [0.05 0.2]	-0.31 [-0.5 -0.13]	-0.92 [-1.49 -0.39]	-0.95 [-1.54 -0.39]	-2.94 [-4.78 -1.24]	-1.85 [-3 -0.77]	-5.45 [-8.85 -2.31]
Bolivia	BOL	-0.13 [-0.22 -0.06]	-0.77 [-1.26 -0.33]	-0.61 [-1 -0.25]	-2.88 [-4.68 -1.21]	-1.41 [-2.29 -0.58]	-5.41 [-8.79 -2.29]	-2.32 [-3.76 -0.96]	-7.86 [-12.76 -3.32]
Bosnia and Herzegovina	BIH	0.74 [0.31 1.2]	1.14 [0.48 1.84]	0.33 [0.14 0.54]	0.73 [0.31 1.19]	-0.21 [-0.34 -0.09]	-0.55 [-0.88 -0.23]	-0.82 [-1.33 -0.34]	-2.27 [-3.68 -0.96]
Botswana	BWA	0.32 [0.13 0.52]	0.54 [0.23 0.87]	-0.21 [-0.34 -0.09]	-0.57 [-0.92 -0.24]	-0.82 [-1.33 -0.34]	-2.48 [-4.04 -1.05]	-1.82 [-2.95 -0.75]	-5.55 [-9.02 -2.35]
Brazil	BRA	0.19 [0.08 0.31]	0.4 [0.17 0.65]	-0.42 [-0.67 -0.17]	-1.14 [-1.86 -0.48]	-1.36 [-2.21 -0.57]	-3.68 [-5.98 -1.56]	-2.41 [-3.91 -1.01]	-6.33 [-10.27 -2.68]
Brunei Darussalam	BRN	0.01 [0.01 0.02]	0.03 [0.01 0.05]	-0.28 [-0.45 -0.11]	-0.87 [-1.41 -0.37]	-0.81 [-1.32 -0.34]	-2.58 [-4.19 -1.09]	-1.56 [-2.53 -0.65]	-4.65 [-7.55 -1.97]
Bulgaria	BGR	-0.07 [-0.12 -0.03]	-0.21 [-0.34 -0.09]	-0.39 [-0.64 -0.16]	-1.34 [-2.18 -0.57]	-1.08 [-1.75 -0.45]	-3.77 [-6.12 -1.59]	-1.72 [-2.79 -0.71]	-5.78 [-9.4 -2.44]
Burkina Faso	BFA	0.26 [0.11 0.43]	0.52 [0.22 0.85]	-0.3 [-0.48 -0.12]	-0.8 [-1.3 -0.34]	-1 [-1.62 -0.42]	-2.76 [-4.48 -1.17]	-1.91 [-3.1 -0.8]	-5.14 [-8.35 -2.18]
Burundi	BDI	0.23 [0.1 0.37]	0.39 [0.17 0.63]	-0.14 [-0.23 -0.06]	-0.39 [-0.64 -0.17]	-0.65 [-1.06 -0.27]	-1.97 [-3.21 -0.83]	-1.49 [-2.41 -0.62]	-4.47 [-7.26 -1.89]
Cabo Verde	CPV	0.21 [0.09 0.34]	0.35 [0.15 0.57]	0.06 [0.02 0.09]	0.13 [0.06 0.21]	-0.27 [-0.44 -0.11]	-0.79 [-1.29 -0.33]	-0.59 [-0.96 -0.25]	-1.82 [-2.96 -0.77]
Cambodia	KHM	0.24 [0.1 0.39]	0.44 [0.19 0.72]	-0.07 [-0.12 -0.03]	-0.19 [-0.31 -0.08]	-0.66 [-1.06 -0.27]	-1.88 [-3.05 -0.79]	-1.71 [-2.78 -0.71]	-4.73 [-7.68 -2]
Cameroon	CMR	0.02 [0.01 0.03]	0.05 [0.02 0.08]	-0.37 [-0.6 -0.15]	-1.14 [-1.86 -0.48]	-1.26 [-2.05 -0.52]	-3.8 [-6.17 -1.61]	-1.94 [-3.14 -0.81]	-5.59 [-9.08 -2.37]
Canada	CAN	0.24 [0.1 0.4]	0.49 [0.21 0.79]	-0.34 [-0.55 -0.14]	-0.96 [-1.56 -0.41]	-1.14 [-1.86 -0.48]	-3.56 [-5.78 -1.5]	-2.31 [-3.74 -0.96]	-7.15 [-11.61 -3.02]
Central African Republic	CAF	-0.01 [-0.01 0]	-0.02 [-0.03 -0.01]	-0.39 [-0.63 -0.16]	-1.27 [-2.06 -0.53]	-1.07 [-1.73 -0.44]	-3.43 [-5.57 -1.45]	-2.09 [-3.39 -0.87]	-6.21 [-10.09 -2.63]

		SSP1-2.6		SSP2-4.5		SSP3-7.0		SSP3-7.0 90th p.	
Country	**ISO3**	**2050**	**2100**	**2050**	**2100**	**2050**	**2100**	**2050**	**2100**
Chad	TCD	0.16 [0.07 0.27]	0.32 [0.13 0.51]	-0.26 [-0.41 -0.11]	-0.74 [-1.2 -0.31]	-0.75 [-1.22 -0.31]	-2.34 [-3.81 -0.99]	-1.64 [-2.66 -0.68]	-5.03 [-8.17 -2.13]
Chile	CHL	-0.01 [-0.01 0]	-0.02 [-0.04 -0.01]	-0.29 [-0.47 -0.12]	-0.92 [-1.5 -0.39]	-0.92 [-1.5 -0.38]	-2.98 [-4.84 -1.26]	-1.49 [-2.41 -0.62]	-4.59 [-7.45 -1.94]
China	CHN	0.34 [0.14 0.55]	0.69 [0.29 1.12]	-0.3 [-0.49 -0.13]	-0.8 [-1.29 -0.34]	-1.12 [-1.81 -0.47]	-3 [-4.88 -1.27]	-2.22 [-3.6 -0.93]	-5.82 [-9.46 -2.47]
Colombia	COL	-0.11 [-0.17 -0.04]	-0.35 [-0.57 -0.15]	-0.56 [-0.91 -0.23]	-2.01 [-3.26 -0.85]	-1.19 [-1.93 -0.49]	-3.94 [-6.39 -1.66]	-2.27 [-3.69 -0.94]	-6.82 [-11.08 -2.89]
Comoros	COM	-0.03 [-0.05 -0.01]	-0.09 [-0.14 -0.04]	-0.19 [-0.3 -0.08]	-0.69 [-1.11 -0.29]	-0.51 [-0.83 -0.21]	-2 [-3.26 -0.84]	-1.05 [-1.71 -0.44]	-3.92 [-6.37 -1.65]
Costa Rica	CRI	0.2 [0.09 0.33]	0.38 [0.16 0.62]	-0.14 [-0.23 -0.06]	-0.39 [-0.64 -0.17]	-0.6 [-0.98 -0.25]	-1.78 [-2.9 -0.75]	-1.23 [-2 -0.51]	-3.61 [-5.87 -1.53]
Croatia	HRV	0.23 [0.1 0.37]	0.45 [0.19 0.73]	-0.14 [-0.23 -0.06]	-0.38 [-0.62 -0.16]	-0.66 [-1.07 -0.28]	-1.98 [-3.22 -0.84]	-1.36 [-2.21 -0.57]	-4.16 [-6.76 -1.76]
Cyprus	CYP	0.11 [0.04 0.17]	0.21 [0.09 0.34]	-0.15 [-0.24 -0.06]	-0.42 [-0.68 -0.18]	-0.64 [-1.04 -0.27]	-2.11 [-3.43 -0.89]	-0.98 [-1.59 -0.41]	-3.22 [-5.24 -1.36]
Czech Republic	CZE	0.07 [0.03 0.12]	0.16 [0.07 0.27]	-0.2 [-0.32 -0.08]	-0.57 [-0.93 -0.24]	-0.57 [-0.93 -0.24]	-1.86 [-3.03 -0.79]	-1.52 [-2.46 -0.63]	-5.05 [-8.2 -2.13]
Côte d'Ivoire	CIV	0.11 [0.05 0.19]	0.24 [0.1 0.39]	-0.28 [-0.46 -0.12]	-0.81 [-1.32 -0.34]	-1.05 [-1.7 -0.44]	-3.05 [-4.96 -1.29]	-2.06 [-3.34 -0.86]	-5.69 [-9.24 -2.41]
Democratic Republic of the Congo	COD	0.12 [0.05 0.19]	0.26 [0.11 0.43]	-0.22 [-0.36 -0.09]	-0.62 [-1 -0.26]	-0.96 [-1.55 -0.4]	-2.7 [-4.39 -1.14]	-2.19 [-3.55 -0.91]	-5.88 [-9.54 -2.49]
Denmark	DNK	0.12 [0.05 0.2]	0.23 [0.1 0.38]	-0.04 [-0.07 -0.02]	-0.11 [-0.18 -0.05]	-0.27 [-0.43 -0.11]	-0.81 [-1.32 -0.34]	-0.77 [-1.26 -0.32]	-2.64 [-4.29 -1.11]
Djibouti	DJI	0.05 [0.02 0.08]	0.11 [0.05 0.18]	-0.28 [-0.45 -0.12]	-0.83 [-1.35 -0.35]	-0.85 [-1.38 -0.35]	-2.67 [-4.34 -1.13]	-1.61 [-2.61 -0.67]	-4.86 [-7.89 -2.06]
Dominican Republic	DOM	0.15 [0.06 0.24]	0.28 [0.12 0.45]	-0.14 [-0.22 -0.06]	-0.37 [-0.61 -0.16]	-0.61 [-0.98 -0.25]	-1.87 [-3.04 -0.79]	-1.02 [-1.66 -0.42]	-3.14 [-5.1 -1.33]
Ecuador	ECU	-0.06 [-0.1 -0.03]	-0.66 [-1.08 -0.28]	-0.26 [-0.43 -0.11]	-1.83 [-2.98 -0.77]	-0.78 [-1.27 -0.32]	-4.03 [-6.55 -1.7]	-1.34 [-2.17 -0.55]	-5.84 [-9.49 -2.47]
Egypt	EGY	0.54 [0.23 0.88]	0.78 [0.33 1.27]	0.1 [0.04 0.17]	0.25 [0.11 0.4]	-0.66 [-1.07 -0.27]	-1.84 [-2.99 -0.78]	-1.37 [-2.22 -0.57]	-3.85 [-6.25 -1.63]
El Salvador	SLV	0.89 [0.37 1.45]	1.13 [0.48 1.83]	0.42 [0.18 0.68]	0.91 [0.39 1.48]	-0.08 [-0.13 -0.03]	-0.2 [-0.33 -0.08]	-0.85 [-1.38 -0.36]	-2.25 [-3.66 -0.95]
Equatorial Guinea	GNQ	0.56 [0.23 0.9]	0.78 [0.33 1.26]	0.32 [0.14 0.52]	0.66 [0.28 1.07]	-0.2 [-0.33 -0.08]	-0.53 [-0.87 -0.23]	-0.82 [-1.33 -0.34]	-2.31 [-3.75 -0.98]
Eritrea	ERI	0.15 [0.06 0.24]	0.28 [0.12 0.46]	-0.14 [-0.22 -0.06]	-0.38 [-0.62 -0.16]	-0.56 [-0.91 -0.23]	-1.77 [-2.88 -0.75]	-1.24 [-2.01 -0.52]	-3.96 [-6.43 -1.67]
Estonia	EST	0.36 [0.15 0.59]	0.61 [0.26 0.98]	0.07 [0.03 0.11]	0.17 [0.07 0.27]	-0.23 [-0.37 -0.1]	-0.63 [-1.02 -0.27]	-1.28 [-2.08 -0.53]	-4.04 [-6.56 -1.71]
Eswatini	SWZ	0.17 [0.07 0.28]	0.32 [0.14 0.53]	-0.25 [-0.41 -0.1]	-0.72 [-1.18 -0.31]	-0.7 [-1.13 -0.29]	-2.16 [-3.51 -0.91]	-1.7 [-2.76 -0.71]	-5.15 [-8.36 -2.18]
Ethiopia	ETH	0.56 [0.24 0.91]	0.84 [0.36 1.37]	0.1 [0.04 0.17]	0.25 [0.11 0.41]	-0.67 [-1.08 -0.28]	-1.76 [-2.86 -0.75]	-1.72 [-2.79 -0.72]	-4.45 [-7.23 -1.89]
Fiji	FJI	0.15 [0.06 0.24]	0.24 [0.1 0.39]	-0.11 [-0.17 -0.04]	-0.3 [-0.48 -0.13]	-0.54 [-0.88 -0.23]	-1.67 [-2.71 -0.71]	-1.04 [-1.69 -0.43]	-3.12 [-5.07 -1.32]
Finland	FIN	0.26 [0.11 0.42]	0.46 [0.2 0.75]	-0.01 [-0.02 0]	-0.03 [-0.04 -0.01]	-0.47 [-0.76 -0.19]	-1.41 [-2.28 -0.59]	-1.41 [-2.29 -0.59]	-4.63 [-7.53 -1.96]
France	FRA	0.22 [0.09 0.35]	0.42 [0.18 0.67]	-0.03 [-0.05 -0.01]	-0.09 [-0.14 -0.04]	-0.62 [-1.01 -0.26]	-1.87 [-3.04 -0.79]	-1.31 [-2.13 -0.55]	-3.99 [-6.49 -1.69]
Gabon	GAB	0.23 [0.1 0.37]	0.44 [0.19 0.71]	-0.06 [-0.1 -0.03]	-0.17 [-0.27 -0.07]	-0.69 [-1.12 -0.29]	-1.98 [-3.21 -0.84]	-1.61 [-2.61 -0.67]	-4.51 [-7.32 -1.91]
Georgia	GEO	0.04 [0.02 0.07]	0.1 [0.04 0.16]	-0.26 [-0.42 -0.11]	-0.83 [-1.34 -0.35]	-0.78 [-1.27 -0.32]	-2.76 [-4.48 -1.16]	-1.33 [-2.16 -0.55]	-4.68 [-7.6 -1.97]
Germany	DEU	0.2 [0.08 0.33]	0.38 [0.16 0.61]	-0.03 [-0.06 -0.01]	-0.09 [-0.14 -0.04]	-0.34 [-0.55 -0.14]	-1 [-1.62 -0.42]	-1.11 [-1.8 -0.46]	-3.56 [-5.78 -1.5]
Ghana	GHA	0.33 [0.14 0.53]	0.62 [0.26 1]	-0.05 [-0.07 -0.02]	-0.12 [-0.19 -0.05]	-0.97 [-1.57 -0.4]	-2.59 [-4.2 -1.1]	-1.96 [-3.18 -0.82]	-5.1 [-8.29 -2.16]
Greece	GRC	-0.07 [-0.11 -0.03]	-0.19 [-0.31 -0.08]	-0.37 [-0.6 -0.15]	-1.27 [-2.06 -0.54]	-1 [-1.62 -0.41]	-3.54 [-5.75 -1.5]	-1.5 [-2.43 -0.62]	-5.15 [-8.36 -2.17]
Grenada	GRL	0.74 [0.31 1.2]	0.87 [0.37 1.41]	0.24 [0.1 0.39]	0.54 [0.23 0.87]	-0.42 [-0.68 -0.18]	-1.15 [-1.87 -0.49]	-0.76 [-1.23 -0.32]	-2.16 [-3.5 -0.91]
Guatemala	GTM	0.79 [0.33 1.29]	1.16 [0.49 1.87]	0.28 [0.12 0.46]	0.65 [0.28 1.06]	-0.61 [-0.99 -0.25]	-1.58 [-2.57 -0.67]	-1.4 [-2.27 -0.58]	-3.6 [-5.84 -1.52]
Guinea	GIN	0.21 [0.09 0.34]	0.43 [0.18 0.7]	-0.34 [-0.55 -0.14]	-0.93 [-1.51 -0.39]	-1.11 [-1.8 -0.46]	-3.04 [-4.94 -1.29]	-2.08 [-3.38 -0.87]	-5.52 [-8.97 -2.34]
Guinea-Bissau	GNB	0.58 [0.24 0.95]	0.9 [0.38 1.46]	0.06 [0.02 0.09]	0.14 [0.06 0.23]	-0.52 [-0.85 -0.22]	-1.38 [-2.24 -0.58]	-1.22 [-1.98 -0.51]	-3.21 [-5.21 -1.36]
Guyana	GUY	-0.11 [-0.17 -0.04]	-0.45 [-0.73 -0.19]	-0.59 [-0.96 -0.25]	-2.48 [-4.04 -1.05]	-1.03 [-1.67 -0.42]	-3.94 [-6.4 -1.66]	-1.92 [-3.12 -0.8]	-6.48 [-10.53 -2.74]
Haiti	HTI	0.12 [0.05 0.19]	0.22 [0.1 0.36]	-0.09 [-0.15 -0.04]	-0.25 [-0.4 -0.1]	-0.41 [-0.66 -0.17]	-1.3 [-2.11 -0.55]	-0.81 [-1.31 -0.34]	-2.68 [-4.36 -1.13]
Honduras	HND	0.35 [0.15 0.57]	0.59 [0.25 0.96]	-0.07 [-0.11 -0.03]	-0.17 [-0.27 -0.07]	-0.6 [-0.97 -0.25]	-1.68 [-2.73 -0.71]	-1.31 [-2.13 -0.55]	-3.69 [-5.99 -1.56]

		SSP1-2.6		SSP2-4.5		SSP3-7.0		SSP3-7.0 90th p.	
Country	**ISO3**	**2050**	**2100**	**2050**	**2100**	**2050**	**2100**	**2050**	**2100**
Hungary	HUN	-0.02 [-0.03 -0.01]	-0.06 [-0.09 -0.02]	-0.31 [-0.5 -0.13]	-1 [-1.62 -0.42]	-0.74 [-1.19 -0.3]	-2.54 [-4.13 -1.07]	-1.62 [-2.63 -0.67]	-5.55 [-9.01 -2.34]
Iceland	ISL	0.2 [0.08 0.32]	0.33 [0.14 0.53]	-0.08 [-0.14 -0.04]	-0.23 [-0.37 -0.1]	-0.39 [-0.63 -0.16]	-1.2 [-1.95 -0.51]	-0.73 [-1.18 -0.3]	-2.37 [-3.85 -1]
India	IND	-0.1 [-0.17 -0.04]	-0.29 [-0.47 -0.12]	-0.5 [-0.81 -0.21]	-1.58 [-2.57 -0.67]	-1.26 [-2.05 -0.52]	-3.79 [-6.16 -1.6]	-2.15 [-3.49 -0.89]	-6.09 [-9.89 -2.58]
Indonesia	IDN	-0.09 [-0.15 -0.04]	-0.27 [-0.45 -0.12]	-0.55 [-0.89 -0.23]	-1.72 [-2.8 -0.73]	-1.16 [-1.88 -0.48]	-3.35 [-5.44 -1.42]	-1.99 [-3.22 -0.83]	-5.43 [-8.81 -2.3]
Iraq	IRQ	0.27 [0.11 0.44]	0.44 [0.19 0.71]	-0.09 [-0.14 -0.04]	-0.23 [-0.37 -0.1]	-0.81 [-1.31 -0.34]	-2.55 [-4.14 -1.08]	-1.29 [-2.1 -0.54]	-4.13 [-6.7 -1.74]
Ireland	IRL	0.17 [0.07 0.28]	0.28 [0.12 0.45]	0.06 [0.02 0.1]	0.13 [0.06 0.22]	-0.27 [-0.44 -0.11]	-0.82 [-1.32 -0.34]	-0.8 [-1.3 -0.33]	-2.54 [-4.12 -1.07]
Islamic Republic of Iran	IRN	0.27 [0.11 0.44]	0.48 [0.21 0.78]	-0.11 [-0.18 -0.05]	-0.3 [-0.48 -0.13]	-0.88 [-1.43 -0.37]	-2.66 [-4.32 -1.12]	-1.67 [-2.71 -0.69]	-5.02 [-8.15 -2.12]
Israel	ISR	0.12 [0.05 0.2]	0.23 [0.1 0.38]	-0.18 [-0.29 -0.07]	-0.52 [-0.84 -0.22]	-0.69 [-1.12 -0.29]	-2.27 [-3.68 -0.96]	-1.16 [-1.88 -0.48]	-3.84 [-6.25 -1.62]
Italy	ITA	0.52 [0.22 0.84]	0.87 [0.37 1.41]	0.09 [0.04 0.14]	0.21 [0.09 0.34]	-0.61 [-0.99 -0.25]	-1.68 [-2.73 -0.71]	-1.32 [-2.14 -0.55]	-3.67 [-5.96 -1.55]
Jamaica	JAM	0.37 [0.16 0.61]	0.58 [0.24 0.93]	0.09 [0.04 0.15]	0.22 [0.09 0.35]	-0.31 [-0.5 -0.13]	-0.85 [-1.38 -0.36]	-0.82 [-1.33 -0.34]	-2.33 [-3.78 -0.98]
Japan	JPN	0.03 [0.01 0.04]	0.06 [0.03 0.1]	-0.36 [-0.58 -0.15]	-1.14 [-1.85 -0.48]	-0.96 [-1.55 -0.4]	-3.11 [-5.05 -1.31]	-1.87 [-3.04 -0.78]	-5.77 [-9.37 -2.44]
Jordan	JOR	0.05 [0.02 0.08]	0.11 [0.05 0.18]	-0.23 [-0.37 -0.09]	-0.71 [-1.16 -0.3]	-0.84 [-1.36 -0.35]	-2.96 [-4.81 -1.25]	-1.31 [-2.13 -0.54]	-4.62 [-7.5 -1.95]
Kazakhstan	KAZ	0.17 [0.07 0.27]	0.32 [0.14 0.52]	-0.28 [-0.46 -0.12]	-0.84 [-1.36 -0.35]	-0.9 [-1.46 -0.37]	-2.98 [-4.84 -1.26]	-1.57 [-2.54 -0.65]	-5.23 [-8.5 -2.21]
Kenya	KEN	0.34 [0.14 0.55]	0.47 [0.2 0.76]	-0.02 [-0.04 -0.01]	-0.06 [-0.1 -0.03]	-0.68 [-1.1 -0.28]	-1.94 [-3.15 -0.82]	-1.5 [-2.44 -0.63]	-4.2 [-6.83 -1.78]
Korea	KOR	-0.1 [-0.16 -0.04]	-0.33 [-0.53 -0.14]	-0.41 [-0.67 -0.17]	-1.56 [-2.54 -0.66]	-0.83 [-1.34 -0.34]	-3.15 [-5.13 -1.33]	-1.79 [-2.9 -0.74]	-6.27 [-10.19 -2.65]
Kuwait	KWT	0.34 [0.14 0.56]	0.58 [0.25 0.94]	0.01 [0 0.01]	0.01 [0.01 0.02]	-0.82 [-1.32 -0.34]	-2.42 [-3.93 -1.02]	-1.6 [-2.59 -0.66]	-4.77 [-7.74 -2.02]
Kyrgyz Republic	KGZ	0.37 [0.15 0.6]	0.69 [0.29 1.11]	-0.07 [-0.11 -0.03]	-0.17 [-0.28 -0.07]	-0.8 [-1.3 -0.33]	-2.31 [-3.75 -0.98]	-1.74 [-2.81 -0.72]	-5 [-8.12 -2.12]
Lao P.D.R.	LAO	-0.03 [-0.05 -0.01]	-0.08 [-0.12 -0.03]	-0.4 [-0.65 -0.17]	-1.4 [-2.28 -0.59]	-0.78 [-1.26 -0.32]	-2.74 [-4.45 -1.16]	-1.49 [-2.42 -0.62]	-4.95 [-8.05 -2.09]
Latvia	LVA	0.31 [0.13 0.5]	0.53 [0.23 0.86]	0.02 [0.01 0.03]	0.04 [0.02 0.06]	-0.28 [-0.45 -0.12]	-0.79 [-1.29 -0.33]	-1.21 [-1.97 -0.5]	-3.86 [-6.27 -1.63]
Lebanon	LBN	0.34 [0.14 0.55]	0.51 [0.22 0.83]	0.05 [0.02 0.08]	0.12 [0.05 0.19]	-0.48 [-0.77 -0.2]	-1.4 [-2.28 -0.59]	-0.92 [-1.49 -0.38]	-2.8 [-4.55 -1.18]
Lesotho	LSO	-0.04 [-0.06 -0.02]	-0.1 [-0.16 -0.04]	-0.43 [-0.69 -0.18]	-1.52 [-2.48 -0.64]	-1.12 [-1.82 -0.46]	-3.98 [-6.47 -1.68]	-2.01 [-3.26 -0.83]	-6.64 [-10.79 -2.81]
Liberia	LBR	0 [-0.01 0]	-0.01 [-0.01 0]	-0.42 [-0.69 -0.18]	-1.29 [-2.1 -0.55]	-1.09 [-1.77 -0.45]	-3.2 [-5.19 -1.35]	-2.02 [-3.28 -0.84]	-5.58 [-9.06 -2.36]
Libya	LBY	1 [0.42 1.62]	1.23 [0.52 1.99]	0.48 [0.2 0.79]	1.05 [0.44 1.7]	-0.4 [-0.66 -0.17]	-1.05 [-1.7 -0.44]	-1.23 [-1.99 -0.51]	-3.2 [-5.2 -1.36]
Lithuania	LTU	0.22 [0.09 0.36]	0.42 [0.18 0.68]	0 [0 0]	0 [0 0]	-0.32 [-0.52 -0.13]	-0.94 [-1.53 -0.4]	-1.2 [-1.95 -0.5]	-3.91 [-6.35 -1.65]
Luxembourg	LUX	0.38 [0.16 0.62]	0.6 [0.25 0.97]	0.16 [0.07 0.26]	0.35 [0.15 0.57]	-0.27 [-0.44 -0.11]	-0.76 [-1.24 -0.32]	-0.93 [-1.51 -0.39]	-2.82 [-4.59 -1.19]
Madagascar	MDG	0.47 [0.2 0.77]	0.75 [0.32 1.21]	0.12 [0.05 0.19]	0.28 [0.12 0.45]	-0.51 [-0.83 -0.21]	-1.37 [-2.23 -0.58]	-1.39 [-2.25 -0.58]	-3.71 [-6.02 -1.57]
Malawi	MWI	0.46 [0.2 0.76]	0.76 [0.32 1.23]	-0.03 [-0.04 -0.01]	-0.07 [-0.11 -0.03]	-0.78 [-1.26 -0.32]	-2.13 [-3.46 -0.9]	-1.95 [-3.17 -0.81]	-5.25 [-8.52 -2.22]
Malaysia	MYS	0.16 [0.07 0.26]	0.33 [0.14 0.53]	-0.24 [-0.38 -0.1]	-0.65 [-1.05 -0.27]	-0.82 [-1.33 -0.34]	-2.28 [-3.71 -0.97]	-1.65 [-2.67 -0.69]	-4.4 [-7.14 -1.86]
Mali	MLI	0.3 [0.13 0.49]	0.55 [0.24 0.9]	-0.26 [-0.42 -0.11]	-0.71 [-1.15 -0.3]	-1.13 [-1.84 -0.47]	-3.24 [-5.26 -1.37]	-2.1 [-3.4 -0.87]	-5.81 [-9.44 -2.46]
Mauritania	MRT	0.39 [0.16 0.63]	0.65 [0.27 1.05]	-0.03 [-0.05 -0.01]	-0.08 [-0.13 -0.03]	-0.82 [-1.34 -0.34]	-2.37 [-3.85 -1]	-1.71 [-2.77 -0.71]	-4.88 [-7.92 -2.06]
Mauritius	MUS	0.53 [0.22 0.86]	0.67 [0.28 1.08]	0.22 [0.09 0.36]	0.48 [0.21 0.79]	-0.22 [-0.36 -0.09]	-0.58 [-0.94 -0.25]	-0.9 [-1.46 -0.37]	-2.45 [-3.98 -1.04]
Mexico	MEX	-0.01 [-0.01 0]	-0.02 [-0.03 -0.01]	-0.48 [-0.77 -0.2]	-1.42 [-2.31 -0.6]	-1.3 [-2.1 -0.54]	-3.73 [-6.06 -1.58]	-2.01 [-3.25 -0.83]	-5.56 [-9.03 -2.35]
Moldova	MDA	0.05 [0.02 0.08]	0.11 [0.05 0.18]	-0.23 [-0.37 -0.1]	-0.69 [-1.12 -0.29]	-0.57 [-0.92 -0.24]	-1.89 [-3.06 -0.8]	-1.32 [-2.15 -0.55]	-4.58 [-7.44 -1.93]
Mongolia	MNG	0.26 [0.11 0.42]	0.5 [0.21 0.82]	-0.09 [-0.15 -0.04]	-0.25 [-0.4 -0.1]	-0.77 [-1.25 -0.32]	-2.33 [-3.79 -0.98]	-1.7 [-2.76 -0.71]	-5.22 [-8.48 -2.21]
Montenegro	MNE	0.07 [0.03 0.12]	0.17 [0.07 0.28]	-0.33 [-0.54 -0.14]	-0.97 [-1.57 -0.41]	-0.92 [-1.5 -0.38]	-2.86 [-4.64 -1.21]	-1.46 [-2.36 -0.6]	-4.46 [-7.24 -1.88]
Morocco	MAR	0.25 [0.11 0.41]	0.47 [0.2 0.76]	-0.08 [-0.13 -0.03]	-0.2 [-0.33 -0.09]	-0.74 [-1.21 -0.31]	-2.21 [-3.59 -0.93]	-1.33 [-2.16 -0.55]	-3.95 [-6.41 -1.67]
Mozambique	MOZ	0.13 [0.06 0.22]	0.27 [0.12 0.44]	-0.28 [-0.45 -0.11]	-0.8 [-1.3 -0.34]	-0.93 [-1.51 -0.39]	-2.8 [-4.55 -1.19]	-1.97 [-3.19 -0.82]	-5.63 [-9.15 -2.38]

		SSP1-2.6		SSP2-4.5		SSP3-7.0		SSP3-7.0 90th p.	
Country	**ISO3**	**2050**	**2100**	**2050**	**2100**	**2050**	**2100**	**2050**	**2100**
Myanmar	MMR	0.36 [0.15 0.59]	0.62 [0.26 1]	0.02 [0.01 0.03]	0.05 [0.02 0.09]	-0.57 [-0.92 -0.24]	-1.56 [-2.54 -0.66]	-1.48 [-2.4 -0.62]	-4.03 [-6.55 -1.71]
Namibia	NAM	0.44 [0.19 0.72]	0.67 [0.28 1.08]	-0.08 [-0.13 -0.03]	-0.2 [-0.33 -0.09]	-0.68 [-1.1 -0.28]	-1.96 [-3.18 -0.83]	-1.76 [-2.85 -0.73]	-5.08 [-8.24 -2.15]
Nepal	NPL	0.12 [0.05 0.2]	0.27 [0.11 0.43]	-0.29 [-0.47 -0.12]	-0.83 [-1.34 -0.35]	-0.93 [-1.5 -0.39]	-2.78 [-4.52 -1.18]	-1.94 [-3.15 -0.81]	-5.61 [-9.1 -2.37]
Netherlands	NLD	0.29 [0.12 0.46]	0.44 [0.19 0.71]	0.11 [0.04 0.17]	0.24 [0.1 0.38]	-0.13 [-0.22 -0.06]	-0.36 [-0.59 -0.15]	-0.65 [-1.06 -0.27]	-2.01 [-3.27 -0.85]
New Zealand	NZL	-0.05 [-0.08 -0.02]	-0.23 [-0.38 -0.1]	-0.3 [-0.49 -0.13]	-1.46 [-2.37 -0.61]	-0.72 [-1.17 -0.3]	-3.18 [-5.17 -1.34]	-1.11 [-1.8 -0.46]	-4.5 [-7.31 -1.9]
Nicaragua	NIC	0.77 [0.32 1.25]	1.03 [0.44 1.66]	0.31 [0.13 0.51]	0.7 [0.3 1.13]	-0.34 [-0.55 -0.14]	-0.89 [-1.45 -0.38]	-0.9 [-1.46 -0.38]	-2.39 [-3.89 -1.01]
Niger	NER	-0.06 [-0.09 -0.02]	-0.18 [-0.3 -0.08]	-0.37 [-0.6 -0.15]	-1.48 [-2.41 -0.62]	-0.89 [-1.45 -0.37]	-3.58 [-5.82 -1.51]	-1.65 [-2.67 -0.68]	-6.17 [-10.02 -2.6]
Nigeria	NGA	0.21 [0.09 0.34]	0.4 [0.17 0.65]	-0.25 [-0.41 -0.11]	-0.71 [-1.15 -0.3]	-0.92 [-1.48 -0.38]	-2.63 [-4.27 -1.11]	-1.83 [-2.96 -0.76]	-5.06 [-8.22 -2.14]
North Macedonia	MKD	0.08 [0.03 0.13]	0.15 [0.06 0.24]	-0.08 [-0.12 -0.03]	-0.22 [-0.36 -0.09]	-0.3 [-0.49 -0.12]	-0.99 [-1.61 -0.42]	-0.79 [-1.28 -0.33]	-2.8 [-4.54 -1.18]
Norway	NOR	0.17 [0.07 0.28]	0.33 [0.14 0.53]	-0.06 [-0.1 -0.03]	-0.16 [-0.27 -0.07]	-0.41 [-0.67 -0.17]	-1.27 [-2.07 -0.54]	-1.21 [-1.97 -0.5]	-4.03 [-6.54 -1.7]
Oman	OMN	-0.06 [-0.09 -0.02]	-0.17 [-0.27 -0.07]	-0.47 [-0.76 -0.19]	-1.62 [-2.63 -0.68]	-1.09 [-1.78 -0.45]	-3.61 [-5.86 -1.52]	-2.2 [-3.56 -0.91]	-6.59 [-10.7 -2.79]
Pakistan	PAK	-0.13 [-0.21 -0.05]	-0.39 [-0.64 -0.17]	-0.45 [-0.73 -0.19]	-1.57 [-2.56 -0.66]	-1.19 [-1.93 -0.49]	-4.04 [-6.57 -1.71]	-2.02 [-3.27 -0.83]	-6.42 [-10.42 -2.71]
Panama	PAN	0.23 [0.09 0.37]	0.42 [0.18 0.68]	-0.12 [-0.19 -0.05]	-0.31 [-0.5 -0.13]	-0.56 [-0.91 -0.23]	-1.62 [-2.63 -0.68]	-1.18 [-1.91 -0.49]	-3.37 [-5.48 -1.43]
Papua New Guinea	PNG	-0.04 [-0.07 -0.02]	-0.11 [-0.18 -0.05]	-0.36 [-0.58 -0.15]	-1.11 [-1.81 -0.47]	-1 [-1.62 -0.41]	-2.95 [-4.8 -1.25]	-1.7 [-2.75 -0.71]	-4.75 [-7.71 -2.01]
Paraguay	PRY	-0.09 [-0.15 -0.04]	-0.36 [-0.58 -0.15]	-0.35 [-0.56 -0.14]	-1.5 [-2.44 -0.63]	-0.72 [-1.17 -0.3]	-3.06 [-4.97 -1.29]	-1.65 [-2.68 -0.68]	-6.24 [-10.14 -2.64]
Peru	PER	-0.14 [-0.22 -0.06]	-0.46 [-0.75 -0.2]	-0.5 [-0.82 -0.21]	-1.85 [-3.01 -0.78]	-1.25 [-2.03 -0.52]	-4.26 [-6.91 -1.8]	-2.14 [-3.47 -0.88]	-6.66 [-10.82 -2.82]
Philippines	PHL	-0.04 [-0.06 -0.02]	-0.1 [-0.17 -0.04]	-0.43 [-0.71 -0.18]	-1.41 [-2.29 -0.6]	-0.95 [-1.55 -0.4]	-2.93 [-4.75 -1.24]	-1.61 [-2.61 -0.67]	-4.65 [-7.55 -1.97]
Poland	POL	0.19 [0.08 0.3]	0.37 [0.16 0.6]	-0.05 [-0.09 -0.02]	-0.14 [-0.22 -0.06]	-0.38 [-0.61 -0.16]	-1.12 [-1.82 -0.47]	-1.25 [-2.02 -0.52]	-4.05 [-6.57 -1.71]
Portugal	PRT	-0.01 [-0.01 0]	-0.02 [-0.03 -0.01]	-0.24 [-0.39 -0.1]	-0.8 [-1.29 -0.34]	-0.74 [-1.2 -0.31]	-2.59 [-4.2 -1.09]	-1.41 [-2.29 -0.58]	-4.72 [-7.67 -2]
Puerto Rico	PRI	-0.05 [-0.07 -0.02]	-0.13 [-0.22 -0.06]	-0.28 [-0.45 -0.11]	-1.01 [-1.64 -0.43]	-0.64 [-1.03 -0.26]	-2.31 [-3.75 -0.97]	-1.06 [-1.72 -0.44]	-3.65 [-5.92 -1.54]
Qatar	QAT	0.39 [0.16 0.63]	0.69 [0.29 1.11]	0.1 [0.04 0.15]	0.23 [0.1 0.37]	-0.61 [-0.99 -0.25]	-1.74 [-2.83 -0.74]	-1.41 [-2.29 -0.59]	-4.1 [-6.66 -1.73]
Republic of Congo	COG	0.11 [0.04 0.17]	0.24 [0.1 0.38]	-0.37 [-0.59 -0.15]	-1.03 [-1.67 -0.44]	-1.15 [-1.87 -0.48]	-3.22 [-5.23 -1.36]	-2.38 [-3.86 -0.99]	-6.35 [-10.32 -2.69]
Romania	ROU	0.02 [0.01 0.03]	0.04 [0.02 0.07]	-0.32 [-0.52 -0.13]	-0.98 [-1.6 -0.41]	-0.74 [-1.2 -0.31]	-2.45 [-3.97 -1.03]	-1.54 [-2.5 -0.64]	-5.11 [-8.29 -2.16]
Russia	RUS	0.45 [0.19 0.73]	0.83 [0.35 1.34]	-0.13 [-0.22 -0.06]	-0.35 [-0.56 -0.15]	-1.03 [-1.67 -0.43]	-2.99 [-4.85 -1.26]	-2.18 [-3.54 -0.91]	-6.35 [-10.31 -2.69]
Rwanda	RWA	0.18 [0.08 0.3]	0.33 [0.14 0.54]	-0.25 [-0.41 -0.1]	-0.72 [-1.17 -0.31]	-0.81 [-1.32 -0.34]	-2.46 [-4 -1.04]	-1.71 [-2.77 -0.71]	-4.98 [-8.08 -2.11]
Samoa	WSM	0.01 [0.01 0.02]	-0.36 [-0.58 -0.15]	-0.14 [-0.23 -0.06]	-1.44 [-2.34 -0.6]	-0.43 [-0.7 -0.18]	-2.76 [-4.48 -1.16]	-0.95 [-1.54 -0.39]	-4.52 [-7.34 -1.91]
San Marino	SMR	0.01 [0.01 0.02]	-0.36 [-0.58 -0.15]	-0.14 [-0.23 -0.06]	-1.44 [-2.34 -0.6]	-0.43 [-0.7 -0.18]	-2.76 [-4.48 -1.16]	-0.95 [-1.54 -0.39]	-4.52 [-7.34 -1.91]
São Tomé and Príncipe	STP	0.61 [0.26 1]	0.89 [0.38 1.44]	0.25 [0.1 0.4]	0.56 [0.24 0.9]	-0.21 [-0.34 -0.09]	-0.54 [-0.88 -0.23]	-0.82 [-1.33 -0.34]	-2.18 [-3.54 -0.92]
Saudi Arabia	SAU	0.16 [0.07 0.26]	0.33 [0.14 0.53]	-0.16 [-0.25 -0.06]	-0.43 [-0.7 -0.18]	-0.9 [-1.46 -0.37]	-2.83 [-4.59 -1.19]	-1.66 [-2.69 -0.69]	-5.17 [-8.4 -2.19]
Senegal	SEN	0.57 [0.24 0.92]	0.86 [0.36 1.39]	0.07 [0.03 0.12]	0.17 [0.07 0.28]	-0.6 [-0.97 -0.25]	-1.62 [-2.64 -0.69]	-1.46 [-2.37 -0.61]	-3.95 [-6.42 -1.67]
Serbia	SRB	-0.03 [-0.05 -0.01]	-0.09 [-0.14 -0.04]	-0.39 [-0.63 -0.16]	-1.25 [-2.04 -0.53]	-0.95 [-1.54 -0.39]	-3.2 [-5.2 -1.35]	-1.5 [-2.44 -0.62]	-5 [-8.13 -2.11]
Sierra Leone	SLE	0.2 [0.08 0.33]	0.42 [0.18 0.67]	-0.25 [-0.4 -0.1]	-0.67 [-1.09 -0.28]	-0.93 [-1.5 -0.39]	-2.56 [-4.15 -1.08]	-1.82 [-2.94 -0.76]	-4.84 [-7.87 -2.05]
Slovak Republic	SVK	0.07 [0.03 0.11]	0.16 [0.07 0.25]	-0.23 [-0.38 -0.1]	-0.68 [-1.1 -0.29]	-0.72 [-1.17 -0.3]	-2.34 [-3.79 -0.99]	-1.77 [-2.88 -0.74]	-5.73 [-9.3 -2.42]
Slovenia	SVN	0.41 [0.17 0.67]	0.72 [0.31 1.17]	0.05 [0.02 0.08]	0.12 [0.05 0.2]	-0.46 [-0.74 -0.19]	-1.29 [-2.09 -0.54]	-1.33 [-2.16 -0.55]	-3.91 [-6.34 -1.65]
Solomon Islands	SLB	0.09 [0.04 0.14]	0.19 [0.08 0.31]	-0.24 [-0.4 -0.1]	-0.7 [-1.13 -0.29]	-0.78 [-1.26 -0.32]	-2.21 [-3.59 -0.94]	-1.42 [-2.31 -0.59]	-3.87 [-6.28 -1.64]
Somalia	SOM	0.45 [0.19 0.73]	0.65 [0.28 1.05]	0.1 [0.04 0.15]	0.23 [0.1 0.37]	-0.45 [-0.73 -0.19]	-1.24 [-2.02 -0.53]	-1.3 [-2.11 -0.54]	-3.59 [-5.82 -1.52]
South Africa	ZAF	-0.09 [-0.15 -0.04]	-0.29 [-0.47 -0.12]	-0.6 [-0.97 -0.25]	-2.15 [-3.5 -0.91]	-1.22 [-1.98 -0.5]	-4.11 [-6.68 -1.74]	-2.33 [-3.78 -0.96]	-7.12 [-11.57 -3.01]

		SSP1-2.6		SSP2-4.5		SSP3-7.0		SSP3-7.0 90th p.	
Country	**ISO3**	**2050**	**2100**	**2050**	**2100**	**2050**	**2100**	**2050**	**2100**
Somalia	SOM	0.45 [0.19 0.73]	0.65 [0.28 1.05]	0.1 [0.04 0.15]	0.23 [0.1 0.37]	-0.45 [-0.73 -0.19]	-1.24 [-2.02 -0.53]	-1.3 [-2.11 -0.54]	-3.59 [-5.82 -1.52]
South Africa	ZAF	-0.09 [-0.15 -0.04]	-0.29 [-0.47 -0.12]	-0.6 [-0.97 -0.25]	-2.15 [-3.5 -0.91]	-1.22 [-1.98 -0.5]	-4.11 [-6.68 -1.74]	-2.33 [-3.78 -0.96]	-7.12 [-11.57 -3.01]
South Sudan	SSD	0.76 [0.32 1.24]	0.94 [0.4 1.52]	0.39 [0.16 0.63]	0.81 [0.34 1.32]	-0.21 [-0.34 -0.09]	-0.55 [-0.89 -0.23]	-0.96 [-1.56 -0.4]	-2.62 [-4.25 -1.11]
Spain	ESP	0.44 [0.18 0.71]	0.72 [0.31 1.16]	0.09 [0.04 0.14]	0.2 [0.09 0.33]	-0.6 [-0.98 -0.25]	-1.7 [-2.77 -0.72]	-1.39 [-2.25 -0.58]	-3.96 [-6.43 -1.67]
Sri Lanka	LKA	0.06 [0.03 0.1]	0.14 [0.06 0.22]	-0.26 [-0.43 -0.11]	-0.76 [-1.23 -0.32]	-0.79 [-1.28 -0.33]	-2.28 [-3.7 -0.97]	-1.55 [-2.51 -0.65]	-4.27 [-6.94 -1.81]
St. Vincent and the Grenadines	VCT	0.12 [0.05 0.19]	0.23 [0.1 0.38]	-0.16 [-0.26 -0.07]	-0.44 [-0.72 -0.19]	-0.45 [-0.73 -0.19]	-1.36 [-2.21 -0.57]	-0.84 [-1.36 -0.35]	-2.54 [-4.12 -1.07]
Sudan	SDN	0.72 [0.3 1.17]	1.01 [0.43 1.64]	0.27 [0.11 0.44]	0.61 [0.26 1]	-0.52 [-0.84 -0.22]	-1.39 [-2.25 -0.59]	-1.42 [-2.31 -0.59]	-3.82 [-6.2 -1.62]
Suriname	SUR	-0.08 [-0.12 -0.03]	-0.27 [-0.44 -0.11]	-0.53 [-0.86 -0.22]	-2.14 [-3.48 -0.9]	-0.97 [-1.58 -0.4]	-3.68 [-5.97 -1.55]	-1.73 [-2.81 -0.72]	-5.89 [-9.57 -2.49]
Sweden	SWE	0.11 [0.05 0.17]	0.21 [0.09 0.34]	-0.12 [-0.19 -0.05]	-0.33 [-0.53 -0.14]	-0.44 [-0.71 -0.18]	-1.44 [-2.34 -0.61]	-1.22 [-1.98 -0.51]	-4.34 [-7.06 -1.83]
Switzerland	CHE	0.11 [0.04 0.17]	0.23 [0.1 0.37]	-0.26 [-0.41 -0.11]	-0.75 [-1.21 -0.31]	-0.82 [-1.33 -0.34]	-2.59 [-4.21 -1.1]	-1.68 [-2.73 -0.7]	-5.23 [-8.49 -2.21]
Syria	SYR	0.23 [0.1 0.37]	0.39 [0.16 0.63]	-0.08 [-0.13 -0.03]	-0.21 [-0.34 -0.09]	-0.7 [-1.13 -0.29]	-2.2 [-3.57 -0.93]	-1.2 [-1.94 -0.5]	-3.85 [-6.25 -1.63]
Tajikistan	TJK	-0.12 [-0.19 -0.05]	-0.69 [-1.12 -0.29]	-0.31 [-0.5 -0.13]	-1.73 [-2.82 -0.73]	-1.05 [-1.69 -0.43]	-4.9 [-7.96 -2.07]	-1.97 [-3.19 -0.81]	-7.98 [-12.97 -3.37]
Tanzania	TZA	0.06 [0.02 0.1]	0.13 [0.05 0.2]	-0.32 [-0.53 -0.13]	-1.03 [-1.67 -0.43]	-0.95 [-1.54 -0.39]	-3.01 [-4.89 -1.27]	-1.8 [-2.91 -0.75]	-5.36 [-8.71 -2.27]
Thailand	THA	-0.06 [-0.1 -0.03]	-0.2 [-0.32 -0.08]	-0.29 [-0.46 -0.12]	-1.08 [-1.75 -0.46]	-0.96 [-1.56 -0.4]	-3.44 [-5.58 -1.45]	-1.74 [-2.83 -0.72]	-5.66 [-9.19 -2.39]
The Bahamas	BHS	0.4 [0.17 0.64]	0.64 [0.27 1.03]	0.13 [0.05 0.21]	0.3 [0.13 0.49]	-0.31 [-0.51 -0.13]	-0.85 [-1.37 -0.36]	-0.89 [-1.44 -0.37]	-2.44 [-3.96 -1.03]
The Gambia	GMB	0.5 [0.21 0.81]	0.8 [0.34 1.29]	0.04 [0.01 0.06]	0.09 [0.04 0.14]	-0.54 [-0.88 -0.23]	-1.47 [-2.39 -0.62]	-1.31 [-2.12 -0.54]	-3.52 [-5.72 -1.49]
Togo	TGO	0.31 [0.13 0.51]	0.6 [0.25 0.97]	-0.09 [-0.14 -0.04]	-0.22 [-0.36 -0.09]	-1 [-1.62 -0.42]	-2.7 [-4.38 -1.14]	-1.91 [-3.1 -0.8]	-5.03 [-8.16 -2.13]
Trinidad and Tobago	TTO	0.65 [0.27 1.06]	0.83 [0.35 1.34]	0.32 [0.13 0.52]	0.68 [0.29 1.1]	-0.07 [-0.11 -0.03]	-0.17 [-0.28 -0.07]	-0.51 [-0.83 -0.21]	-1.37 [-2.22 -0.58]
Tunisia	TUN	1.01 [0.42 1.64]	1.33 [0.56 2.15]	0.58 [0.24 0.94]	1.2 [0.51 1.94]	-0.18 [-0.29 -0.07]	-0.45 [-0.74 -0.19]	-0.79 [-1.29 -0.33]	-2.09 [-3.4 -0.89]
Turkmenistan	TKM	0.32 [0.13 0.52]	0.48 [0.21 0.78]	0 [0 0.01]	0.01 [0 0.02]	-0.68 [-1.11 -0.28]	-2.09 [-3.4 -0.89]	-1.41 [-2.28 -0.58]	-4.43 [-7.19 -1.87]
Türkiye	TUR	0.03 [0.01 0.05]	0.07 [0.03 0.11]	-0.25 [-0.41 -0.1]	-0.83 [-1.36 -0.35]	-0.85 [-1.38 -0.35]	-3.13 [-5.08 -1.32]	-1.22 [-1.98 -0.5]	-4.47 [-7.27 -1.89]
Uganda	UGA	0.39 [0.16 0.64]	0.6 [0.26 0.97]	-0.01 [-0.01 0]	-0.02 [-0.03 -0.01]	-0.7 [-1.13 -0.29]	-1.94 [-3.15 -0.82]	-1.53 [-2.48 -0.64]	-4.19 [-6.8 -1.77]
Ukraine	UKR	0.14 [0.06 0.23]	0.3 [0.13 0.49]	-0.04 [-0.06 -0.02]	-0.1 [-0.16 -0.04]	-0.43 [-0.7 -0.18]	-1.3 [-2.12 -0.55]	-1.18 [-1.92 -0.49]	-3.85 [-6.26 -1.63]
United Arab Emirates	ARE	0.09 [0.04 0.14]	0.18 [0.08 0.3]	-0.26 [-0.42 -0.11]	-0.77 [-1.26 -0.33]	-1.02 [-1.66 -0.42]	-3.34 [-5.42 -1.41]	-1.82 [-2.95 -0.75]	-5.72 [-9.3 -2.42]
United Kingdom	GBR	0.09 [0.04 0.15]	0.17 [0.07 0.28]	-0.09 [-0.14 -0.04]	-0.24 [-0.39 -0.1]	-0.38 [-0.62 -0.16]	-1.26 [-2.04 -0.53]	-0.86 [-1.39 -0.36]	-2.93 [-4.75 -1.24]
United States	USA	-0.02 [-0.04 -0.01]	-0.06 [-0.1 -0.03]	-0.67 [-1.09 -0.28]	-2.08 [-3.38 -0.88]	-1.61 [-2.61 -0.67]	-4.81 [-7.82 -2.04]	-2.31 [-3.74 -0.96]	-6.67 [-10.83 -2.82]
Uruguay	URY	0.19 [0.08 0.31]	0.32 [0.14 0.52]	-0.01 [-0.01 0]	-0.02 [-0.03 -0.01]	-0.57 [-0.93 -0.24]	-1.74 [-2.83 -0.74]	-1.15 [-1.87 -0.48]	-3.48 [-5.66 -1.47]
Uzbekistan	UZB	0.17 [0.07 0.27]	0.31 [0.13 0.5]	-0.12 [-0.19 -0.05]	-0.33 [-0.53 -0.14]	-0.8 [-1.29 -0.33]	-2.6 [-4.23 -1.1]	-1.47 [-2.39 -0.61]	-4.87 [-7.91 -2.06]
Vanuatu	VUT	0.87 [0.37 1.42]	0.76 [0.32 1.24]	0.58 [0.24 0.94]	1.04 [0.44 1.68]	0.15 [0.06 0.24]	0.36 [0.15 0.58]	-0.32 [-0.52 -0.13]	-0.84 [-1.36 -0.35]
Venezuela	VEN	0.18 [0.08 0.3]	0.36 [0.15 0.59]	-0.37 [-0.59 -0.15]	-1.04 [-1.69 -0.44]	-1.2 [-1.94 -0.5]	-3.42 [-5.55 -1.45]	-2.08 [-3.37 -0.86]	-5.72 [-9.28 -2.42]
Vietnam	VNM	-0.07 [-0.12 -0.03]	-0.24 [-0.39 -0.1]	-0.47 [-0.77 -0.2]	-1.82 [-2.95 -0.77]	-0.81 [-1.31 -0.33]	-2.98 [-4.84 -1.26]	-1.54 [-2.5 -0.64]	-5.16 [-8.39 -2.18]
Yemen	YEM	0.71 [0.3 1.16]	0.88 [0.38 1.43]	0.43 [0.18 0.7]	0.85 [0.36 1.38]	-0.06 [-0.11 -0.03]	-0.17 [-0.27 -0.07]	-0.85 [-1.38 -0.35]	-2.4 [-3.9 -1.01]
Zambia	ZMB	0.22 [0.09 0.36]	0.37 [0.16 0.61]	-0.18 [-0.3 -0.08]	-0.51 [-0.83 -0.22]	-0.88 [-1.42 -0.36]	-2.73 [-4.43 -1.15]	-2.04 [-3.31 -0.85]	-6.13 [-9.95 -2.59]
Zimbabwe	ZWE	0.04 [0.02 0.07]	0.09 [0.04 0.15]	-0.42 [-0.69 -0.18]	-1.38 [-2.24 -0.58]	-1 [-1.62 -0.41]	-3.34 [-5.42 -1.41]	-2.02 [-3.28 -0.84]	-6.39 [-10.38 -2.7]

References

Akyapi, Berkay, Matthieu Bellon, and Emanuele Massetti. 2025. “Estimating macro-fiscal effects of climate shocks from billions of geospatial weather observations.” *American Economic Journal: Macroeconomics*, 17(3): 114–159.

Bellon, Matthieu and Emanuele Massetti. 2022. “Economic Principles for Integrating Adaptation to Climate Change into Fiscal Policy.” IMF Staff Climate Note 2022/001, International Monetary Fund, Washington, DC.

Burke, Marshall, Solomon M. Hsiang, and Edward Miguel. 2015. “Global non-linear effect of temperature on economic production.” *Nature 527*(7577): 235–39.

Carleton, Tamma, Esther Duflo, B. Kelsey Jack, and Guglielmo Zappalà. 2024. “Adaptation to Climate Change.” In *Handbook of the Economics of Climate Change* 1(1): 143-248. North-Holland.

Copernicus Climate Change Service, Climate Data Store. 2021. CMIP6 climate projections. Copernicus Climate Change Service (C3S) Climate Data Store (CDS). https://doi.org/10.24381/cds.c866074c

Dell, Melissa, Benjamin F. Jones, and Benjamin A. Olken. 2012. “Temperature shocks and economic growth: Evidence from the last half century.” *American Economic Journal: Macroeconomics* 4(3): 66–95.

Harris, I., T. J. Osborn, P. Jones, and D. Lister. 2020. Version 4 of the CRU TS Monthly High-Resolution Gridded Multivariate Climate Dataset. *Scientific Data*. https://doi.org/10.1038/s41597-020-0453-3

Harris, Jason, Bryn Battersby, Mehdi Raissi, John Zohrab, and Jyoti Rahman. (2022a. “Armenia–Quantifying Fiscal Risks from Climate Change.” IMF Staff Country Report 2022/329, International Monetary Fund, Washington, DC. https://doi.org/10.5089/9798400224140.002

Harris, Jason, Tjeerd Tim, John Zohrab, Viera Karolova, and Jyoti Rahman. 2022b. “Georgia–Updating the Balance Sheet and Quantifying Fiscal Risks from Climate Change.” IMF Staff Country Report 2022/150, International Monetary Fund, Washington, DC. https://doi.org/10.5089/9798400209970.002

Hausfather, Zeke, and Glen P. Peters. 2020. “Emissions–the ‘Business as Usual’ Story Is Misleading.” *Nature* 577: 618–20. https://www.nature.com/articles/d41586-020-00177-3

IPCC. 2021. “Annex VII: Glossary.” In *Climate Change 2021: The Physical Science Basis*. New York: Cambridge University Press. doi:10.1017/9781009157896.022

Kahn, Matthew E., Kamiar Mohaddes, Ryan NC Ng, M. Hashem Pesaran, Mehdi Raissi, and Jui-Chung Yang. 2021. “Long-term macroeconomic effects of climate change: A cross-country analysis.” *Energy Economics* 104: 105624.

Kalkuhl, Matthias, and Leonie Wenz. 2020. “The impact of climate conditions on economic production. Evidence from a global panel of regions.” *Journal of Environmental Economics and Management* 103: 102360.

Kemp, Luke, Chi Xu, Joanna Depledge, Kristie L. Ebi, Goodwin Gibbins, Timothy A. Kohler, Johan Rockström and others. 2022. "Climate endgame: Exploring catastrophic climate change scenarios" *Proceedings of the National Academy of Sciences* 119(34): e2108146119.

Kotz, M., A. Levermann, and L. Wenz. 2024. “The economic commitment of climate change.” *Nature* 628(8008): 551–57.

Lee, J.-Y., J. Marotzke, G. Bala, L. Cao, S. Corti, J.P. Dunne, F. Engelbrecht, and others. 2021. "Future Global Climate: Scenario-Based Projections and Near-Term Information." In *Climate Change 2021: The Physical Science Basis.* Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Masson-Delmotte, V., P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T.K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou (eds.). Cambridge: Cambridge University Press.

Massetti, Emanuele, and Filippos Tagklis. 2024. FADCP Climate Dataset: Temperature and Precipitation. Reference Guide. International Monetary Fund, Washington, DC.

Massetti, Emanuele, and Robert Mendelsohn. 2018. "Measuring Climate Adaptation: Methods and Evidence." *Review of Environmental Economics and Policy* 2(2): 324–341.

Meinshausen, M., C. F. Schleussner, K. Beyer, G. Bodeker, O. Boucher, J. G. Canadell, J. S. Daniel, and others. 2024. "A perspective on the next generation of Earth system model scenarios: towards representative emission pathways (REPs)." *Geosci. Model Dev.* 17: 4533–59. https://doi.org/10.5194/gmd-17-4533-2024

Mitra, P., M. Raissi, B. Versailles, S. Centorrino, M. Ivanyna, K. Kirabaeva, E. Massetti, and others. 2025. "Integrating Climate Change into Macroeconomic Analysis: A Review of Data, Models, and Scenarios." IMF Working Paper 2025/170, International Monetary Fund, Washington, DC. https://doi.org/10.5089/9798229021890.001

Mohaddes, K., and M. Raissi. 2025. "Rising Temperatures, Melting Incomes: Country-Specific Macroeconomic Effects of Climate Scenarios." *PLOS Climate* 4(9): e0000621. https://doi.org/10.1371/journal.pclm.0000621

Morris, Jennifer, Steven K. Rose, John Reilly, Angelo Gurgel, Sergey Paltsev, and C. Adam Schlosser. 2025. "Reconciling widely varying estimates of the global economic impacts from climate change." *Nature Climate Change*: 1–4.

Nath, Ishan B., Valerie A. Ramey, and Peter J. Klenow. 2024. "How much will global warming cool global growth?" NBER Working Paper 32761, National Bureau of Economic Research, Cambridge, MA. doi: 10.3386/w32761

Newell, Richard G., Brian C. Prest, and Steven E. Sexton. 2021. "The GDP-temperature relationship: implications for climate change damages." *Journal of Environmental Economics and Management* 108: 102445.

O'Neill, Brian C., Elmar Kriegler, Keywan Riahi, Kristie L. Ebi, Stephane Hallegatte, Timothy R. Carter, Ritu Mathur, and Detlef P. van Vuuren. 2014. "The Scenario Framework for Climate Change Research: Introduction and Overview." *Climatic Change* 122(3): 383–95. https://doi.org/10.1007/s10584-013-0905-2

O'Neill, Brian C., Elmar Kriegler, Keywan Riahi, Kristie L. Ebi, Stephane Hallegatte, Timothy R. Carter, Ritu Mathur, and Detlef P. van Vuuren. 2017. "The Roads Ahead: Narratives for Shared Socioeconomic Pathways Describing World Futures in the 21st Century." *Global Environmental Change* 42: 169–80. https://doi.org/10.1016/j.gloenvcha.2015.01.004

Pesaran, M. Hashem. 2015. *Time series and panel data econometrics*. London: Oxford University Press.

Pielke Jr, Roger, and Justin Ritchie. 2021. "Distorting the View of Our Climate Future: The Misuse and Abuse of Climate Pathways and Scenarios." *Energy Research & Social Science* 72: 101890.

Riahi, Keywan, Detlef P. van Vuuren, Elmar Kriegler, Jae Edmonds, Brian C. O'Neill, Christophe F. Bauer, Kok K. Calvin, and others. 2017. "The Shared Socioeconomic Pathways and Their Energy, Land Use, and Greenhouse Gas Emissions Implications: An Overview." *Global Environmental Change* 42: 153–68. https://doi.org/10.1016/j.gloenvcha.2016.05.009

Tim, Tjeerd, and Jyoti Rahman. 2024. User Guide for the Quantitative Climate Risk Assessment Fiscal Tool (Q-CRAFT). International Monetary Fund, Washington, DC. https://www.imf.org/-/media/Files/Topics/Fiscal/Fiscal-Risks/Tool/qcraft-user-guidev10.ashx

Tol, R. S. 2021. "The Economic Impact of Weather and Climate." CESifo Working Paper 8946, CESifo, Munich.

Tol, R. S. 2024. "A Meta-analysis of the Total Economic Impact of Climate Change." *Energy Policy 185*" 113922.