Climate-Informed LT Growth Model

Some Theoretical Foundations and Practical Results

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Vienna University of Economics and Business (WU Wien)

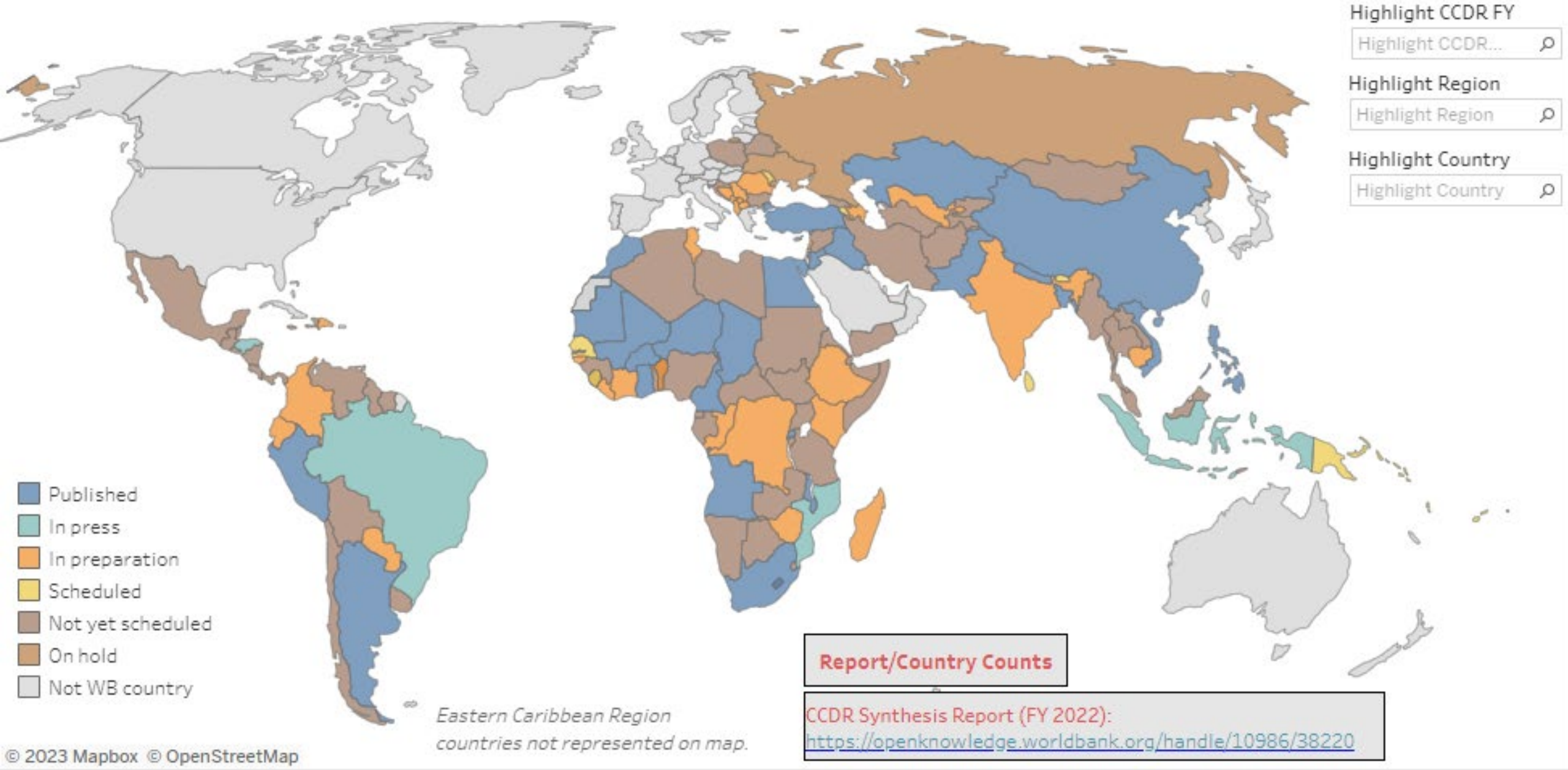
World Bank Country Climate and Development Report (CCDR)

- A new core diagnostic study to :

  (i) analyze how a country's development goals can be achieved in the context of climate change and the global decarbonization effort; and

  (ii) prioritize climate-smart interventions to improve development outcomes in key sectors.

- 25 prepared, 25 more in preparation



1- Modeling Objectives

Quantify future (by 2050) **aggregate (macro)** and poverty **distributional** impacts (income, location, employment sector, etc.) of

(a) climate change

(b) adaptation (to climate shocks) policies/investment

(c) mitigation (of global warming) policies/investments

OUTLINES

- Approach
- Baseline model (without climate change)
- Extension to Climate Change: energy sector
- Extension to Climate Change: GHG emissions/pollution
- Extension to Climate Change: biophysical economic damages
- Poverty implications
- Application: CCDR Approach
- Application: impact of CC on growth and poverty (past CCDRs)
- Application: adaptation and mitigation results (previous CCDRs)
- Modeling steps (case of WB CCDRs)

1- Climate change and economic damages (approach)

- Developing countries – **adaptation/mitigation**

Adaptation Policy Interventions and **Investments**

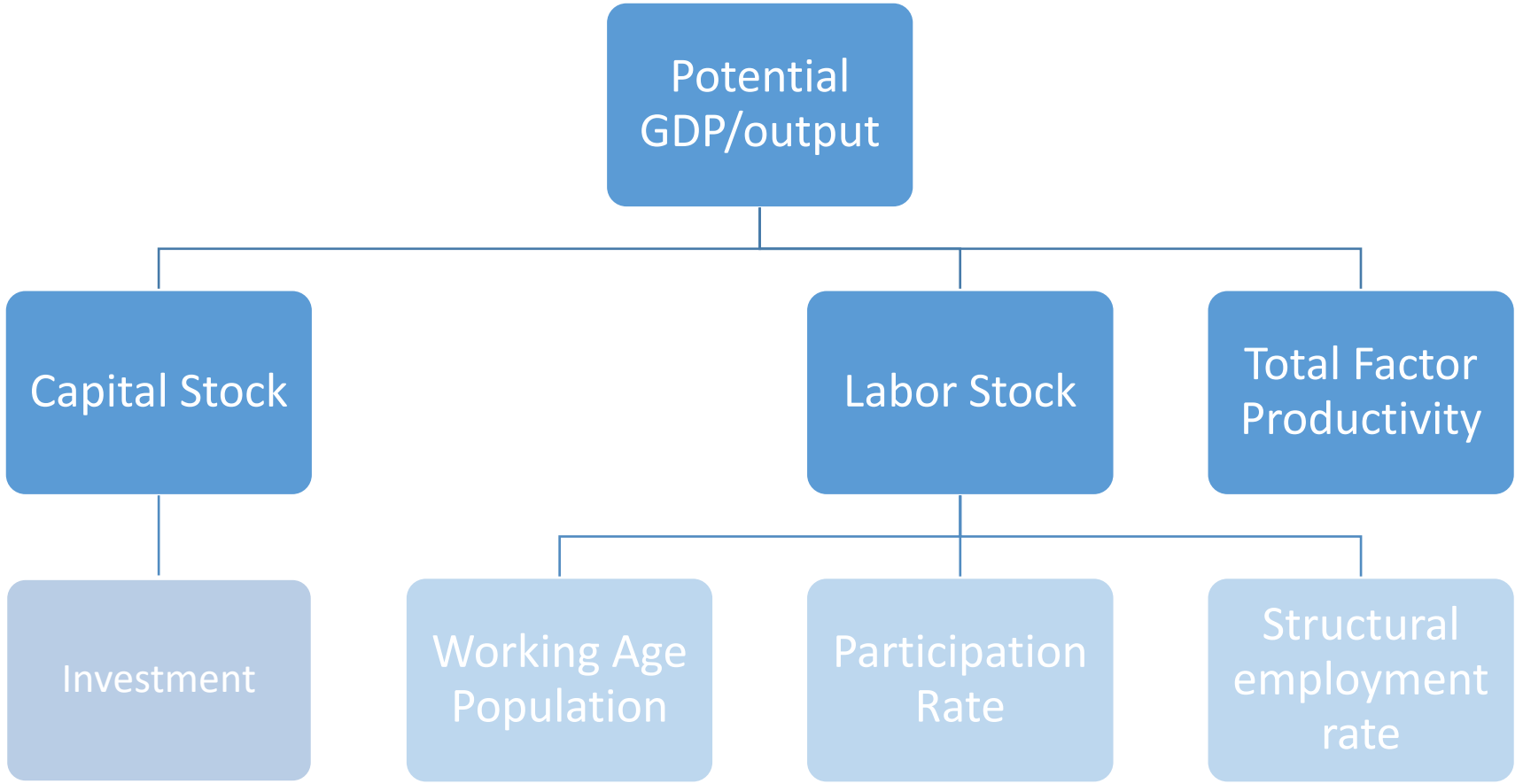
		Without CC policies	With CC policies
Growth Objectives	**Lower growth**	Lowest GDP, highest poverty	GDP down, poverty up
	Stronger growth	Increased GDP, reduced poverty	Highest GDP, lowest poverty

Development outcomes in the context of Climate Change

Green, Resilient and Inclusive Development - GRID

Adaptation/Mitigation Investment Options

2- Baseline model (LRAS/potential output)



Production Function Uses Standard Cobb-Douglas Form

2- Baseline model (potential output)

Potential output/GDP is the level of output associated with full capacity utilization

- Labor force participation rate is at its trend level
- Unemployment rate is at its “natural” rate
- No excess demand or supply

Adjustment mechanisms in the model serve to adjust demand in line with supply.

- In the short run – output is driven by demand.
- In the long run – the model is limited by supply constraints.

2- Baseline model (potential output)

- Output is produced with capital and labor (factors of production) – Stocks and productivity/efficiency

$$Y_t^* = A_t N_t^{*\alpha} K_{t-1}^{1-\alpha}$$

- α is the labor share of income.

$$\alpha = \frac{WN}{Y} \qquad (1-\alpha) = \frac{rK}{Y}$$

2- Baseline model (structural employment)

$$N_t^* = WAPop_t \cdot P_t^* \cdot (1 - U_t^*)$$

- $LF_t^* = WAPop_t \cdot P_t^*$ (structural Labour Force)
- $N_t^* = LF_t^* \cdot (1 - U_t^*)$ (structural Employment)

2- Baseline model (output gap)

$$Output\ GAP_t = \left(\frac{Y_t}{Y_t^*} - 1\right) * 100$$

- The measure tells us the relative demand/supply pressures
- In the long run, the output gap always closes.

3 - Extension of Baseline Model to Climate Change

1. **Disaggregated energy sector** is integrated into the production side of the economy, given the importance of hydrocarbons as a source of greenhouse gas emissions and particulate pollution.

2. **Emissions and pollution** is added to capture the key channels through which economic activity affects climate outcomes (Energy, Transport, Livestock, etc.).

3. **Damage functions** are introduced to determine how higher temperatures and changes in weather and rainfall conditions may impact economic activity.

3.1a - Extension of Baseline Model to CC (energy sector)

$$Y_t^* = \underbrace{A_t}_{aggregate\ TFP} \times \underbrace{K_t^{\alpha}}_{capital\ stock} \times \underbrace{N_t^{*\beta}}_{structural\ employment} \times \underbrace{Y_{E,t}^{\gamma}}_{\textbf{Energy output}}$$

$$P_t^{ELE} = \left[\omega_{FOS} P_t^{FOS^{(1-\sigma_1)}} + \omega_{REN} P_t^{REN^{(1-\sigma_1)}}\right]^{\frac{1}{1-\sigma_1}}$$

will depend on global commodity prices

will depend on the levelized cost of electricity

$$P_t^{FOS} = \left[\omega_{OIL} P_t^{OIL^{(1-\sigma_2)}} + \omega_{COL} P_t^{COL^{(1-\sigma_2)}} + \omega_{GAS} P_t^{GAS^{(1-\sigma_2)}}\right]^{\frac{1}{1-\sigma_2}}$$

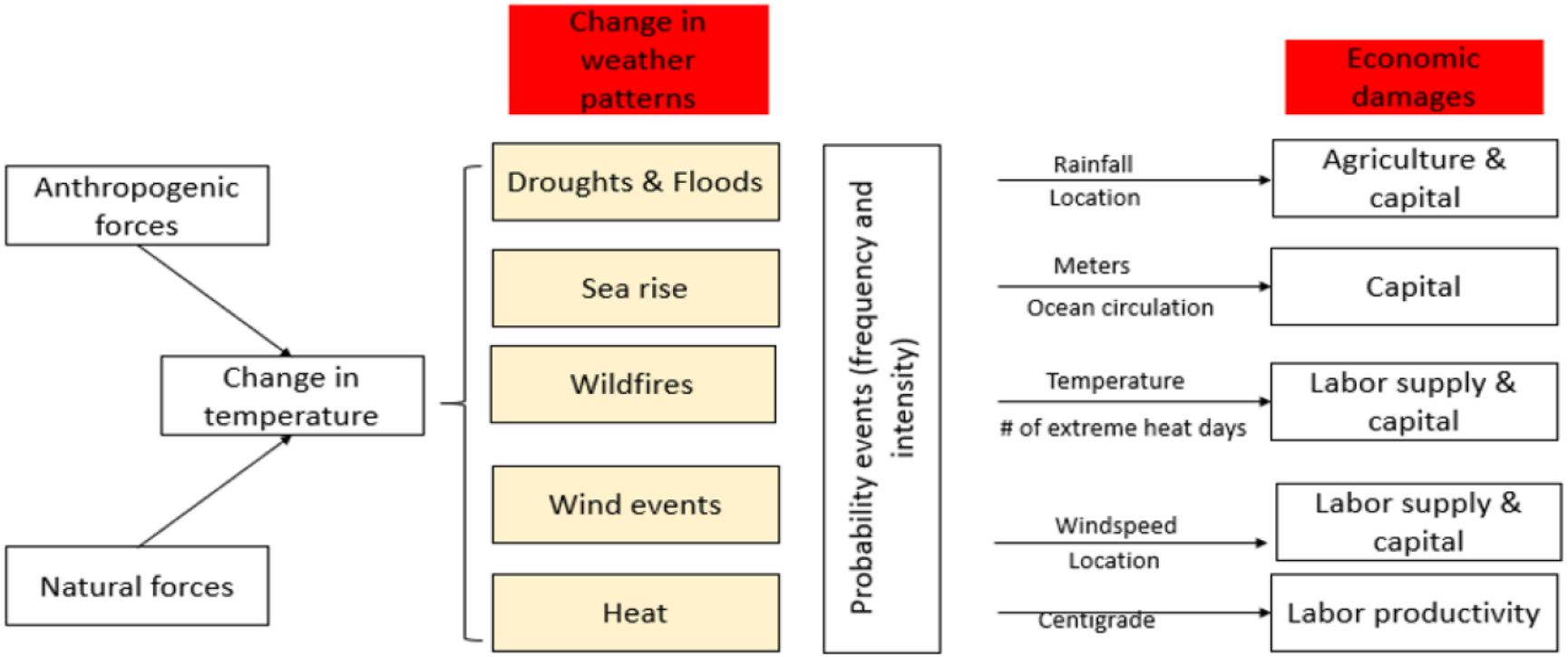
$$P_t^{REN} = \left[\omega_{WND} P_t^{WND^{(1-\sigma_3)}} + \omega_{SOL} P_t^{SOL^{(1-\sigma_3)}} + \omega_{HYD} P_t^{HYD^{(1-\sigma_3)}} + \omega_{BIO} P_t^{BIO^{(1-\sigma_3)}}\right]^{\frac{1}{1-\sigma_3}}$$

Policy counterfactuals: prices (carbon taxes, pro-renewable subsidies, etc.)

3.1b - Extension of Baseline Model to CC (sectoral GHC emissions)

- GHC emissions endogenous to growth/sectoral economy dynamics
- Energy: mapping source of energy used > emission levels
- Other sectors (supply side of the economy): Transport, Livestock, etc.
- **Policy counterfactuals** (e.g., in the energy sector): energy mix/decarbonization

3.1c - Extension of Baseline Model to CC (economic damages)



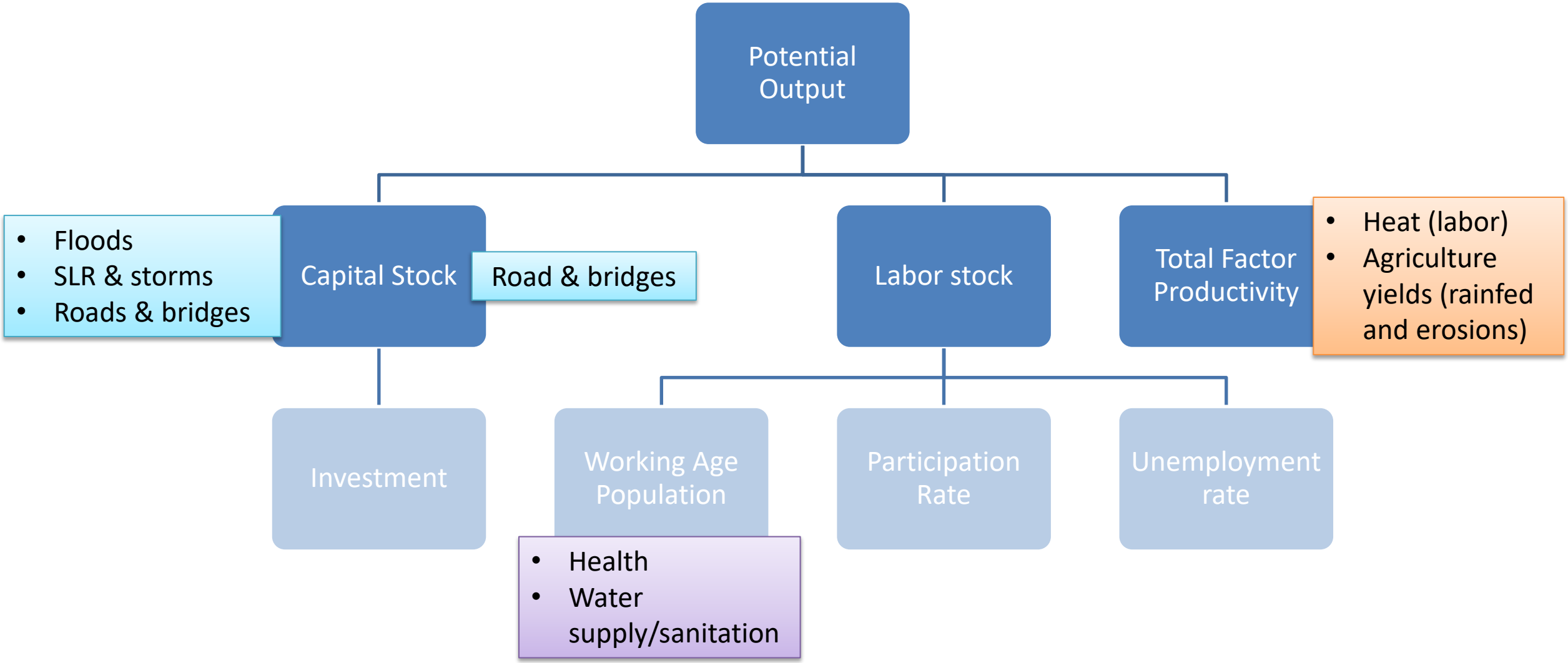
- Modeling (a) climate events (changes in weather patterns) and (b) related economic damages
- Climate change negatively impacts worker productivity and labor supply; destroys capital (roads, bridges, etc.)

3.1c - Extension of Baseline Model to CC (economic damages)

- **Damage functions** are introduced to determine how higher temperatures and changes in weather and rainfall conditions may impact economic activity.
- World Bank and MIT research collaboration: **biophysical modeling/damage functions**

Climate impact channels	Input data in the model
Labor productivity (Heat)	Loss of labor productivity
Labor supply (Health)	Loss of hours worked and workers
Water supply and sanitation	Labor supply and loss of labor productivity
Rainfed crops	Loss of agricultural yield
SLR and storm surge	Loss of physical capital stock (built-up asset, land, etc.)
Crops erosions	Loss of agricultural yield due to vegetations conditions
Damage to roads and bridges	Degradation of physical capital and loss of productivity
Urban flooding	Damage to physical capital

3.1c - Extension of Baseline Model to CC (economic damages)



3.1c - Extension of Baseline Model to CC (flooding channel)

- With climate change, the frequency of flooding is expected to increase (van der Schrier et al. 2018).
- Flood damage enters the model through physical capital:

$$Y_t^* = A_t \cdot N_t^{*\alpha} \cdot K_{t-1}^{1-\alpha} - \frac{Y}{K} DS_t$$

Average capital productivity

Damages stock of capital

Where

$K_t = \tilde{K}_t - DS_t$: Total capital

$\tilde{K}_t = (1-\delta)\tilde{K}_{t-1} + I_t - I_t^{REP}$: Physical capital without climate damages

3.1c - Extension of Baseline Model to CC (crop yields channel)

- Agricultural damage reduces TFP because the same amount of capital and labor produces a smaller amount of crop output than in previous years.

$$Y_t^* = (1 + d_t \cdot \omega_{AGR}^{Y}) A_t \cdot {N_t^*}^{\alpha} \cdot K_{t-1}^{1-\alpha} - \frac{Y}{K} DS_t$$

Agricultural damage

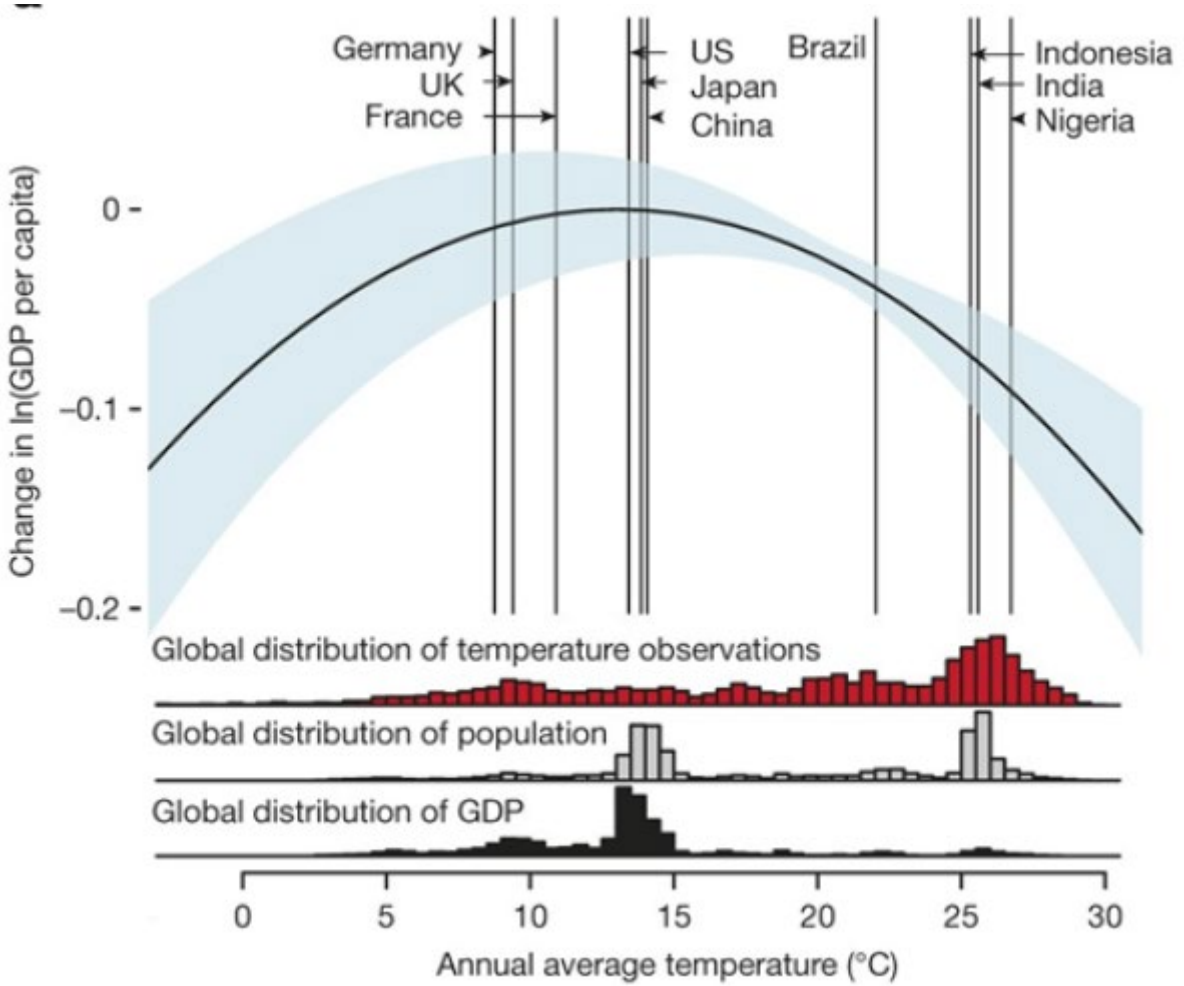
Share of agriculture in production

3.1c - Extension of Baseline Model to CC (labor productivity channel)

- Countries to the left of the peak will gain in productivity due to the increase in temperature

- Countries with already high average temperatures (right) will experience a decrease in productivity.

  (Burke, Hsiang, & Miguel, 2015)



3.1c - Extension of Baseline Model to CC (labor productivity channel)

- Potential GDP is again modified, taking into account the losses in labor productivity due to heat.

- In order to account for the loss of labor productivity, we convert the labor in the model to actual work hours:

$$Y_t^* = (1 + d_t \cdot \omega_{AGR}^Y) A_t \cdot [(1 - h_t) N_t^*]^\alpha \cdot K_{t-1}^{1-\alpha} - \frac{Y}{K} DS_t$$

percentage
of hours lost

4 - Poverty implications (e.g., macro to micro simulations)

- Links the macro model to household survey data to simulate distributional impacts over the forecast period.

    1. Changes in employment (sectoral reallocation of employment, changes in labor force participation)
    2. Changes in wages and salaries
    3. Changes in relative prices (food vs. non-food)

- Poverty impacts can be disaggregated by income groups, regions/rural vs. urban, sector of employment, type of employment (informal vs. formal), gender, etc.

5 - Application: putting everything together

- **Baseline Growth (no CC)**
- Alternative growth scenarios (w/ baseline model)

- **Climate scenario modeling (uncertainty/paths)**
- Alternative climate scenarios - distribution (frequency and intensity)
- E.g., pessimistic, optimistic, etc.

- **Impact of CC - Results and comparisons**
- **Main output: econ damages, GHC emissions, GDP and poverty impact**
    - *Cases without climate change*
    - *Cases with climate change*
    - *Cases with climate change + Adaptation and/or Mitigation.*

5 - Application: putting everything together

High | Trends | Low

3 Baselines
x

Crops-Rainfed | Crops-Erosions | Heat | Health

Inland flood | SLR and storm | Road and Bridges | Clean Cooking

8 Impact Channels
x

Channel Pessimistic | Channel Optimistic

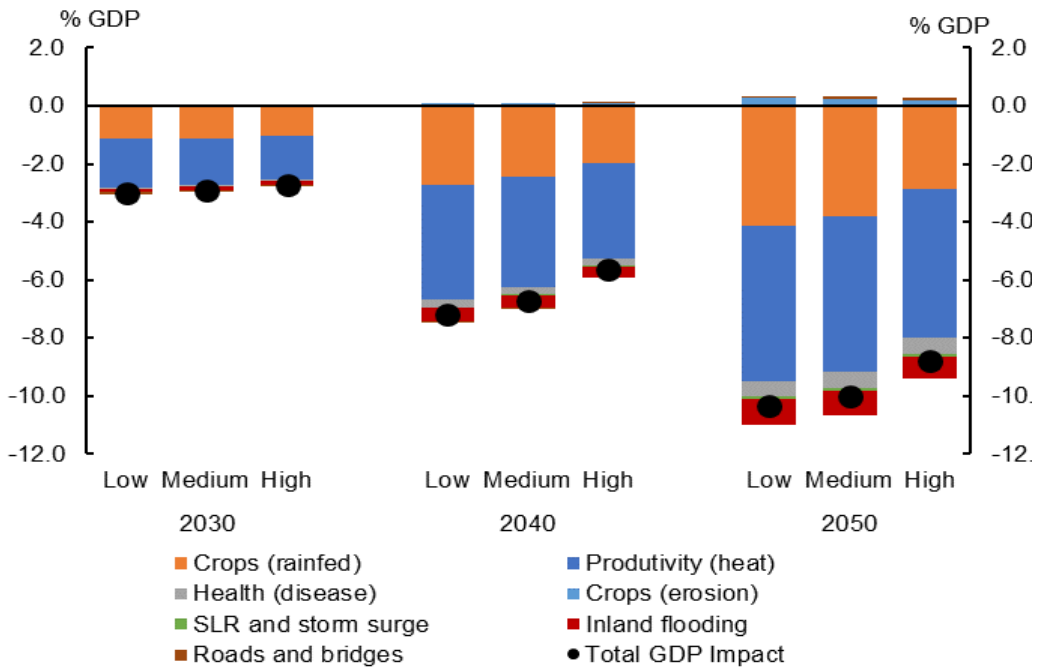
Combined Pessimistic | Combined Optimistic

Climate Scenarios

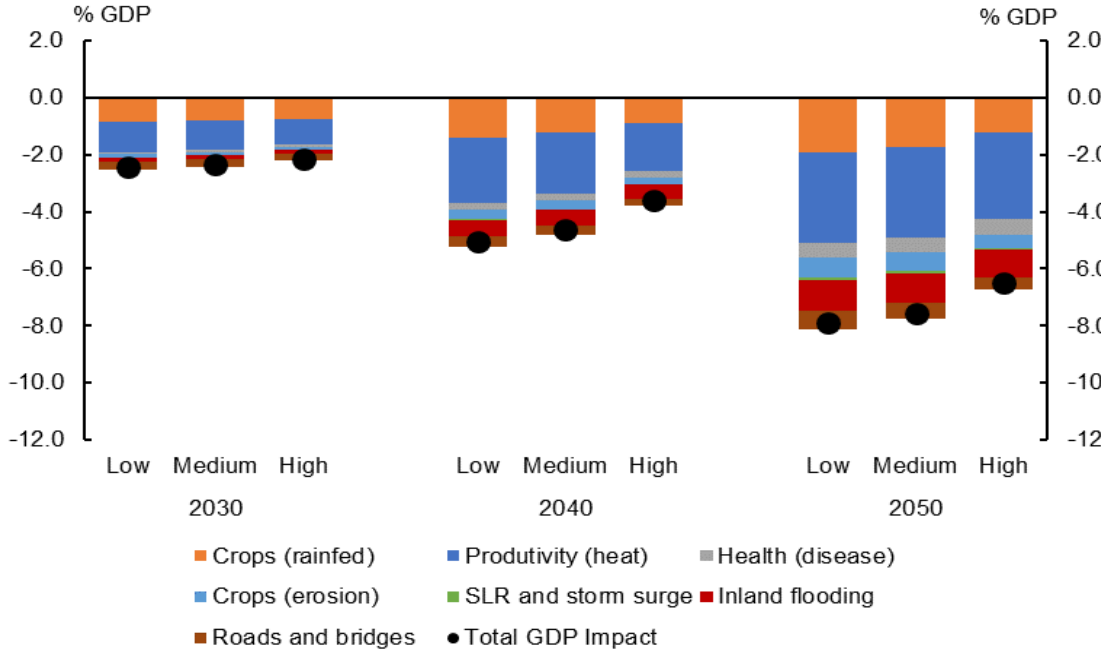
5 - Application: impact of climate change on growth (Guinea-Bissau)

baseline under alternative growth baselines.

Dry/Hot Mean



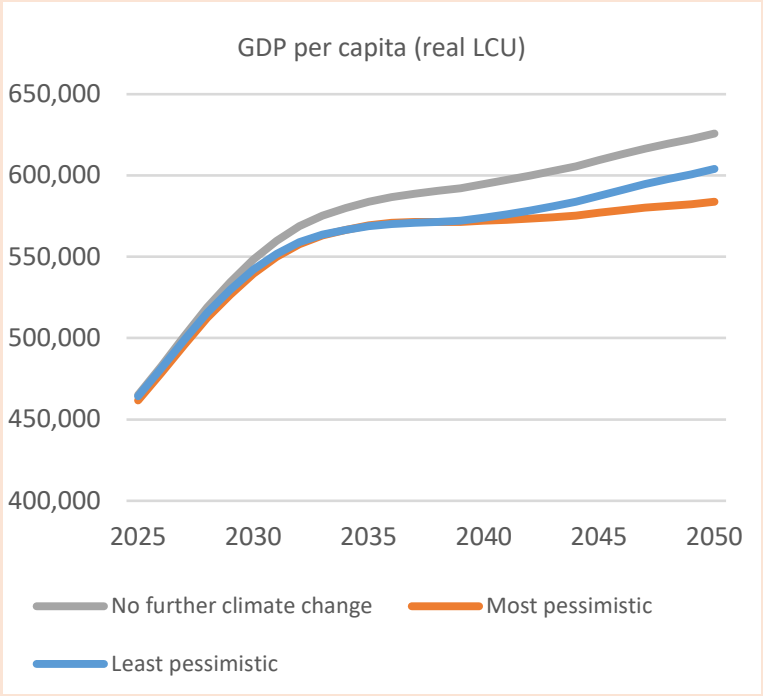
Wet/Warm Mean



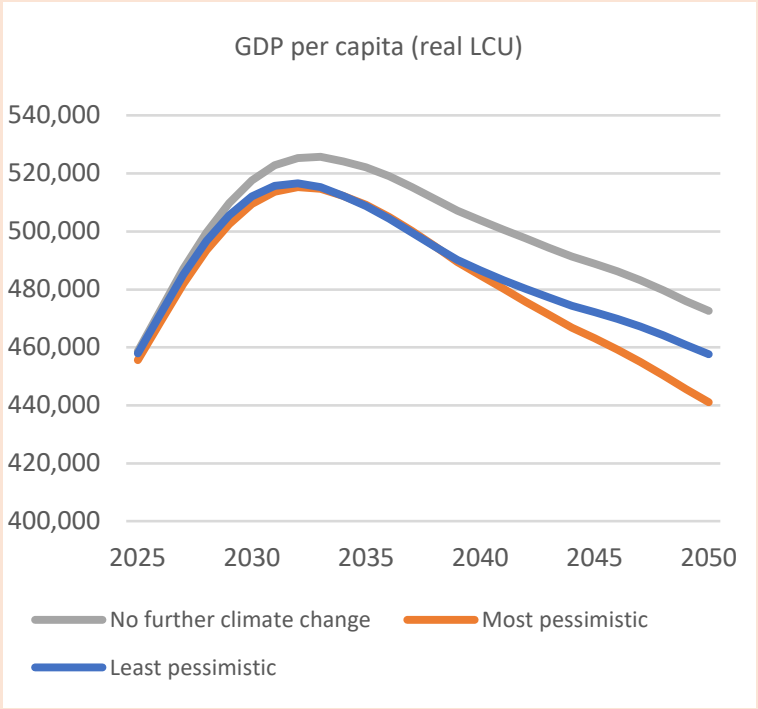
Source(s): GNB-ccMFMod.

5 - Application: impact on per-capita growth (Burkina Faso)

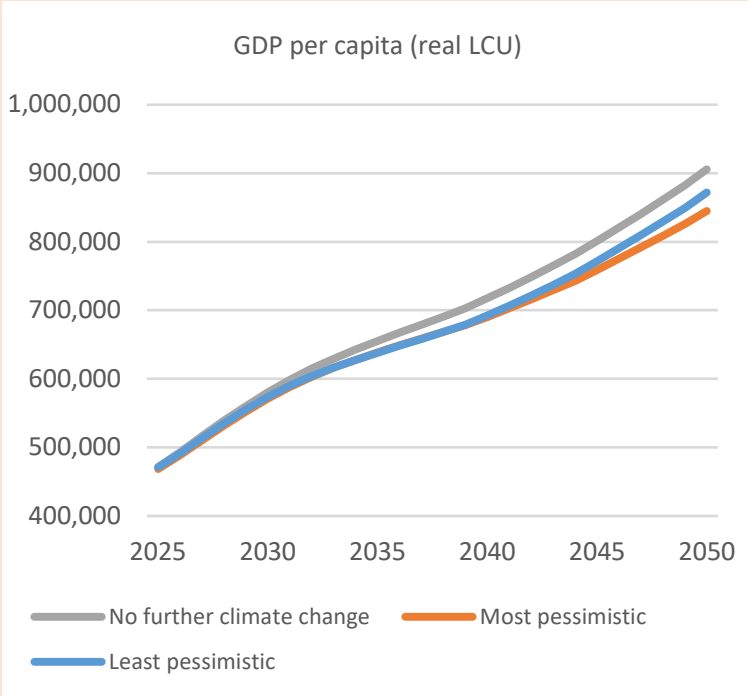
Medium growth scenario. Modest per capita growth across climate scenarios will fail to lift Burkina Faso out of the LIC group



Low growth scenario. Only slightly increased GDP per capita by 2050 means Burkina Faso remains in the group of LICs

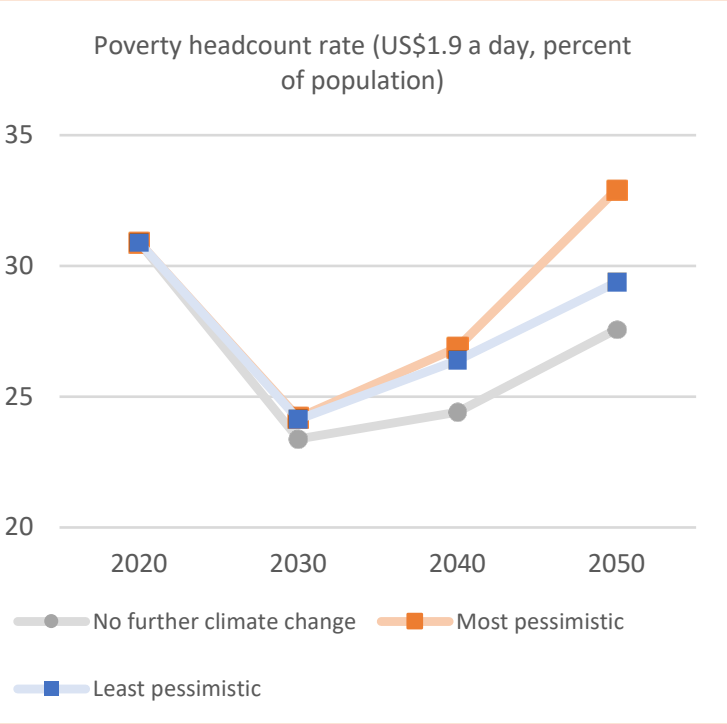


High growth scenario. Steady per capita growth allows Burkina Faso to be upgraded to the group of lower-middle-income countries by 2040

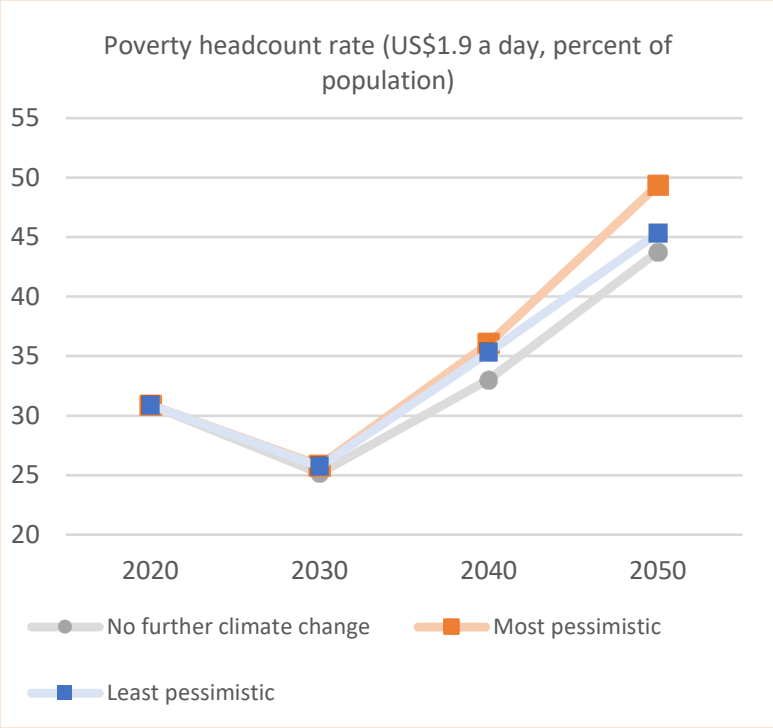


5 - Application: impact on poverty (Burkina Faso)

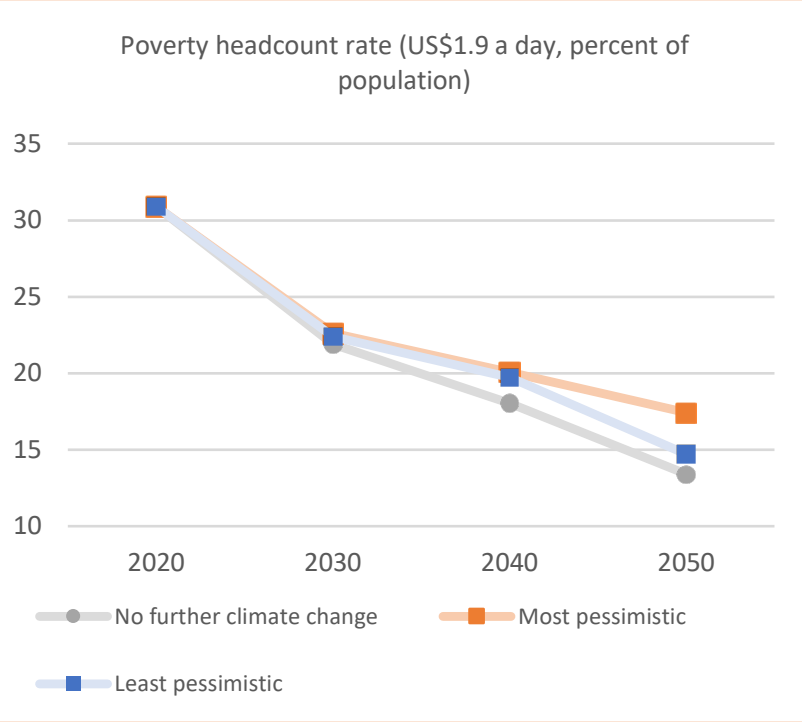
Medium growth scenario. Poverty will remain relatively stable in the long run, only increasing slightly in the most pessimistic climate change scenario



Low growth scenario. The poverty rate will increase significantly for all climate scenarios

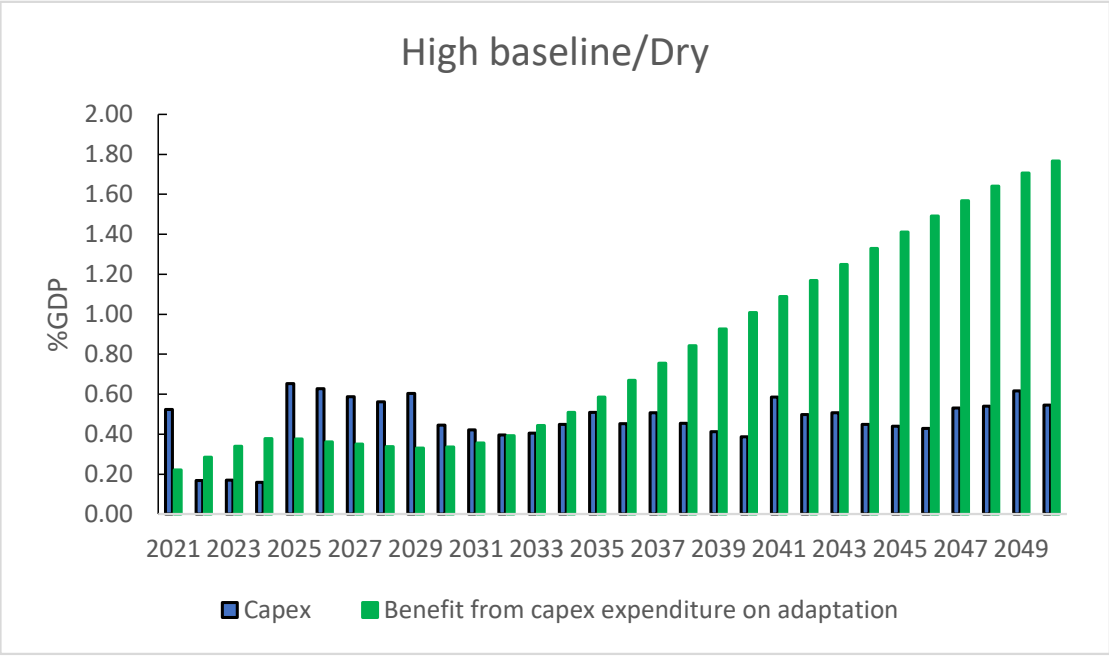


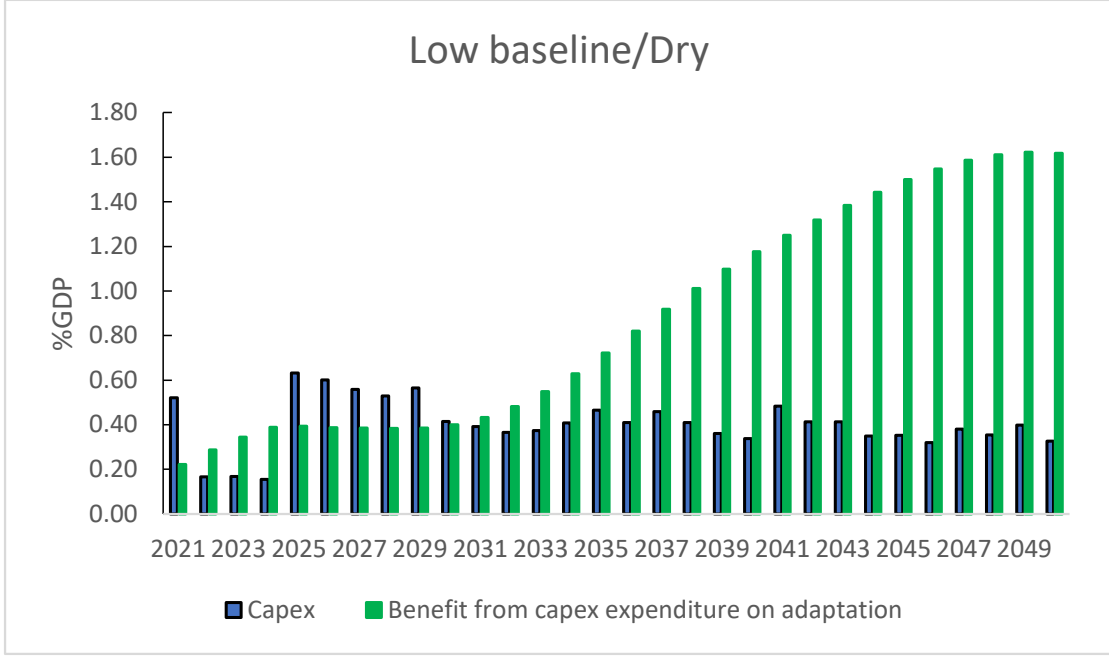
High growth scenario. Across climate scenarios, poverty will fall continuously throughout the projection period given strong growth



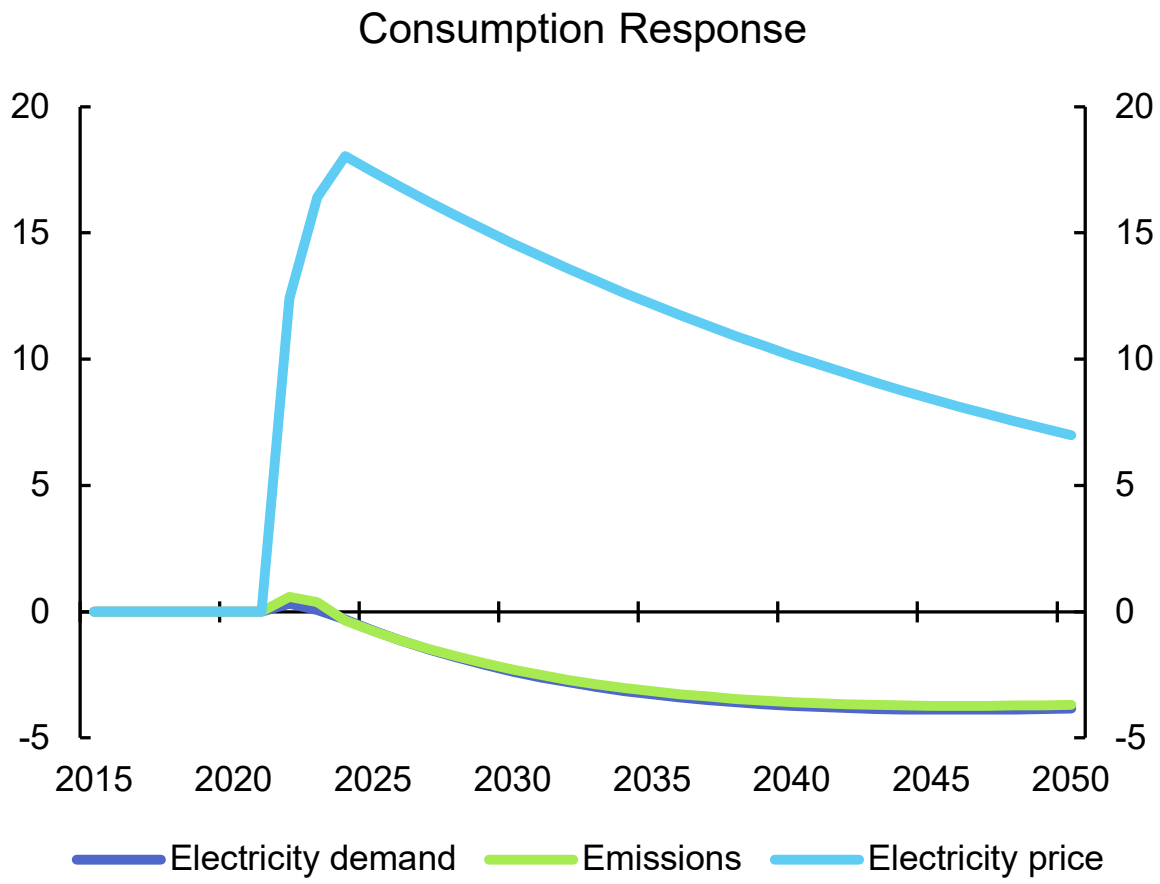
5 - Application: impact of adaptation (Burkina Faso)

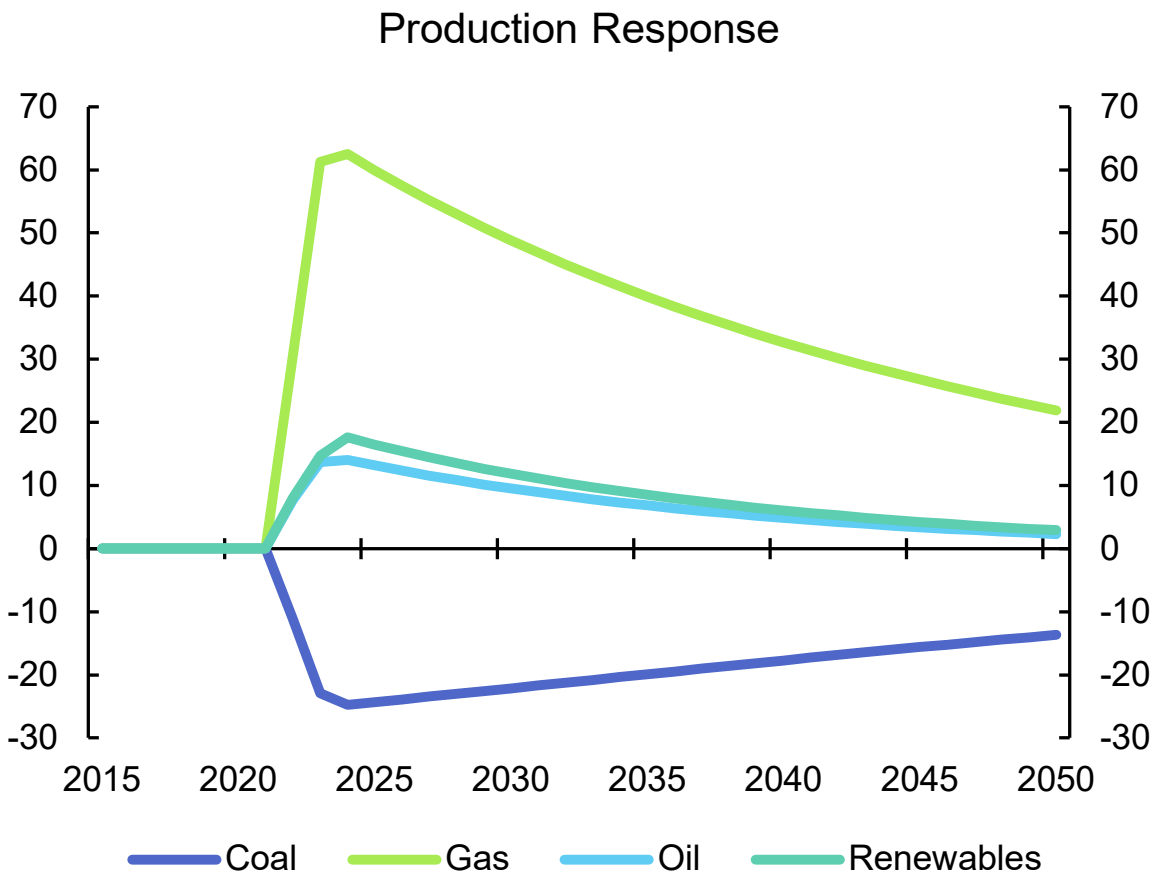
- Adaptation investments for selected damages > Related gains (reduced econ damages).
- Benefits of adaptation (avoided damages) vs. Costs of adaptation



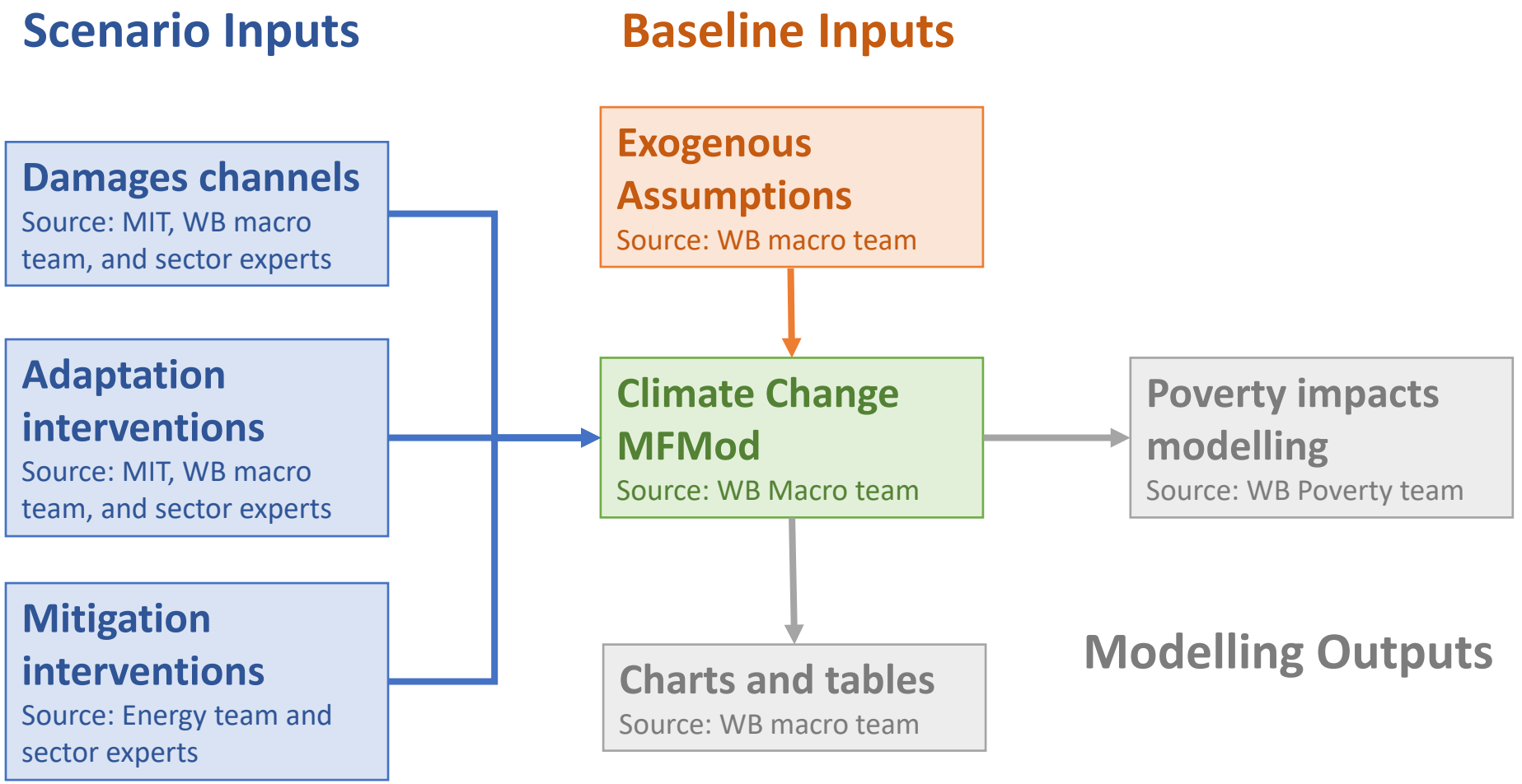


5 – Application: impact of a $20 carbon tax (mitigation)





6 - Modeling approach: key steps (WB CCDRs)



Thank you

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