Economic Growth, Development and Climate Change

Workshop on Climate Change Adaptation in the Economic Development Sector Using Integrated Water Resources Management (IWRM) Tools

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Introduction

- Economist at Climate Analytics, guest researcher at CESifo (Munich) and the Potsdam Institute for Climate Impact Research (PIK, Potsdam)

- Lead author:
  - UNEP Africa's and Global Adaptation Gap reports (2013, 2014, 2015, 2016);
  - UNEP/UNECA/AfDB "Economic Growth, Development and Climate Change in Africa" (forthcoming);
  - World Bank Socioeconomic vulnerability of five African countries: Cameroon, Ghana, Malawi, Mali and Senegal (on-going).

Damage, Losses & Development

Cyclone Chapala hitting Yemen in 2015

Outline

1. Introduction
2. Approaches
    a. Integrated Assessment Models (IAM)
    b. Computable General Equilibrium models (CGE)
    c. Macro-econometric based approach
3. Macro-econometric based approach
    a. Description of the approach
    b. Results for Northern African countries
4. Looking forward

Integrated Assessment Models (IAM)

IAMs are models of analysis that combines results and models from the physical, biological, economic, and social sciences, and the interactions among these components, in a consistent framework to evaluate the status and the consequences of environmental change and the policy responses to it (IPCC, 2014)

Pros

- Most well-known IAMs for impacts: FUND, PAGE, DICE/RICE (AD-), WITCH.
- "*Simple approach*" – neither requiring significant computing capacity (DICE excel spreadsheet) nor large amount of data
- Ability to project impacts far into the future: accounting for future development trajectory, technological change

Cons

- Long-term mean temperature as main driver of impacts (**but**) – with questionable damage function: Pindyck (2013) -- provocatively states: "*When it comes to the damage function, however, we know almost nothing, so developers of IAMs can do little more than make up functional forms and corresponding parameter values.*"
- Damages only accounted sectorally: no deferred / cross-sectoral impacts.
- Limited ability at the country level (of existing models)

Computable General Equilibrium (CGE)

CGE modeling reproduces the structure of the whole economy and therefore the nature of all existing economic transactions among diverse economic agents (productive sectors, households, and the government, among others) – using equations describing variables and a database in line with variables (IDB, 2016)

Pros

- Solid ability at the country-level – particularly when already available in Ministry of Economics / Planning
- More intense data and computation needs (e.g. Social Accounting Matrix) – but still manageable
- Better description of sectoral interaction / deferred impacts in the aftermath of a shock

Cons

- Often based on temperature – similar damage function calibration as for IAM
- Always reaching equilibrium – is there really supply / demand equilibrium in the aftermath of a disaster?
- Free flow of labour (free transfer of labour force) and capital from across sectors and regions [in some cases].

Macro-econometric based approach

Macro-econometric based approach consists in inferring from historical data (here socioeconomic and climate data) the relation between a set of explanatory variables (climate) and dependent variables (economy) using econometric and statistical approaches.

Pros

- Good ability at the country-level / regional level (country-specific inference)
- *Deferred impacts not explicitly but implicitly accounted for*
- Ability to model independently sectors
- [Should be] Prerequisite for designing damage functions
- Possibility to integrate precipitation and temperature
- Ability to capture effects of extremes with well-designed econometric model

Cons

- Very intense data and computation needs (e.g. 10Tb of climate data) – reliant on data availability
- *Deferred impacts not explicitly but implicitly accounted for*
- Climate Analogy assumption
- More complex statistical and econometric appraisal – requiring expertise in both econometrics, economics and climate science

Macro-econometric approach

Macro-econometric approach / hybrid model for the projections used for project with UNEP/UNECA/AfDB and currently with World Bank.

- Rationale and constraints
- Initial considerations
- Model framework
- Central assumptions
- Results

Macro-econometric approach

- Rationale:
  - Available IAMs and CGEs providing limited insights of climate change impacts, focusing only on temperature;
  - Extremely limited evidence basis;
  - Better accounting for extremes: droughts, floods, heat (using indices);
- Conditions:
  - Developing a model providing results at the country-level (and progressively at the sub-national / sectoral level – World Bank);
  - Flexible, replicable and open.

Initial considerations

- Need to better understand historical relation between climate variables (precipitation, temperature) and economic indicators – development of new macro-econometric model

- Model based on most recent climate econometric advances:
  - ✓Use of a predefined **climate data index** taking into account intra-annual climate variability and geographical exposure (Brown et al. 2013)
  - ✓Decomposition of the overall economic output (GDP) in **sectorial economic outputs** (Dell et al. 2012; Brown et al. 2013) agricultural vs. non-agricultural – further sub-divided in services and industry (without pre-assuming a possible functional form)
  - ✓Detection and projection of **non-linear patterns** and breakpoints (Schlenker & Roberts 2009)

Model Framework

- Dependent variables:
  - GDP Growth rate in country *i* from year *t-1* to *t* (ΔY_{it})
  - Growth rate of agriculture, services and industry sectors ($\Delta y_{it,s}$)
- Explanatory variables:
  - Climate variables: Percentage of area in country *i* exposed to a certain interval *I* of a climate index or variable in period *t* ($X_{it,I}$)
  - Annual deviation from historical mean or trend
  - Time-lagged effects ($X_{it-1,I}$)
- Detecting non-linear patterns by using a segmented linear multivariate regression (piecewise)
- Randomization-selection of coefficients based on root-mean squared error (RMSE)

Central assumptions

- Cobb-Douglas **production function** – economic output as a function of labour (L), capital (K), total factor productivity (A) and output elasticities (a):
    - Country's production is subdivided in unit of territory and time sub-period – with (weighted temporal and geographical sum equal to country's production)
    - Production in unit is weighted according to population density (or agricultural area for agricultural sector)
    - Cross-unit effect not explicitly modelled
- Future effect on output defined by **climate analogy** (Hallegatte et al. 2007), an event of similar intensity in same pool (or region) induces a same-range fluctuation across time

Regression model

Year-to-year variation of aggregate output, at year *t* for country *i*

Summation over all levels *l* of the climate index

Piece/bin of climate variable exposure

Areas exposed to *l*, during the period t and in the country i

Country time-invariant fixed-effect

Standard error clustered at the country level, time variant factors

$$\Delta Y_{it} = \sum_{s=1}^{2}\sum_{l=1}^{n} \beta_{rsl}\,(X_{it,l})^2 + \pi(T_{it} - \bar{T}_h) + \gamma V_{it,s} + \phi_i + \alpha_{rt} + \varepsilon_{it}$$

Summation over two sectors s of country i's economy

Sector in the country i's economy subregion r

Coefficient of climate analogy defined for each interval/bin *l* on sector output s in subregion r

Effect of temperature as a deviation to historical mean

Vector of control variables

Regional time-variant fixed effect (!!!)

Randomisation-filtering method

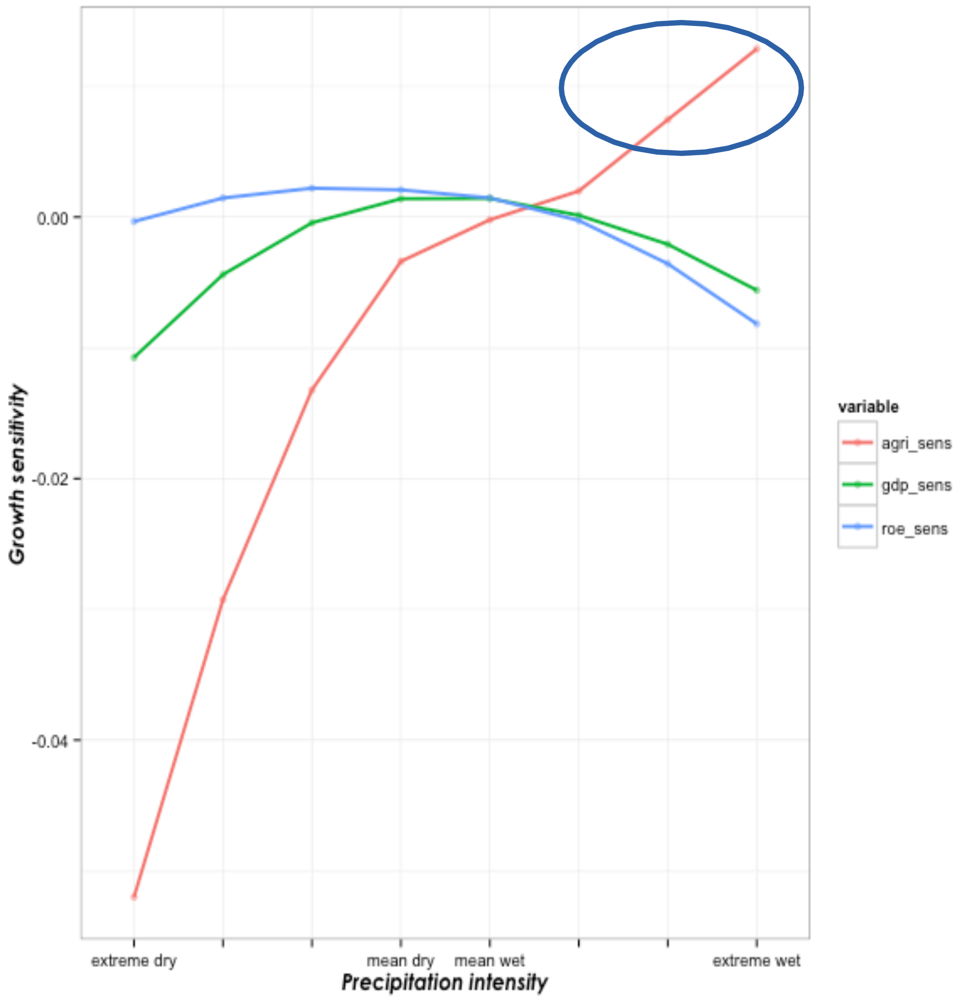
- Randomisation and filtering method inspired from physics and financial econometrics.
- Randomisation using Monte Carlo simulation

$$\beta_{rl} \overset{iid}{\sim} N(\widehat{\beta_{r,l}}, se_{\beta_{r,l}}) \text{ et } \pi_r \overset{iid}{\sim} N(\widehat{\pi_r}, se_{\pi_r})$$

- Selection of best coefficient using RMSE (ΔY_{it} vs. $\widehat{\Delta Y_{it}}$)

$$\widehat{\Delta Y_{it}} = \sum_{l=1}^{n} \beta_{rl} \, (X_{it,l})^2 + \pi_r (T_{it} - \bar{T}_h) + \gamma_r V_{it,s} + \phi_i$$

Northern Africa sensitivity (indicative)



- GDP growth equally sensitive to extreme wet and dry events.
- GDP growth sensitivity hiding very large sectoral discrepancy.
- Agriculture strongly sensitive to extreme dry events – but possible beneficial effects of very and extreme wet events.
- Rest-of-the-economy less sensitive but significant effect of extreme wet events (e.g. business disruption).

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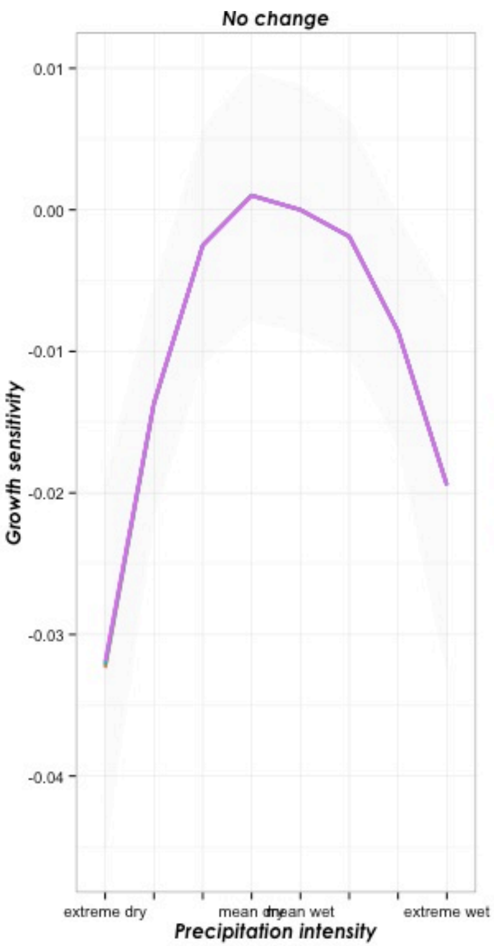
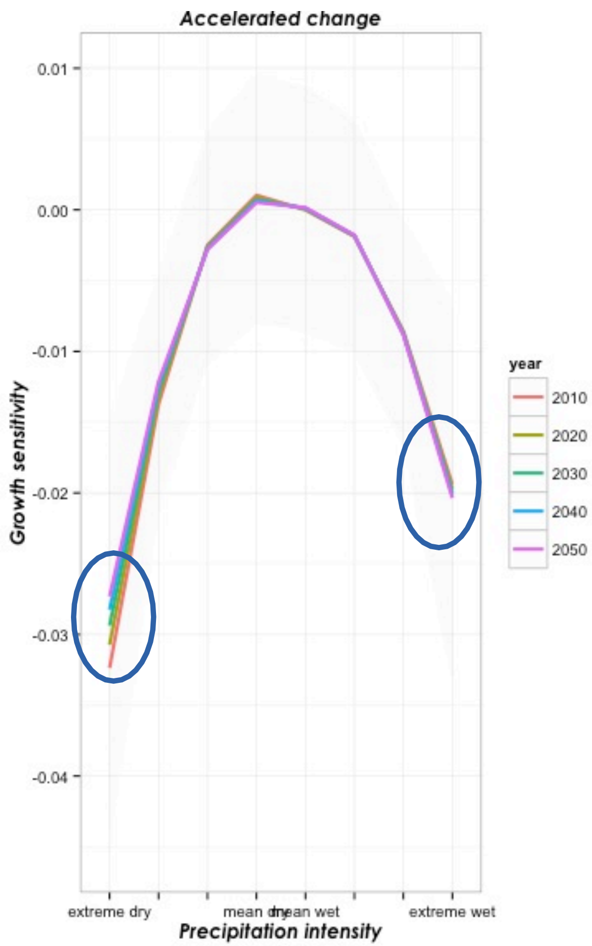
Dynamic sensitivity



- Case of a dynamic economy – reduction of the share of agriculture, increase in services and industry.
- Overall sensitivity of GDP growth decreases in "accelerated change" scenario.
- While sensitivity to extreme dry decreases, sensitivity to extreme wet events increases.
- Negative macroeconomic consequences of structural change possible for countries exposed to large increase in frequency and intensity of flooding events.



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Looking forward

- *No silver bullet, no winner-takes-all?* Need to improve interconnectedness of econometric-based, CGE and IAM approaches.
- *Agent / livelihood-based modelling?* Large increase in computation capacity, possibility to largely increase current models' resolutions.
- *More new models or more integration?* Increasing resilience as a process started by a decision. Need to increase integration of existing / future models' outputs in government macroeconomic models.

Thank you!

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Main references

- Dell, M., Jones, B. F., & Olken, B. A. (2012). Temperature Shocks and Economic Growth: Evidence from the Last Half Century. American Economic Journal: Macroeconomics, 4(3), 66–95. doi:10.1257/mac.4.3.66

- Schlenker, W., & Roberts, M. J. (2009). Nonlinear temperature effects indicate severe damages to U.S. crop yields under climate change. Proceedings of the National Academy of Sciences of the United States of America, 106(37), 15594–15598. doi:10.1073/pnas.0906865106

- Brown, C., Meeks, R., Ghile, Y., & Hunu, K. (2013). Is water security necessary ? An empirical analysis of the effects of climate hazards on national-level economic growth. Philosophical Transactions of the Royal Society, (371), 1–19. Retrieved from http://rsta.royalsocietypublishing.org/content/371/2002/20120416.abstract

- Moore, F. C., & Diaz, D. B. (2015). Temperature impacts on economic growth warrant stringent mitigation policy. Nature Climate Change, (January 2015), 1–5. doi:10.1038/nclimate2481

- Hallegatte, S., Hourcade, J.-C., & Ambrosi, P. (2007). Using climate analogues for assessing climate change economic impacts in urban areas. Climatic Change, 82(1-2), 47–60. doi:10.1007/s10584-006-9161-z

- Burke, M., Hsiang, S. M., & Miguel, E. (2015). Global non-linear effect of temperature on economic production. Nature, (1), 1–16. doi:10.1038/nature15725