Leibniz Gemeinschaft

Abschließender Sachstandsbericht
Leibniz-Wettbewerb

Economic Growth Impacts of Climate Change (ENGAGE)
Antragsnummer: SAW-2016-PIK-1

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Federführendes Leibniz-Institut: Potsdam Institut für Klimafolgenforschung

Projektleiter:
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Hinweise zur Erstellung

Der Sachstandsbericht ist bis zu sechs Monate nach Ende der Projektlaufzeit einzureichen und soll einen Umfang von 5 Seiten nicht überschreiten.

Die Sachstandsberichte sollen Informationen zum Projektverlauf hinsichtlich der Meilensteine und Ziele des Vorhabens selbst und hinsichtlich der übergeordneten Leibniz-Ziele des Leibniz-Wettbewerbs für den Senatsausschuss Wettbewerbsverfahren (SAW) beinhalten. Der SAW nimmt die Berichte zur Kenntnis und ggf. auf ihrer Grundlage Stellung zum Vorhabenverlauf gegenüber der Projektleiterin oder dem Projektleiter des Vorhabens.

Bitte tragen Sie ergänzend zum Sachstandsbericht in die Maske im elektronischen Antragssystem ein Executive Summary (max. 400 Wörter) ein sowie Informationen zu Ergebnissen und Erfolgen (Publikationsliste, Wissenstransfer, etc.), Chancengleichheit und Internationalisierung, und Vernetzung.

Der Sachstandsbericht kann auf Deutsch oder Englisch abgefasst werden.

Folgende Vorgaben hinsichtlich Textgestaltung und Seiteneinrichtung der Sachstandsberichte sollen berücksichtigt werden:

- Seitenränder: Der rechte, linke und obere Seitenrand betragen 2,5 cm, der untere Seitenrand 2 cm.
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- Tabellen: für eingefügte Tabellen, Graphiken usw. gelten die Angaben analog.

Inhalt

1. Zielerreichung und Umsetzung der Meilensteine

The project succeeded to make significant contributions to both of its key research questions: (i) How and to what extent does climate change affect long-term economic growth trajectories? (ii) How does the inclusion of economic growth impacts play out in the integrated assessment of selected climate impacts and mitigation strategies? With regard to Point (i), the project laid the empirical and methodological foundation for developing damage projections and damage functions for floods and tropical cyclones (Geiger et al. 2018, Krichene et al. 2020, Sauer et al. 2021, Lange et al. 2020). The project also investigated the persistence of climate damages and the associated impact on economic growth for different impact channels by comparing the implications of output, capital, and productivity losses (Piontek, 2019). This lays out a research agenda to connect impact-specific damage functions to different drivers of growth. With regard to Point (ii), the project used newly available empirical estimates of the growth impacts of temperature change (Burke et al. 2015) to successfully perform an integrated analysis of impacts and mitigation, investigating the uncertain persistence of damages specifically (Schultes et al. 2020). The project built the base for a broader research agenda involving impact-specific model intercomparisons of integrated assessment models (Piontek et al., under review). However, the completion of such a broad task was beyond the reach of the project.

While the project made good progress overall, it had to be extended due to parental leave and was further impacted when two key researchers left PIK during that time. Finally, a shift in the modelling strategy led to an adjustment of WP3. In the following, we describe the work progress and achievements on a task-by-task basis.

WP1: Conceptual and empirical analysis of climate change impacts on economic growth

Task 1.1 - Empirical analysis of the impacts of tropical cyclones and floods on growth
We developed the indicator “people exposed to extreme events” as a basis to consider different types of events jointly. For tropical cyclones Geiger et al. (2018) developed a historical global data set of tropical cyclone exposure (publicly available), based on state-of-the-art tropical cyclone and wind field modelling. It develops an emulator allowing the projection of actual exposure to future tropical cyclones, an improvement over projections just based on changes in storm intensity and/or frequency. This data set is used by Krichene et al. (2020) for an empirical analysis of the growth effect of exposure to tropical cyclones, finding significant and persistent negative effects in most cyclone-prone countries. For fluvial floods, Sauer et al. (2021) develop an empirical model linking damages to climate-induced changes in hazard, exposure and vulnerability. They find that global warming already increases flood damages.

Task 1.2 - Conceptual model of climate impact channels on economic growth
Piontek et al. (2019) perform the first comprehensive comparative analysis of long-term dynamics of one-time climate shocks on key production factors in a standard macroeconomic growth model (DICE, Nordhaus 2017), finding large differences in the persistence of such shocks depending on the impact channel. This highlights the need to investigate individual channels and their persistence both through modelling and empirical analysis, instead of using aggregated damage functions. Using the DICE model allowed a direct link to the available literature on damages, but unfortunately precluded linkages to Task 1.3, as the model is global without trade effects. The empirical results from Task 1.1 could not be taken up in this task due to the delays in their availability.
To study the capital channel in more detail, Kuhla et al. (2021) developed an event-based neoclassical growth model that can account for limits in reconstruction investment in the disaster aftermath, as they may arise from a scarcity of trained labour and destroyed infrastructure (based on Hallegatte et al., 2007). Further, the model can account for disaster

insurance as a coping strategy to speed-up reconstruction and mitigate indirect losses in the disaster aftermath. The model was calibrated to Hurricane strikes in the US in the period 1980 to 2010 and shows that limits in reconstruction investment may lead to long-term persistent effects as found by Krichene et al. (2020). Further, the model reveals the importance of the event-based approach since larger events cause disproportionally large indirect losses.

Task 1.3 - The role of international market linkages in shaping climate change impacts
The ifo GAME Database on geological and meteorological events (formerly GeoMet) was updated to a longer time-horizon (1979 – 2014) and has been reconstructed completely from scratch on a geographically disaggregated 0.5° x 0.5° coordinate raster grid, including improved treatment measures. This data base is now publicly available. Three econometric studies were performed looking at the effect of natural disasters on migration (Gröschl & Steinwachs 2017), economic growth (Felbermayr et al. 2018) and the role of country borders and infrastructure connectivity for the spatial transmission of disaster effects (Gröschl et al. 2020). Little evidence is found for effects of disasters on medium- to long-run migration, though when considering income heterogeneity, middle-income countries are found to experience significant push and pull effects. The 2nd study finds pronounced negative effects of weather events on economic activity at the local level, shifting the local growth path downward over the long run. Substantial heterogeneity is identified across income groups. Results of the final study suggest that international borders, the overall availability of roads, and major roads connectivity differences play a very important role for the propagation of spatial spillover effects and hence potentially matter for the mitigation of disaster consequences.

WP2: Projections of economic damages from flood events and tropical cyclones under climate change

Task 2.1 - Projections of meteorological and hydrological extreme events

Based on the Intersectoral Impact Model Intercomparison Project Framework (Frieler et al. 2017) the study by Lange et al. (2020) provides global projections for exposure to 6 types of extreme events (river floods, tropical cyclones, crop failure, wildfires, droughts, heatwaves) for three emission trajectories. The study investigates uncertainty from climate and impact modelling and finds substantial exposure increases already by present day warming, with strong future increases with increasing temperature. Tropical cyclones under future climate change are also investigated in Geiger et al. (under review).

Task 2.2 - Translation into direct economic losses
The departure of a key member of the project team in 2019 and higher than anticipated challenges related to both the empirical assessment of Task 1.1 and the projections of extreme events in Task 2.1 led to a delay in this task. Building on the empirical model for economic damages from fluvial floods developed under Task 1.1 (Sauer et al., 2021), projections of future flood events from Task 2.1 are now being used to derive future flood damage time series accounting for changes in hazard and exposure. A historical analysis of drivers for vulnerability changes further permits to extent the study by projections of different vulnerability scenarios (Sauer et al. in preparation). Future economic damages from tropical cyclones can be derived by combining the projections from Task 2.1 with newly available damage functions for tropical cyclone wind impacts (Eberenz et al. 2020). A novel tropical cyclone model that adds damages from storm surge will further refine cyclone damage estimates (Vogt et al., in preparation). Further, building on the completed empirical analysis of growth effects of both floods and tropical cyclones (Krichene et al. 2020), efforts are now under way to calculate resulting future impacts on GDP (Krichene et al., in preparation).

Task 2.3 - Provision of input to integrated assessment modeling
As this task builds on Task 2.2 it could not be completed during the project time. However, building on the work conducted within ENGAGE two papers are now under way developing

and applying a temperature-dependent damage function for tropical cyclones in the integrated assessment model REMIND.

WP 3: Macroeconomic dynamics of climate impacts on land

Task 3.1 - Integrating land as a production factor into the REMIND-MAgPIE framework
Extensive progress has been made in developing the coupling between the models REMIND and MAgPIE in recent years (e.g. Kriegler et al. 2017). In particular, agricultural production costs were consistently integrated in the REMIND budget. However, during the project time PIK started to develop a Multisectoral Growth Model (MSGM) with an explicit agricultural sector. Against that background, and given the already high complexity of REMIND, it was decided to refrain from including land as an explicit production factor in REMIND, deferring this to the MSGM. A conceptual MSGM with land has been applied in first experiments.

Task 3.2 - Modelling multiple climate impacts on agricultural and forest land in the coupled REMIND-MAgPIE system

The focus in this task was put on developing an endogenous dynamic forestry sector in the MAgPIE model, due to the importance of forests in the context of climate change mitigation through targeted afforestation and avoiding deforestation as part of the national climate policy portfolio. The development of this module was very time consuming, given that a detailed literature review and exchange with forest modeling experts was first conducted. The implementation is now completed (Mishra et al., in preparation). With the new MAgPIE release 4.3, a dynamic representation of planted forests and natural vegetation was made public. This allows MAgPIE to simulate land competition between forestry and agriculture in all SSP scenarios (including further implications for land use and land use change emissions) (Mishra et al., in preparation). Additionally, the framework for integrating climate impacts on land use is now established (changes in agricultural yields and water availability through the link to the LPJmL dynamic vegetation model), but due to the longer than expect model development work, it was not applied during the project lifetime.

WP4: Integrated assessment of climate change impacts and mitigation

Task 4.1 - Improved representation of climate change impacts in the integrated assessment modeling framework REMIND-MAgPIE

Under this task the REMIND model was expanded by a soft-coupled damage module. This approach allows for high flexibility and increased complexity in the damage calculation. Three different damage functions from the literature were implemented (Nordhaus 2017, Howard & Sterner 2017, Burke et al. 2015). Building on the insights from Task 1.2, we additionally introduced an explicit persistence parameter allowing to vary between level and growth rate damages to capture this key uncertainty. In ongoing work this damage module is also used to apply the newly developed tropical cyclone damage function.

Task 4.2 - Integrated analysis of climate change impacts and mitigation policies

The developments under Task 4.1 were applied in a study focusing on the effect of varying degrees of persistency of damages in cost-benefit analysis (Schultes et al. 2020). Furthermore, this study for the first time applies a “least total cost” approach in a process-based integrated assessment model. Damage costs are combined with a mitigation target, for example hedging against tipping points. Compared to the standard cost-effectiveness approach this increases in particular near-term mitigation efforts, making this highly relevant in the policy analysis. This work was complemented by a Perspective Paper focusing on linking biophysical to economic damages and improving integrated assessment (Piontek et al., under review).

2. Aktivitäten und Hindernisse

Activities

PIK activities comprised both the scientific work and the project coordination. The scientific activities were four-fold. The conceptual model on different impact channels was developed and applied. The REMIND model was extended by a damage module taking up a variety of damage functions from the literature as well as an extension of the empirical damage function by Burke et al. (2015) with a persistence parameter. Based on data from the ISIMIP project as well as observational data, empirical analyses of damages of floods and tropical cyclones were conducted. Projections of future exposure to different types of extreme events were developed and two public data bases (on historical people exposed to tropical cyclones and on gridded GDP data continuous from 1850 to 2100) were prepared. The MAgPIE model was advanced with a new module on timber and an improved representation of the modules on forestry and natural vegetation, with the goal to represent dynamic forestry. This involved a consolidation of forest resource assessment data and the MODIS satellite data for validation, as well as a representation of carbon stored in harvested wood products using IPCC guidelines. Wood demand scenarios for the different Shared Socioeconomic Pathways were developed. Furthermore, MAgPIE was updated to include a representation of climate impacts.

ifo activities comprised gathering updated input data to the Gridded ifo GAME Database from primary sources, as well as processing and mapping the data to compile the new database. In addition, data on covariates at the same level of geographical detail have been gathered and processed. ifo designed the empirical strategies for ex-post analysis required to reach the goals of task 1.3 and carried out the corresponding applied econometric analyses.

The work resulted in 19 scientific publications (8 published in peer-reviewed journals, 11 under review or in preparation). The results have been presented at various international conferences and scientific workshops. Furthermore, PIK as project lead organized two international workshops (2016, 2019). Two project-internal workshops took place (2016 at PIK, 2018 at ifo).

Obstacles

The workflow at PIK was disrupted multiple times due to parental leave of two project members as well as the departure of two project members in 2017 and 2019 respectively, for which no replacements could be found. This affected in particular the completion of the projections for economic damages and their inclusion in integrated assessment under Tasks 2.2 and 2.3. Due to the challenges around the implementation of the forestry sector in the MAgPIE model the competition of the PhD thesis of Abhijeet Mishra was delayed until after the end of the project.

For ifo, the data originally intended for the analysis of the impact of natural disasters on global international migration flows (Abel and Sander 2014) turned out to be heavily interpolated and hence inadequate for quantitative research. Instead, the underlying census data provided by the World Bank were used. To analyze the impact of natural disasters on financial flows, it was planned to obtain transaction-level information on person to person money transfers from Western Union (WU). However, negotiating a cooperation and data-usage contract between ifo and WU, including free provision of data by WU for research purposes, took longer than anticipated, so the next steps of this research must be deferred to a future project.

3. Ergebnisse und Erfolge

The project led to 7 accepted publications, 6 under review (see publication list) and layed the foundation for 5 paper in preparation with PIK authors. The results of the conceptual channel study are published in a leading economics journal (Environmental and Resource Economics, Piontek et al. 2019) and were presented at two international environmental economics conferences (SURED and EAERE 2016). An early version of the paper by Schultes et al. (2020) was presented at an international conference (IAMC 2017). The scenarios developed in the study have been submitted to the scenario database for the Working Group 3 Report in the 6th IPCC Assessment report. The future projections of exposure to extreme events have been published in Earth's Future (Lange et al. 2020). These results are made available to the

public under the ISIpedia* project. The ENGAGE work was also topic of a keynote at IAMC 2019. Two public data sets have been made available for the community (Geiger et al. 2018, Geiger 2018). The MAgPIE team was invited to become part of ForMIP, a forestry-focused model intercomparison project led by Ohio State University. The PhD thesis of Abhijeet Mishra is planned to be completed in August 2021.
The work under task 1.3 resulted in 3 publications (Gröschl et al. 2017, Felbermayr et al. 2018, Gröschl et al. 2020) and was presented at a number of conferences and workshops, notably: the European Economic Association Annual Meeting, the International Economics Workshop, Development Economics and Policy Conference, Seventh International conference on Industrial Organization and Spatial Economics, Conference on Environmental Economics. Thomas Steinwachs has successfully completed his doctoral dissertation “Geography Matters: Spatial Dimensions of Trade, Migration and Growth” in September 2018, graded “summa cum laude” by the University of Munich (LMU).

Two international workshops were organized at PIK. The kick-off event for the project, entitled “Understanding the impacts of climate change on growth and development”, was held June 20-21 2016. A final symposium presenting project results in a broader context and discussing next steps with a wide range of interdisciplinary experts was held October 7-8 2019. This resulted in a Perspective Paper written collaboratively with participants (Piontek et al. under review). Furthermore, team members co-organized a session and workshop “Counting the economic costs of climate change” at Impacts World 2017, an international interdisciplinary event for scientists and stakeholders on climate change impacts.

4. Chancengleichheit

Franziska Piontek managed the project, co-authoring key publications of the project and organizing the two international workshops. Katja Frieler supported the project in her role as PI of the ISIMIP project and group leader of the ISIMIP team. Jasmin Gröschl has supported the ENGAGE consortium as a striving female post-doctoral researcher by co-authoring research conducted by ifo under task 1.3. ifo’s general equal opportunity guidelines applied to its hiring activities for research assistants and research interns who temporarily supported research tasks in ENGAGE along the way.

5. Qualitätssicherung

The Gridded GAME database and all procedures needed to reproduce the database from its primary sources as well as results presented in the papers „Do Natural Hazards Cause International Migration?” and “Shedding Light on the Spatial Diffusion of Disasters” have been archived and documented at the LMU-ifo Economics & Business Data Center (EBDC) with restricted access. The data bases TCE-DAT & on GDP, which were developed in the project, as well as the ISIMIP data are available open access.

Most publications are either published open access, are available as working papers, in the PIK Publication Database or the CESifo website. An exception are some papers still under review. The electronic version of the dissertation “Geography Matters: Spatial Dimensions of Trade, Migration and Growth” is also available open access (Steinwachs 2018).

6. Zusätzliche eigene Ressourcen

Alexander Popp (PIK) supervised the PhD work by Abhijeet Mishra and supported the development of the MAgPIE model. Katja Frieler (PIK) supported and guided the work in WPs 1 and 2 and co-authored several publications. Marian Leimbach (PIK) supported and co-authored the conceptual channel study (Piontek et al. 2019). Elmar Kriegler (PIK) guided the

* https://www.isimip.org/isipedia/

project and participated in the development of the damage module in REMIND. They contributed about 5 PM in-kind to ENGAGE. Jasmin Gröschl (ifo) joined the ENGAGE research team as a coauthor to the studies "Do Natural Hazards Cause International Migration?" and "Shedding Light on the Spatial Diffusion of Disasters". She received her own funding from the DFG and contributed about one person-month per year to ENGAGE in-kind.

7. Strukturen und Kooperation

A joint ENGAGE kick-off workshop took place at PIK on June 21, 2016, in conjunction with the international expert workshop. A joint ENGAGE project workshop took place at ifo Institute on October 18-19, 2018. During this workshop, achieved research outputs were discussed and the scope for future project cooperation between PIK and ifo was addressed. Continuous communication of scientific progress and preliminary results has been ensured by regular bilateral phone-conferences between ifo and PIK.

In cooperation between PIK and ifo, PIK's wind field model for tropical cyclones has been used to compile data on gridded hurricane wind-speeds at the same level of spatial resolution used by the Gridded ifo GAME Database. The output of this exercisehas been included in the GAME Database and greatly improves the way it measures extreme wind speeds.

ifo has successfully used ENGAGE to extend its international networking activities by having cooperated with two researchers from the University of Utrecht (co-authors of the paper by Felbermayr et al. (2018)) and with a researcher of the Victoria University of Wellington (New Zealand), who served on the PhD-Board of Thomas Steinwachs. PIK has successfully developed a cooperation with Stéphane Hallegatte (World Bank), who served as an advisor to the ENGAGE project. Collaboration with him extended to a follow-up project (SLICE, see Section 8). The project symposium led to an international collaboration on a Perspective Paper. At PIK, the ENGAGE project was crucial to advance the collaboration between the biophysical impact modeling conducted in the ISIMIP project and the integrated assessment team. The MAgPIE team developed a new cooperation with the team developing the Global Timber Model (Ohio State University), and deepened its cooperation with the land-use modeling teams of the GLOBIOM (IIASA) and the IMAGE (PBL) models.

8. Ausblick

The ENGAGE project was instrumental in laying the foundation for multiple new projects and future activities. The ifo GAME Database provided by ENGAGE will be used to further investigate the short-term effects of natural disasters on trade and underlying production and consumption effects on a monthly basis by Dr. Jasmin Gröschl (ifo). Moreover, ifo and PIK have extended their collaboration with the ongoing projects SLICE and ROCHADE. The work on developing future projections of economic climate change impacts for individual channels and their investigation with the REMIND model is continuing in the SLICE (BMBF) and the CHIPS (JPI AXIS) projects. It is expanded to the question of distributional effects of climate change impacts. New research questions for the MAgPIE forestry modeling will focus on the importance of plantations in meeting long-term timber demand, using timber as replacement for building material and the impact of a paperless world on land-use. The application of the coupled REMIND-MAgPIE system with climate change impacts is planned in the framework of a new project on global commons. The collaboration between the REMIND-MAgPIE teams, the LPJmL model and the ISIMIP team will be deepened in the further development of the Potsdam Integrated Assessment Model (PIAM).

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