Leibniz
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Final Report
Leibniz Competition

Climate Change Impacts on Migration and Urbanization
IMpeTUs

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Anlage zum abschließenden Sachstandsbericht
Leibniz-Wettbewerb

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1. Executive Summary

Migration represents a global phenomenon persisting throughout history. In times of crisis it is more important than ever to understand migration and its various drivers as well as its consequences. The IMPETUS-project was dedicated to migration and its influence on urban development with a special emphasis on climate change. In the form of natural hazards, slow-onset impacts, or general economic developments, climate change affects international and within-country migration. The Impetus-project aimed for a connected, quantitative modeling approach to understand the linkages between migration, urbanization, and climate change at different spatial scales.

We developed the first global model of bilateral migration that can account for the important self-amplifying effect of existing migrant communities (diasporas), as well as for the two-way dependence of emigration on origin-country incomes. With this model, we showed, among other findings, that past climate change may already have increased mobility within and between the richer parts of the world, while inhibiting migration within and out of poorer world regions; a finding that runs counter to widespread notions of “climate migration” from the Global South to industrialized countries. Further, combining biophysical climate impact models with a gravity-model of population change, we found that the cumulative number of additional internal migrants until 2050 could reach the order of 100 million globally, depending on the climate model and scenario.

From the policy perspective, it was found that climate change literacy (i.e., knowledge about climate change) is a major determinant of why some individuals migrate in response to rising temperatures because this knowledge helps individuals translate their perceptions of temperature changes into an understanding of its irreversible long-term consequences. Changing climate conditions (but not weather effects) lead to more out-migration in the long run, especially by less educated individuals. Furthermore, it was shown that, in Germany,

climate change migrants receive high support levels comparable to those received by political refugees which contrasts with attitudes towards economic migrants. People are more likely to accept justifications for taking climate change migrants when they realize that the expected number of migrants is relatively low.

Spatial patterns of international and internal migration to and within Germany were analyzed by means of regression analyses. There are significant differences between German and non-German migration patterns and between different subgroups of immigrants. The location choices of new immigrants, and particularly refugees, are strongly correlated with regional ethnic Diasporas. Regarding the impact of international migration on the internal migration of German citizens, a significant negative correlation between immigration and the regional net-migration balance of German citizens was found. Immigration has the potential to dampen population loss in shrinking (rural) regions. However, because immigration is strongly concentrated in certain urban areas, existing spatial inequalities might be reinforced. Based on the evidence, different population scenarios have been projected using the estimated international migration flows towards Germany.

Urban development is characterized by physical properties, including proximity to existing settlements, water bodies, roads, and protected areas. Three different urban growth types were identified: neighborhood expansion next to prior settlements, discontinuous development still attracted by settlements, and leapfrogging repelled by settlements. Especially the leapfrogging phenomenon is a crucial finding in urban land-cover change city research because it quantifies new built-up areas without direct proximity to formerly existing urban land-cover. By relating the urban development to population changes, the influence of migration on urbanization is taken into account. The model coupling represents the first of its kind combining the full model chain from international migration down to local urbanization activities.

Significant contributions to the understanding of migration have been made. Although many papers have been published, further publications are expected in the next months. The results will feed into follow-up work in other projects and activities at the partner institutions.

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1. Achievement of objectives and milestones

“International Migration model initial implementation” (M1): The international migration model has been implemented in the Python programming language. It provides a numerical framework for dynamic simulations of global between-country migration, keeping track of all migrant and native populations over time. In addition, fertility and mortality, as well as a simplified representation of the assimilation of migrants into the host population have been implemented in order to consistently account for demographic changes. The model equations were calibrated on historical migration data. Compared to the original proposal, it was decided to calibrate and apply the model directly to the full set of countries (except for a number of small countries and disputed territories), rather than a smaller subset of countries. The model achieves a good fit to historical net migration rates of many important emigration and immigration countries (Rikani & Schewe, 2021).

“Urbanization Model running” (M2): The urban land-cover model is calibrated to empirical changes of urban (built-up) areas, which are obtained from the global Climate Change Initiative (CCI) land-cover map series 1992-2020. The likelihood of changes to urban land-cover is extracted from changes between the years 1995 and 2020. This likelihood is based on the proximity to existing urban land-cover areas at the earlier time. Corresponding likelihoods based on proximity to water bodies, roads, and protected areas contribute partly and are included in the model (Glockmann et al.). The projection results of the model have been validated by the receiver operating characteristic (ROC) method and generated a figure of merit of up to 35 % for example cases. This is a common performance for comparable land-cover model approaches (Pontius et al., 2008).

“Future immigration policy scenarios” (M3): We collected survey evidence from the Afrobarometer that is matched with geo-referenced climate data to provide further evidence on migration aspirations and climate change in developing countries. We show that climate change literacy (i.e., knowledge about climate change) is a major determinant of why some individuals migrate in response to rising temperatures because this knowledge helps individuals translate their perceptions of temperature changes into an understanding of its irreversible long-term consequences (Helbling et al., 2021). Furthermore, an additional field survey was conducted in Germany to study attitudes towards climate migrants and refugees in potential target countries of migration and flight. We show that climate change migrants receive high support levels comparable to those received by political refugees (migrants who need special protection) and that contrast with attitudes towards economic migrants (who are often not seen as in need of special protection) (Helbling, 2020). We also see that people are more likely to accept justifications for taking climate change migrants when they realize that the expected number of migrants is relatively low.

“Climate change impacts on international migration” (M4): The international migration model has been applied to a set of global scenarios of country-specific economic development, according to the five Shared Socio-Economic Pathways (SSPs), up to 2100. The scenarios were then modified to account for the effects of climate change on global economic development, using two alternative approaches from the recent climate-economics (Kalkuhl & Wenz, 2020). The related analysis of indirect climate impacts on migration shows, among other findings, the crucial role of assumptions about the so-called mobility transition.

“Domestic migration” (M5): We investigated domestic migration in two studies. We project the development of regional population until the year 2100. Literature research on population forecast methods as well as population projections, for Germany in particular, revealed a lack of differentiated approaches to internal and external migration flows. Therefore, we decided to develop scenarios for Germany at the county level (NUTS3) based on the common cohort component method which takes into account the international migration flows provided by WP1. The scenarios are based on the assumption that the intra-national spatial distribution of immigrants from certain origin regions follows patterns from the past. Our application also

offers the opportunity to adjust the ratio of internal and external migration between rural and urban areas and for the respective SSP-scenarios. Finally, the county-level-projections for each scenario were converted to the 0.5°grids and thus became usable for WP5.

“Coupling of model components” (M6): The model components international migration, domestic migration, and urbanization have been successfully coupled. For the German case study, estimates of the international migration model (WP1) feed into the domestic migration model (WP3) which then feeds into the urbanization model (WP5). The last step required an association between population change and land-cover change which has been implemented by a simple multi-linear regression model with population and year as independent variables. A corresponding manuscript is drafted by Glockmann et al.

2. Activities and obstacles

Results from the international migration model development and application were presented at a number of scientific events, as well as in media interviews and stakeholder consultations. At these and other occasions, we established contacts with other researchers in the field and with interested stakeholders in the policy domain, such as the German Federal Foreign Office or the Internal Displacement Monitoring Center. In terms of obstacles, the calibration of the model required more time than initially expected, leading to a delay in the preparation of subsequent manuscripts. In-depth analysis of bilateral flow estimates also revealed that model calibration on existing data does not support any predictability of bilateral migration flows in the time domain. While this does not preclude use of the dynamic model as a scenario tool, it falls short of the original goals in our model development. This is however a general problem of any such migration models (Beyer et al., 2022), and will be at the focus of follow-up research.

A major problem for the empirical analysis lies in the lack of opportunity to isolate “climate change refugees” from other immigrants. Thus, any projection of future regional population growth will be based on the assumption that the sub-national spatial distribution of climate change refugees follows a similar logic as the spatial distribution of current immigration (e.g. war refugees and labor migrants). In addition, German statistics offer only a short time series (due to the 2011 census) and a low level of detail in terms of reliable data on regional population development and migration. Furthermore, there are some uncertainties in the statistical processing of refugee migration (especially for the years 2015/2016). Results were e.g. presented and discussed at the Congress of the European Regional Science Association (ERSA) and internal workshops.

The assessment of climate change impacts on internal migration was accompanied by stakeholder dialogues and consultations in the framework of the World Bank’s “Groundswell” reports, which helped put the modeling results into a broader socio-political context and thus increase their visibility and accessibility not only for researchers but also practitioners and the general public. A number of related dissemination activities, such as media interviews, were carried out by the project partners. Obstacles included limited availability of population data for many countries, as well as limited computing resources on the CUNY side which precluded exploring a larger ensemble of climate and impact models.

Projections of urbanization based on past trends from pursued successfully. The projections were driven by the future domestic population scenarios provided by project partners. The results of the urban growth model are as well (SSP) scenario maps for multiple years, i.e. starting with the year 2025. The approach was presented at two conferences during the project period: (1) The 3rd International Land Use Symposium 2019 in Paris, and (2) the 2nd International Conference on Natural Hazards and Risks in a Changing World 2021 in Potsdam. An encountered obstacle during the incorporation of the population data was the distribution of population onto the available space. Eventually, we found an operational way

to implement the population projections into the urban land-cover model by linear regression. The various model components between migration and urbanization were successfully coupled.

Project results of all partners were presented at the final event of the project. Due to the pandemic restrictions we decided in favor of a webinar. Four presentations were discussed by four discussants. The event was well attended.

3. Results and successes

WP1 has developed and implemented the first numerical model that can dynamically simulate global bilateral migration, accounting for the important self-amplifying effect of existing migrant communities (Diasporas). Additional innovations compared to the state of the art include an explicit representation of the two-way dependence of emigration on origin-country incomes - with poverty inhibiting migration, and middle-income countries showing the largest emigration rates - and the separate representation of emigration, transit, and return migration flows. The model is expected to serve as a versatile tool to address various topical research questions. It has already received praise from senior scientists at the UN Population division and World Bank as an important methodological development.

In WP2, five papers on the relationship between climate change, migration/urbanization and further socio-economic outcomes (health) have been published in or are currently under review at international journals. A first empirical study (Helbling and Meierrieks, 2021) examines the relationship between weather, climate change and migration in the short- and long-run from a macro (country-level) perspective. The findings of this study show that changing climate conditions (but not weather effects) lead to more out-migration in the long run, especially by less educated individuals. In a parallel study (Helbling and Meierrieks) we investigate the influence of increasing temperatures on rural-urban migration. We come to the conclusion that higher temperatures correlate with higher urbanization rates in the long run and that this relationship is especially relevant in poorer and more agriculture-dependent countries with an urban bias as well as in initially non-urban countries in hotter climate zones. In addition, surveys on migration intentions due to climate change in African countries have been completed (Helbling et al., 2021). Finally, a survey was conducted regarding attitudes towards climate refugees in Germany (Helbling, 2020). Based on that expertise was prepared to advise the public on the determinants of migration and flight and the role of climate change in these processes.

In WP3, a paper on the spatial patterns of international and internal migration to and within Germany has been published (Heider et al., 2020). In addition, a successful master thesis emerged from the work package. Spatial regression analyses show significant differences between German and non-German migration patterns and between different subgroups of immigrants. The location choices of new immigrants, and particularly refugees, are strongly correlated with regional ethnic Diasporas. A second paper is on the impact of international migration on the internal migration of German citizens (Heider et al.): Using regional variation in the influx of refugees between 2008 and 2018 as an explanatory variable and applying an instrumental variable identification strategy, we find a significant negative correlation between immigration and the regional net-migration balance of German citizens. Based on the evidence from our papers, we have projected different population scenarios using the projected international migration flows towards Germany provided from WP1 (Glockmann et al.). The scenarios underline previous results that international migration has strong effects on regional demographic trends. We can show that immigration has the potential to dampen population loss in shrinking (rural) regions. However, because immigration is strongly concentrated in certain urban areas, existing spatial inequalities might be reinforced.

In WP4 biophysical climate impact projections (projected changes in crop yield and water resources) have been combined with a spatial population down-scaling model, to derive estimates of how much additional internal migration might be expected due to these impacts. Initial results indicated that the cumulative number of additional internal migrants until 2050 could reach the order of 100 million globally, depending on the climate model and scenario. Meanwhile these estimates have refined and extended, using calibration data for additional countries (Clement et al., 2021). In addition, scenarios of country-specific economic growth with and without climate change have been developed and incorporated into the international migration model. The migration model was applied to a set of historical economic states. Comparison between these suggests that past climate change has acted to increase mobility within and between the richer parts of the world, while it has inhibited migration within and out of poorer world regions; a finding that runs counter to widespread notions of “climate migration” from the Global South to industrialized countries (Rikani et al., under review).

For an urban growth model such as the one developed in WP5 the use of high-resolution satellite images for 100 example areas on a global scale is novel. Thereby, three different urban growth types were identified: neighborhood expansion closest to in the proximity to prior settlements, discontinuous development still attracted by settlements and leapfrogging repelled by settlements. Especially the leapfrogging phenomenon is a crucial finding in urban land-cover change city research because it quantifies new urban land conversion without direct proximity to formerly existing urban land-cover. The observed increase in the likelihood at high distances of up to 30 km and more has not been described before (Glockmann et al., 2022).

The model coupling in WP6 represents the first of its kind that combines the full model chain from international migration down to local urbanization activities (Glockmann et al.). Within WP6 an “unplanned”, additional paper has been written. It discusses conceptual limitations and data requirements that were encountered when measuring the effect of climate change on migration flows. The manuscript is now under review with one of the major journals in the field (Helbling et al.).

4. Equal opportunities

In total, there were ten colleagues working in the project, of whom four new staff members have been hired by the project partners. Among these new hires there is unfortunately only one female colleague. Job announcements explicitly encouraged female applications; however, almost no applications from female applicants were received in most cases. All project partners have implemented strategies to promote diversity and equal opportunities. PIK has been awarded the “Total e-quality” award for its equality and diversity strategies. The IMpeTUs team includes four colleagues from abroad or with some migration background, i.e. one PhD student from Italy, one project partner at the City University of New York, the senior employee at WZB is from Switzerland, and the PI at PIK has a Brazilian citizenship.

5. Quality assurance

The IMpeTUs consortium is aware of the DFG guidelines of good scientific practice and followed them closely. Regular meetings and telephone conference calls not only facilitate the collaboration, but are also used for quality assurance. A fundamental part of these meetings is the status update of the work packages, which then are exposed to critical questions from the other partners. The consortium published exclusively in peer-reviewed journals. In addition, the project partners are encouraged to submit their manuscripts to open access journals. However, the choice of an appropriate journal needs to take various factors into account and sometimes those journals that are most used by a community are not pure

open access journals. E.g. at PIK only Gold Open Access is supported so that the open access option (Hybrid Open Access) could not be used.

6. Additional in-kind resources

Dr. Bryan Jones (CUNY) in the USA did not receive funding from the project. His contributions were based on his own resources. Prof. Marc Helbling (WZB) received a teaching buyout of one teaching hour. Dr. Daniel Meierrieks, a further senior researcher at the WZB, was predominantly paid via the IMpeTUs project but received further payment by the WZB. Prof. Dr.-Ing. Stefan Siedentop (ILS) was not funded by the project. His input as ILS-project leader was financed by the institute's own resources. PIK contributed high-performance computing time for the international migration and urbanization modeling.

7. Structures and collaboration

During the run-up to the project, close cooperation among the partners was established. The regular project meetings represented an effective platform for the generation and exchange of innovative ideas. In addition to the regular collaboration in the course of the project, the following specific exchanges took place: PIK-S provided climate data to WZB, WZB provided initial advice on immigration policy data to PIK-S, CUNY and PIK-S collaborated on new calibration runs for climate-induced internal migration. After finding a common language, challenges of interdisciplinarity turned out not to be a problem.

In addition, the project also stimulated new collaborations with (international) partners outside the consortium. E.g. PIK-S established cooperation with the World Population Programme at the International Institute for Applied Systems Analysis (IIASA, Austria), in order to gain expertise on demographic forecasting and to further develop the representation of different demographic processes in the international migration model. PIK-R established a new collaboration with the Land Use & Land Use Change Lab at University of California, Berkeley. ILS is collaborating with a researcher from the University of Southern Denmark.

8. Outlook

Although many papers have been published, there is still a set of publications that either need to be (re)submitted or are drafted. Publications that are not published yet are expected to appear in the next months. Accordingly, further publications can be expected beyond the project run-time. E.g. in WP1 it is planned to include the effects of immigration policies, and changes in such policies, into the international migration model; based on the IMPIC database and the future policy scenarios developed in WP2. This is expected to enhance the explanatory power of the model for past migration, and to enable us to address a number of research questions related to future changes in policies and to feedbacks between migration flows and policies (and their enforcement). In addition, we plan to use the model to explore the interaction between international and domestic migration, collaborating with WP3 and WP4, with a particular focus on cities as important migration hubs (WP5). The project results will feed into follow-up work in other projects and activities at the partner institutions. In particular the model chain (WP1+3+5) and coupling (WP6) will be of use to the different communities.

Appendix

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Submitted Publications / in Preparation (IMpeTUs)

Heider, B.; Stroms, P., Koch, J. and Siedentop, S. (under review): Where do immigrants move in Germany? The role of international migration in regional disparities in population development. In: Population, Space and Place (OA; IF = 2.279).

Helbling, M., and Meierrieks, D. (under review): How climate change leads to emigration: Conditional and long-run effects. In: Journal of Population Economics (OA; IF = 1.47).

Helbling, M. and Meierrieks, D. (under review): Global warming and urbanization. In: Journal of Development Economics (OA; IF = 2.855).

Helbling, M., Rybski, D., Schewe, J., Siedentop, S., Glockmann, M., Heider, B., Jones, B., Meierrieks, D., Rikani, A., and Stroms, P. (under review): Measuring the effect of climate change on migration flows: Conceptual limitations and data requirements. In: Population and Environment (IF=3.537).

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