Environmental migration?
An overview of the literature.

Maria Cipollina[1], Luca De Benedictis[2,3], and Elisa Scibè *[2]

[1]University of Molise - cipollina@unimol.it
[2]University of Macerata - luca.debenedictis@unimc.it; e.scibe1@unimc.it
[3]Luiss University

April 29, 2022

Abstract

This article assesses the impact of climate changes and natural hazards on human migration, through a deep systematic review of the literature analyzing environmental factors (both gradual and sudden) as determinants of migration flows (both internal and international). Starting from a systematic approach to bibliographic research, we proceed with a bibliometric analysis of the empirical contributions, their characteristics and findings, and finally, we combine, summarize and explain the large number of empirical evidence using a meta-analysis approach. The literature on the relationship between environmental factors, both climatic changes and natural hazards, and human mobility is characterized by heterogeneous findings: some contributions highlight the role of climate changes as a driver of migratory flows, while others underline how this impact is mediated by geographical, economic and the features of the environmental shock. We believe that our contribution improves the existing literature on several dimensions. First, we map the literature, focusing on economics and empirical essays, and we provide a systematic research of such literature through main bibliographic databases, a review and bibliometric analysis of all resulting papers. Second, we build a citation-based network of contributions, that hollows to identify four separate clusters of paper, that gather papers together according to not only certain characteristics of the analysis but also resulting outcomes. Third, we apply meta-analysis methods on the sample of 96 papers released between 2003 and 2020, published in an academic journal, working papers series, or unpublished studies, providing 3,904 point estimates of the effect of slow-onset events and 2,065 point estimates of the effect of fast-onset events. We also use the clustered structure to highlight how specific features characterizing the cluster influence the magnitude of the estimated effect. Overall, the meta-analytic average effect estimates a small impact of slow- and rapid-onset variables on migration, however positive and significant. When the clustering of the literature is accounted for, however, a significant heterogeneity emerges among the four clusters of papers, giving rise to new evidence on the formation of club-like convergence of literature outcomes. We believe that our analysis can provide, based on the evidence empirical, important information on public policies.

Keywords: Migration, Climate change, Natural disasters, Systematic literature review, Meta-analysis, Co-citations.

JEL Codes: C83, F22, J61, Q51, Q54, Q56.

*Corresponding author. The authors would like to acknowledge the contribution of MUR, which partially funded the visit of Elisa Scibè to the Universitè Libre de Bruxelles, Belgium. Many thanks to Francesca Pallotti, Tom Stanley, and the participants to various seminars and conferences (EUSN2021; MAER-Net Colloquim 2021) for the insightful comments. No conflict of interest applies.

1 Introduction

In a world of changing climate and increasing occurrence of natural hazards, the role of environmental factors in shaping migration patterns has become a most debated topic within institutions and academia. As opposed to a simplistic vision of a general direct role of environmental factors in determining migration flows from environmentally stressed areas and regions hit by calamities, more complex scenarios have emerged, with analyses reporting different and sometimes opposite outcomes. This may not only be due to the intrinsic complexity of their extent and scale, but also to differences in specific characteristics of scientific contributions.

This paper aims to map the economic literature on these topics moving away from a classical literature review and offering a methodology that integrates three approaches in a sequence. The analysis starts with systematic research of the literature through main bibliographic databases and collecting previous reviews and meta-analyses, followed by a review and bibliometric analysis of all resulting papers. This first step produces a sample of 151 papers empirical and non-empirical contributions, spanning the last 20 years and focusing on different geographical areas, taking into account different socio-economic factors, applying different methodologies and empirical approaches. Most importantly, the sample provides a variety of different outcomes on the impact of climatic changes and hazards on migration, revealing three main possible scenarios: (1) active role of environmental factors as a driver of migration; (2) environmental factors as a constraint to mobility; (3) non-significant role of environmental factors among other drivers of migration.

To investigate the determinants of this extreme heterogeneity of outcomes, we postulate the assumption that the inter-connectivity of papers may play a role in shaping such opposite conclusions. Considering the ensemble of papers referenced by each contribution included in the sample, as a second step, we build a bibliographic coupling network, where papers are linked to each other according to the number of shared references. This citation-based method allows for the formation of a network of contributions in the literature space and highlights some potential common grounds among papers. We then run a community detection of the resulting network that produces four main clusters that gather papers together according to not only certain characteristics of the analysis but also resulting outcomes.

We use the clustered structure in the third step of the analysis: a meta-analysis of all estimated effects of environmental variables on human mobility. Meta-analysis (MA), as a "quantitative survey" of literature used to summarize and analyze the literature on environmental migration, offers the possibility to condense the results of all contributions in a single representative result. A highly significant result can be potentially considered as a consensual indication of the external validity of the correlation, or even the causal link, of the phenomena under scrutiny.

Therefore, we build a unique dataset that synthesizes the estimated coefficients of 96 empirical papers included in the sample concerning the effect of slow-onset (e.g. climate change) and fast-onset natural events (e.g. catastrophes) on different kinds of human mobility (international, domestic, and with a clear pro-urban directionality), accounting for main potential sources of heterogeneity (scope, level, unit and area of analysis, theoretical and empirical approaches,

publication biases) and the outcome of the community detection operated in the previous step. Overall, the meta-analytic average effect estimates a small impact of slow- and rapid-onset variables on migration, however positive and significant. When the communities of papers are accounted for, however, a significant heterogeneity emerges among the four clusters of papers, giving rise to new evidence on limits of a consensual effect of climatic shocks on permanent human displacement and the formation of club-like convergence of literature outcomes.
Section 2 offers a systematic review of the literature and gives a detailed description of the data collection process; Section 3 analyses the structural characteristic of the network of the bibliographically coupled papers; Section 4 summarizes and discusses the results of the meta-analysis, finally, Section 5 concludes and offers some possible future extensions of the analysis.

2 Systematic review

This section reports the different phases of the systematic review. We do it schematically to facilitate the understanding of the proposed procedure.

Setting the boundaries. This first step provides the most comprehensive sample of economic contributions on the relationship between climatic variations (and natural hazard) and human mobility, in all its different forms. We implement a systematic review aimed at mapping the body of literature and defining the boundaries of our focus. Systematic reviews have become highly recommended to conduct bibliographic overviews of specific literature because they provide a tool to report a synthesis of the state of the art of a field through a structured and transparent methodology (Page et al., 2021). To allow for comparability with previous meta-analyses and reviews, we also add to our sample all articles included in two recent meta-analyses, Hoffmann et al. (2020) and Beine and Jeusette (2019). We begin with the definition of the research question and the main keywords, to gather and collect data in a sample of contributions. After the definition of inclusion and exclusion conditions, we proceed with a screening by title to exclude off-topic contributions and then to a screening of the text to assure the uniformity of contributions. The resulting sample is then the object of a preliminary bibliometric analysis.

Defining the research question and keywords. The purpose of our systematic search is to collect all possible economic contributions on the impact of environmental factors on migration determinants. We define three keywords of the three phenomena under analysis:

- *climate change*, as most investigated environmental factor in the literature. The events connected to climate change are hereby intended as slow-onset events that gradually modify climatic conditions in the long run. We specifically focus on variation of temperature, precipitation, and soil quality (such as desertification, salinity or erosion), factors that are not expected to cause an immediate and sudden expected impact, but slowly modify environmental conditions;
- *natural disasters*, defined as fast-onset events that introduce a sudden shock (see Table 1);
- *migration*, that captures all possible patterns of human mobility, including within the borders of a country, which might be a potential response to environmental change. Most importantly, internal mobility includes also the process of urbanization of people moving out of rural areas to settle in cities.

Table 1: Classification of natural hazards

Category	Type of hazard
Geophysical	Earthquake Mass movement (rock fall, landslide), Volcanic activity.
Meteorological	Storm (tropical storm, extra-tropical storm, convective storm - including tornadoes), Extreme temperature (cold wave, heat wave, severe winter)
Hydrological	Flood Landslide (wet) Wave action
Climatological	Drought Glacial lake Wildfire
Others	Epidemics Insect infection Miscellaneous*

Note: Classification made within the framework of the EM-DAT (*Emergency Events Database*) developed by the Centre for Research on the Epidemiology of Disasters (CRED). `https://www.emdat.be/classification`
*This category includes biological and extraterrestrial events which, however, are marginally covered by the literature in a small number of contributions.

Collecting data and initial search results. To collect data we use two main literature databases, namely Scopus and Web of Science.[1] Exploiting the specific indexing and keyword definition of both sources[2], the search is run allowing for any kind of document type (articles in journals, book chapters, etc.) but limiting the area to economic literature in English.[3] The obtained sample only includes published documents, however since we perform a MA, it is important to take into account also non-published documents, as a way to control for a well-known publication bias in meta-analytic methodology (see Section 4). Therefore, we use the bibliographic database IDEAS, based on RePEc and dedicated to Economics, to include unpublished and working papers.[4] A selection of the contributions is made manually. Finally, to meet the purpose of comparability with other recent meta-analyses on the impact of environmental factors on migration, we also include all the contributions that have been reviewed in two main articles: Hoffmann et al. (2020) that provide a meta-analysis on 30 empirical papers focusing on country-level studies and Beine and Jeusette (2019) that review 51 papers and offer an investigation of the role of methodological choices of empirical studies (at any level) on the sign and magnitude of estimated results. Merging the results together gives a sample of 203

[1] They contain, respectively, more than 12,000 and 8,000 journals, including social sciences (thus economics). Compared to other common sources (such as Google Scholar), they restrict the search to specific areas, provide detailed information about the specific contribution, and allow for the extraction of the full list of references cited by the paper. This feature will be important for the next steps of the bibliometric analysis and more importantly to build the citation-based network. The extraction is made through bibliometrix, an R tool for science mapping analysis that reads and elaborates the information exported by Scopus and Web of Science (Aria and Cuccurullo, 2017).

[2] The code `key` in Scopus' Advanced Research tool is a combined field that searches the author keywords and controlled vocabulary terms assigned to the document; in Web of Science the code `AK` refers to author keywords, while `KP` refers to "keyword plus" a feature of WoS that assigns words and phrases that appear frequently in the titles of an article's references.

[3] Scopus: `key`("migration" `and` ("natural disasters" `or` "climate change")) `and` (`limit-to` (`subjarea`,"econ")) `and` (`limit-to`(`language`,"English")), Date: 24/11/2020. Web of Science: ((`AK`=(migration `and` ("natural disasters" `or` "climate change"))) `or` (`KP` = (migration `and` ("natural disasters" `or` "climate change")))) `and` `language`: (English) Refined by: `web of science categories`: ("economics"), Date: 24/11/2020.

[4] We use the Advanced Search tool, searching by Keywords and Title: migration `and` ("natural disasters" `or` "climate change").

records.

Screening of the results. We screen the collected items through Scopus and Web of Science by title and we exclude papers on migration of animal, plants or other species, or focusing on topics different from human mobility (i.e. discrimination, crime, wars) or on the impact of environmental variables not corresponding to our definition of environmental factors (air pollution, mineral resources). All the papers in Beine and Jeusette (2019), Hoffmann et al. (2020) and those manually selected from IDEAS RePEc are automatically included in the sample with no concern of incoherence. The screening by title leads to the exclusion of 20 papers. The remaining 183 documents are then screened by text to isolate eligible contents. This stage leads to the removal of additional 32 documents covering on the one hand the analysis of the impact of environmental variables at destination countries (thus not focusing on their role on migration determinants at origin). We also exclude all the papers in which the dependent variable of the empirical exercise is not a measure of human mobility (i.e. remittances, poverty, wealth, employment, etc.). After duplicates removal, the sample results in 151 documents of different kinds: 35 records are non-empirical and contain an ensemble of literature reviews, qualitative analysis, theoretical modeling, and policy papers; 116 records are categorized as empirical, in which the dependent variable is a measure of human mobility and at least one environmental variable is an independent variable.

The PRISMA diagram in Figure 1 shows the process of identification, screening, eligibility, and inclusion of contributions in the final sample. It is important to note that there are two levels of inclusion: the first level identifies the sample of contributions included in our network analysis, while the second level is restricted to quantitative analyses suitable for the meta-analysis. To conduct a meta-analysis it is crucial to select only comparable papers that provide complete information (mainly on estimated coefficients and standard errors) that can then be used to recover the average effect size. This implies the exclusion of papers that do not comply with the requirements of a meta-analysis. However, those excluded papers can be of interest in building the taxonomy of the whole concerned literature, as they may play a role in building links between different contributions (see Section 3). Similarly, non-quantitative (policy, qualitative or theoretical) papers may participate as well in the development of research fronts or to give a direction to a certain thread of contributions and incidentally affect the detection of clusters. These reasons led us to build our citation-based network and perform the network analysis and the community detection on the whole sample, while only the sample for the MA is restricted only to quantitative contributions that meet the coding requirements. Our final database of point estimates for the meta-analysis includes 96 papers released between 2003 and 2020, published in an academic journal, working papers series or unpublished studies, providing 3,904 point estimates of the effect of slow-onset events (provided by 66 studies) and 2,065 point estimates of the effect of fast-onset events (provided by 60 studies).[5]

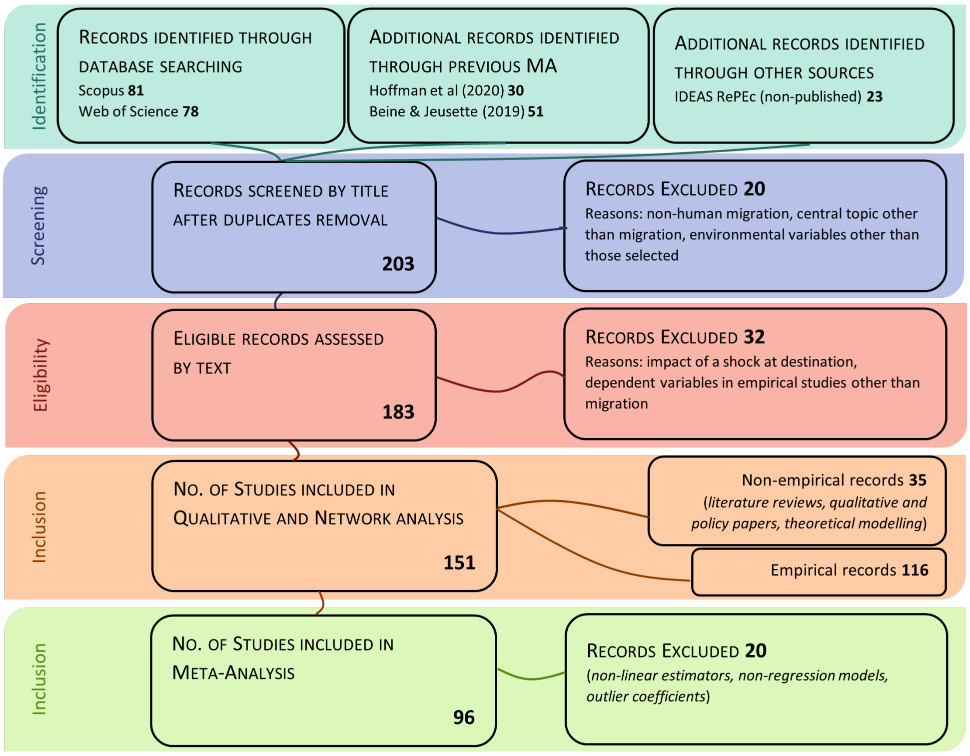
2.1 Bibliometric Analysis

This section summarizes the most relevant features of the ensemble of economic literature collected in our sample.[6]

[5] The list of articles is in the Appendix A.

[6] All records have been uploaded and summary statistics produced using the R tool bibliometrix (Aria and Cuccurullo, 2017). Scopus and Web of Science allow for the download in the bulk of records in .bibtex format, ready to be converted in R objects. Other records are manually entered, depending on the publication status of the single record: for published documents additional research of the specific document is made on Scopus

Figure 1: PRISMA Diagram



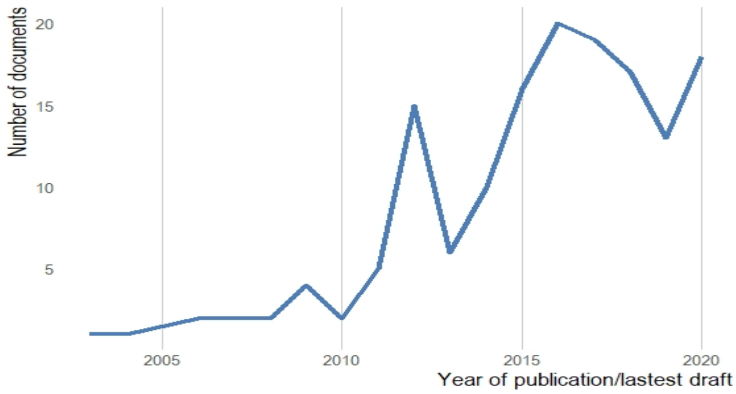
Note: PRISMA Diagram (Liberati et al., 2009) of identification, screening, eligibility and inclusion stages of academic contributions. The resulting sample is obtained through search on Scopus, Web of Science, Google Scholar, IDEAS RePEc, and previous meta-analyses (Hoffmann et al., 2020; Beine and Jeusette, 2019).

The economic literature has started to pay attention to the potential relevance of environmental events on migration in the early 2000s, although the topic had already gained some relevance in global debate decades before, and the scientific production increased sharply in the last 17 years. Figure 2 shows that the scientific production on the specific field is quite recent, spanning from 2003 to 2020, and with a peak of 20 contributions in 2016 and an annual growth rate for the overall period at 18.5 percent. Taking a closer look at the cited references, it is possible to trace back an article published before 2003 (Findley, 1994), that provides a qualitative analysis of drought-induced mobility in Mali (finding no evidence of any role of 1983-85 droughts on migration).

By extracting the author field from the database of all contributions, we observe the frequency of most productive authors and their citations per year. Geographer Clark Gray is the most productive in our sample, authoring 10 articles spanning an entire decade, followed by his co-

and the relative .bibtex file is downloaded and added to the other results; for unpublished papers, which cannot be found in the two sources, a .bibtex is manually created following the structure of fields and information in the downloaded ready-to-use files. After merging each file and removing duplicates we obtain the data source that contains the bibliographic information of all articles, including publication year/latest draft, author(s), title, journal, keywords, affiliations, and references.

Figure 2: Number of documents per year



Note: Sample of academic contributions about migration and environmental factors from Scopus, Web of Science, Google Scholar, IDEAS RePEc, and previous meta-analyses (Hoffmann et al., 2020; Beine and Jeusette, 2019) collected, merged, screened and included by the authors.

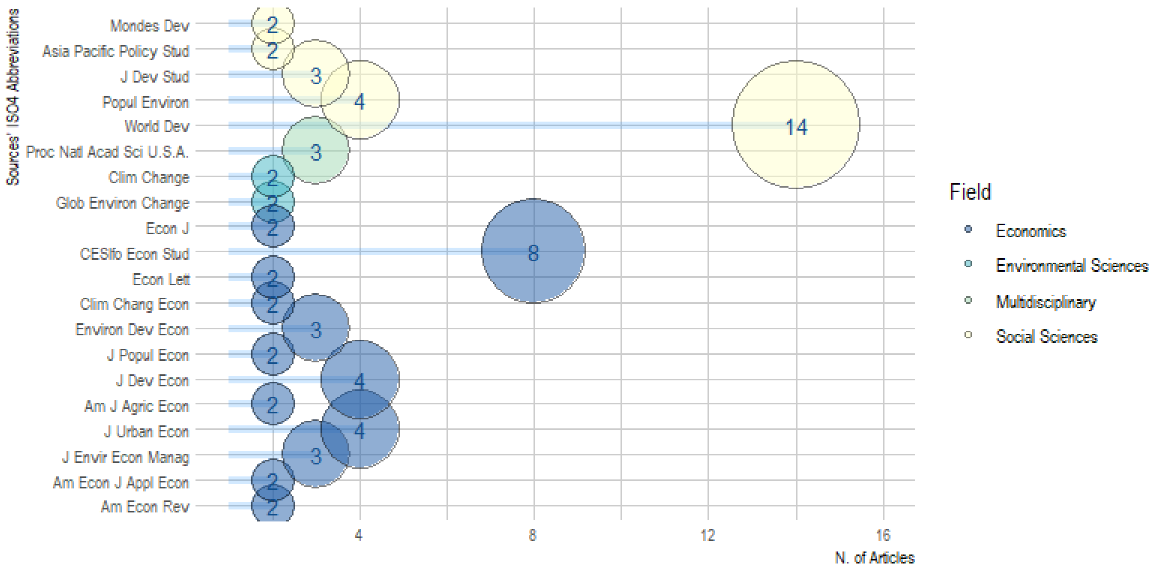
author, economist Valerie Mueller, authoring 6 articles and appearing together in 5 of them. Interestingly, their articles have the highest total citations per year of all most productive authors, especially for the two articles published in 2012 (Gray and Mueller, 2012a,b). Other relevant contributors are Cristina Cattaneo, Katrin Millock and Michael Oppenheimer with 5 documents each. Among the top authors included in the environmental migration literature, Michael Oppenheimer scores the highest *h-index* (Hirsch, 2005) and at least 5 contributions, being globally considered one of the pioneers to warn about the climate emergency both in academic research and international organizations.[7] Michel Beine and Fréderic Docquier, as two prominent economists socializing in migration, appear in the top 10 authors with 3 contributions each, denoting a growing interest in environmental issues within migration literature. Overall 288 authors have contributed to this literature, with 372 appearances, 34 documents are single-authored, the mean number of authors per document is 1.88; when considering exclusively multi-authored documents, the number of co-authors per document rises to 2.16, with a maximum of co-authors of 9.[8]

Various disciplines have put the attention on the topic. Despite journals specialized in economics and econometrics represent the majority of the sources of publication, the literature includes also other disciplines (Figure 3). Specifically, economic environmental migration is the object of publication in journals specialized in environmental sciences, geography, and social sciences such as urban studies, agriculture, demography, political studies. A special mention has to be done for development studies: many reviews and journals specialized in development have issued contributions on the topic, highlighting the trend of observing the topic through development lenses. As an example, 14 documents in our sample are published in *World Development*, a multi-disciplinary journal of development studies.

[7] https://www.reuters.com/investigates/special-report/climate-change-scientists-oppenheimer.

[8] This figure, called collaboration index is calculated only using the total of authors of multi-authored articles over the total of multi-authored articles.

Figure 3: The 20 most relevant publication sources by field



Note: Sample of academic contributions about migration and environmental factors from Scopus, Web of Science, Google Scholar, IDEAS RePEc, and previous meta-analyses (Hoffmann et al., 2020; Beine and Jeusette, 2019) collected, merged, screened and included by the authors.

A picture of the most relevant documents included in the sample is provided by simple measures, such as the number of global citations as reported in Scopus (at the moment of bulk download of all sources), and the number of local citations, which shows how many times a document has been cited by other papers included in the sample. Table 2 shows these measures for the most cited documents in our sample. The difference between global and local citations scores (almost four times higher) reveals that the documents have been cited by papers not included in our sample. It means that environmental migration has attracted the interest of different disciplines or they became part of the two main strands of literature, climate change and migration, separately. 58 papers have not been cited in any of our sample, while 52 have zero citations globally. A part of it can be explained by the 18 papers that has been published recently in 2020, which could not have been cited yet because of timing (except for some contributions published in early 2020 such as Mueller et al. (2020) and Rao et al. (2020).[9] Position and number of citations confirm the central role of papers published by Gray Clark and Valerie Mueller (Gray and Mueller, 2012b,a; Mueller et al., 2014), receiving high citations both globally and internally. Some papers seem to be more relevant locally than globally: Marchiori et al. (2012) and Beine and Parsons (2015) had a bigger influence on our sample of economic environmental migration literature rather than globally, scoring the highest number of local citations. Conversely, Hornbeck (2012) seems to be cited more in literature outside the specific literature of environmental migration.

[9] The issue of timing will be addressed in the network analysis, choosing a specific type of citation-based network, the bibliographic coupling network, to minimize the risk of missing connections between papers.

Table 2: Most cited documents: global and local citations

Author (year)	Global Citations	Author (year)	Local Citations
Gray and Mueller (2012b)	216	Marchiori et al. (2012)	48
Barrios et al. (2006)	203	Gray and Mueller (2012b)	46
Feng et al. (2010)	203	Barrios et al. (2006)	45
Henry et al. (2004)	198	Beine and Parsons (2015)	42
Gray and Mueller (2012a)	154	Feng et al. (2010)	37
Hornbeck (2012)	140	Henry et al. (2004)	36
Mueller et al. (2014)	130	Gray and Mueller (2012a)	36
Gray (2009)	115	Bohra-Mishra et al. (2014)	36
Henry et al. (2003)	112	Halliday (2006)	32
Bohra-Mishra et al. (2014)	111	Mueller et al. (2014)	29

Note: Sample of academic contributions about migration and environmental factors from Scopus, Web of Science, Google Scholar, IDEAS RePEc, and previous meta-analyses (Hoffmann et al., 2020; Beine and Jeusette, 2019) collected, merged, screened and included by the authors.
* Global citations: actual number of citations in Scopus
* Local citations: number of citations within the sample of 151 contributions

As our research of documents is based on keywords, naturally the three most repeated are those put in the search key ("migration", "climate change" and "natural disasters").[10] As far as migration is concerned, it seems that international mobility has been treated more than internal migration; however, internal migration may include also urbanization or rural-urban migration which, aggregated together, are as recurrent as international migration (counting 21 repetitions per group). Environmental migration is also present as a form of *forced migration*, originating refugees, or specifically environmental refugees. Keywords regarding environmental topics show a special focus on slow-onset events (*rainfall, temperature, global warming* and *climate variability*) more than specific rapid-onset events. Although, some of the latter are more recurrent than others, such as *drought, floods* and ultimately *earthquakes*. The cloud of keywords gives also a picture of the geographical scope of the analyses, with Africa being the top region (15 repetitions) as a continent (*Africa*), as specific regions (*Sub-Saharan Africa*) and specific countries within the area (i.e. *Mali, Ethiopia, Burkina Faso*). It is followed by *Mexico* (being a keyword 5 times alone) and *Latin America* in general. Asian countries mostly appear separately instead of as a region, with *Bangladesh, India* and *Vietnam* on top, being the object of specific case studies. Some phrases related to the specific economic model or estimation method used to analyze the data enter the cloud, giving a picture of the direction of empirical studies. Gravity models are most used, mainly for international migration modeling, while event history models are mainly used for micro-econometric analyses at the household or individual level. As already mentioned, environmental migration is often studied looking at potential mechanisms channeling the effect of climate or disasters on human mobility. Some of these channels appear clearly in the cloud, forecasting the main topics the literature treated to analyze the complexity of the phenomenon. Agriculture is a prominent channel explored in environmental literature and it appears in keywords as *agriculture* and *agricultural productivity* representing together the most recurrent words. Agriculture is closely followed by *conflict* which is often investigated in literature as the link between environment and migration. Other important concepts emerging from the cloud and characterizing the literature are *adaptation* and *risk*, as a way of conceiving migration as an adaptive strategy and the adverse environmental conditions as a source of risk for human lives, assets and livelihoods.

[10] Variants of words or concepts have been aggregated in a unique item i.e. *climate change* and *climatic change* or *environmental migrants* and *environmental migration*.

2.2 Overview of major results

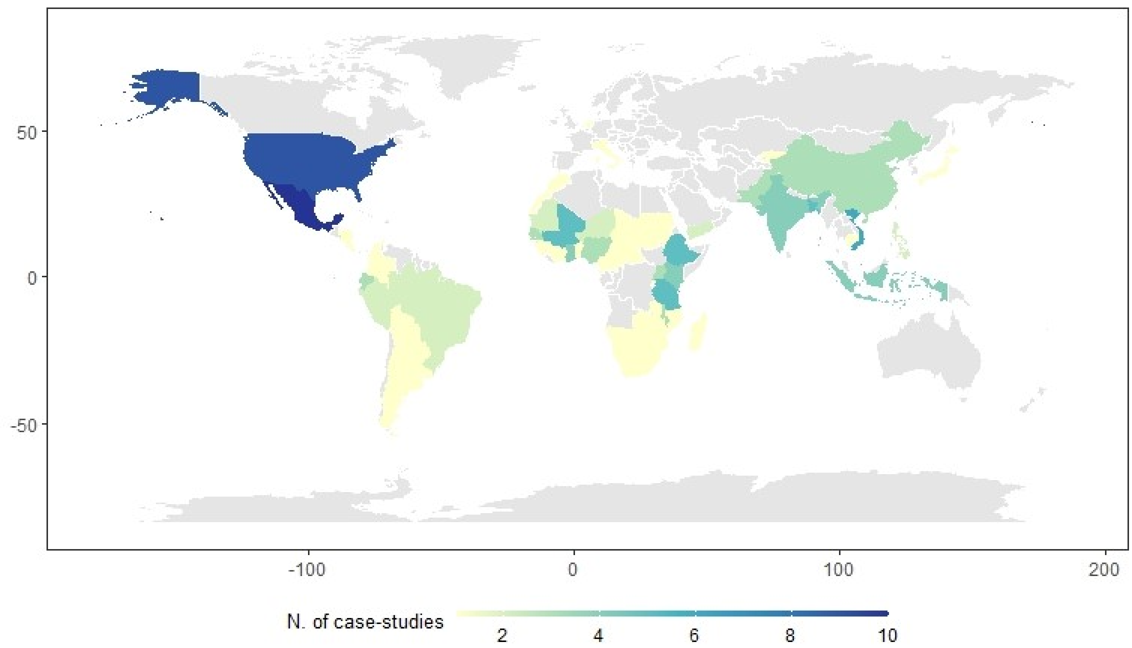
The literature on the effects of climate and natural disasters on migration is characterized by a rich variety of studies both in micro- and macro-economic analyses. Country-level analyses tend to find evidence of a direct or indirect impact of environmental factors on migration patterns, either internally or internationally. Barrios et al. (2006) and Marchiori et al. (2012) find evidence of an increase of internal migration, especially towards urban areas in the case of Sub-Saharan Africa, according to many specific historical and developmental factors. Both contributions highlight how worsening climatic conditions correspond to a faster urbanization process. Marchiori et al. (2012) add also that this climate-driven urbanization process results also in higher international migration rates, acting as a channel of transmission of the effect of climate.

The macro literature, in line with most validated theoretical models of migration, also investigates whether the effect is conditioned to income levels of the country of origins of potential migrants (Marchiori et al., 2012; Beine and Parsons, 2015, 2017). The role of income in a specific origin country experiencing the effects of environmental events is found to be crucial to determine the sign and the magnitude of the impact. Cattaneo and Peri (2016) support from one side the active role of those events in fostering migration, but show how this effect is conditioned to middle-income countries. The effect is opposite when conditioning the analysis to poor countries, highlighting the existence of certain *constraints* to mobility. Worsened environmental conditions may exacerbate liquidity constraints or lack of access to credit aimed at financing the migratory project, which lead to what has been called *poverty trap*. Furthermore, these conditioned results seem to be robust even when another important channel is controlled, agricultural productivity. Climatic conditions and disruptive hazards may constitute major drawbacks for agricultural productivity, leading the agriculture-dependent part of the population to move out from rural areas: Cai et al. (2016) and Coniglio and Pesce (2015) provide evidence of an indirect link between worsened temperature and precipitation conditions and migration, mediated by the level of agricultural dependency of the country of origin. Sudden and fast-onset hazards, on the other side, are not found contributing significantly to human mobility, except in the case of higher-educated population, more mobile than other groups after the disruption of a natural disaster (Drabo and Mbaye, 2015).

Micro-level literature provides a vast variety of case studies on different potential impacts of environmental factors on mobility. In our sample, they almost double macro-level contributions (86 contributions against 47) and provide different scenarios. Firstly, while macro-level studies mostly provide analyses at the global level or for some group of countries or macro-regions, micro-level analyses tend to observe a specific phenomenon hitting a specific area or to study differences in the impact of a common phenomenon in different areas. The most covered region as a whole is Sub-Saharan Africa, with 65 case studies included in the contributions (Figure 4)[11]. When the level of analysis is less aggregated than the national or sub-national level, and individuals or households behavior is observed through the use of surveys, the picture gains complexity and less generalized conclusions. This seems clear in Gray and Wise (2016) who analyze a series of comparable surveys across five Sub-Saharan countries, which have consistent differences. The heterogeneity of responses to climatic variations across those countries is strictly linked to the characteristics of the area and of the specific households. Poorer countries (such

[11] Some contributions are not single-case studies.

Figure 4: Number of case studies covered by the micro-level sub-sample per country



Note: Sub-sample of micro-level studies about migration and environmental factors from Scopus, Web of Science, Google Scholar, IDEAS RePEc, and previous meta-analyses (Hoffmann et al., 2020; Beine and Jeusette, 2019) collected, merged, screened and included by the authors.

as Burkina Faso) mainly experience internal and temporary migration, often on a rural-rural channel as a way to diversify risk (Henry et al., 2003, 2004). Long-distance migration seems to be constrained by liquidity and access to credit to finance those expensive journeys. Migratory trends of Nigerian households are pushed in times of favorable climatic conditions, while the effect of adverse conditions interacts with a negative effect on income and traps populations at origin (Cattaneo and Massetti, 2019). Overall, micro-level studies focused on the African continent highlight the importance of considering the interplay of a variety of factors when it comes to the analysis of the role of environmental factors, defining the new path towards hybrid literature.

The single countries that receive singularly the most attention are Mexico, with 10 case studies, and the U.S., with 9 case studies. This should not be a surprise because of two reasons: firstly, the stock of Mexican emigrates has been constantly the highest in the world (in absolute terms) as well as the migratory flow between Mexico and the U.S. But there might also be a publication-related reason based on the fact that the vast majority of journals in our sample are U.S. based. Major findings support the relevance of environmental drivers (mainly precipitation shortage) on push factors from Mexico (Feng et al. (2010) estimates that a 10% reduction of agricultural productivity driven by scarce rainfall corresponds to the rise of 2% of emigrants).

Southern and Eastern Asia, representing by far the most disaster-prone area in the world[12] also provide a variety of heterogeneous scenarios. The case of Vietnam (Koubi et al., 2016;

[12] In 2019 the 40% of all natural hazards that occurred in the Planet happened in a Southern-Eastern Asian country.

Berlemann and Tran, 2020) shows how the Vietnamese population chooses different coping strategies in response to different kinds of environmental stressors. While gradual climatic variations lead to mechanisms of adaptation *in loco* to new climatic conditions, sudden shocks drive the decision to migrate elsewhere. However, mobility responses to different types of hazards might be different according to their specific consequences and duration (Berlemann and Tran, 2020). On the contrary, the case of Bangladesh supports the hypothesis that the existence of previous barriers of access to migration is worsened by the occurrence of disasters, specifically in the face of recurrent and intense flooding (Gray and Mueller, 2012b).

The specific case of earthquakes across the world (El Salvador in Halliday (2006), Japan in Kawawaki (2018) and Indonesia in Gignoux and Menéndez (2016) for instance) shows a common trend of outcomes: highly disruptive disasters such as earthquakes tend to decrease mobility from the hit area. An interesting mechanism to explain this common trend found in three very different contexts is given by, not only the already mentioned financial constraints but also the possibility of higher local employment opportunities due to post-disaster reconstruction (Gignoux and Menéndez, 2016; Halliday, 2006). Moreover, households are found to respond to hazard by using labor force as a buffer to the damages and redistributing labor within the household, with female mobility drastically dropping more than males and being substituted with increased hours of domestic labor (Halliday, 2012).

Analyses on South American countries also contribute to giving a hint of the complexity of the phenomenon. Thiede et al. (2016) show how internal migration is indeed impacted by rising temperature when considering the general effect; however, it hides an extreme heterogeneity of outcomes when specific characteristics of the areas and individuals are taken into account, resulting in a non-uniform effect.

An evident gap in the literature emerges in Figure 4: European countries have rarely been the object of study of the impact of environmental factors on mobility. This might be motivated by the fact that the European continent is mostly seen as a destination for migrants than an origin. It should not surprise that the two articles covering European countries, namely Italy (Spitzer et al., 2020) and the Netherlands (Jennings and Gray, 2015) analyze historical data of mobility at the beginning of the XX century (respectively earthquake in Sicily and Calabria and climate variability associated with riverine flooding in the Netherlands). Nevertheless, figures show that Europe is not unrelated to the occurrence and frequency of hazards as well as to sizable internal mobility that should receive some attention.

3 The inter-connectivity of papers

Our quantitative approach aims at analyzing the connectivity that exists among papers according to a citation-based approach and detecting the existence of communities or clusters. Since our target literature is characterized by a high heterogeneity of results, both in the direction and magnitude of the impact, we try to investigate the existence of potential specific patterns that lead to a certain type of analysis, methodology, or result under network-analysis lenses. We then use all information from this section to implement the meta-analysis.

3.1 Bibliographic coupling and citation-based approaches

The citation-based approach we choose is called bibliographic coupling[13]. Two scientific papers "bear a meaningful relation to each other when they have one or more references in common". Thus, the fundamentals of the link between two papers are depicted by the number of shared papers they both include in their references, which constitute the strength of the connectivity they have. In other words, a reference that is cited by two papers constitutes a "unit of coupling between them" (Kessler, 1963a). Two articles are then said bibliographically coupled if at least one cited source appears in both articles (Aria and Cuccurullo, 2017). Bibliographic coupling is increasingly becoming widely used in citation analysis, thanks to some specific advantages (and despite some disadvantages). Conceptually, through the linkages established, it gives a representation of the basic literature of reference and, incidentally, implies a relation between two papers that reveals a potential common intellectual or methodological approach (Weinberg, 1974). The constancy of the links between the papers over time, being based on cited references which, once published and indexed, is also an asset (Thijs et al., 2015). Most importantly, bibliographic coupling is more suitable for recent literature than other citation-based approaches. For reasons of timing and extension of the time window[14], using any other citation-based approach would have resulted in a very sparse matrix and created many isolated observations which would not be inter-connected for reasons other than conceptual, but just for the fact that they could not have been cited yet. Not only do the characteristics of our sample motivate the choice of the approach: keeping in mind that this stage of the analysis aims to investigate and map current research fronts in the target literature rather than to look at historical links or the evolution of school of thoughts, bibliographic coupling seems to be the best tool to capture them (Klavans and Boyack, 2017).

To obtain the network of bibliographically coupled papers, we initially extract the list of cited references from each article and build a bipartite network, a rectangular binary matrix $\mathbf{A}$ linking each paper in the sample to their reference (Aria and Cuccurullo, 2017):

$$\mathbf{A} = Paper \times References \tag{1}$$

The matrix $\mathbf{A}$ is composed of 151 rows i representing the papers belonging to the sample and 5.433 columns j representing the ensemble of references cited in each paper in the sample. Each element a_{ij} of the matrix equals 1 when paper i cites paper j in its bibliography; a_{ij} is equal to 0 otherwise. Starting from matrix $\mathbf{A}$, we can derive the bibliographic coupling network $\mathbf{B}$ as

[13] Bibliographic coupling has been first introduced by (Kessler, 1963b,a). It belongs to the broader class of citation-based approaches to science mapping. Other common approaches are co-citation analysis (Small, 1973) and direct citation (Boyack and Klavans, 2010). Co-citation is based on the relationship established by citing authors of a paper: two papers are linked whenever they jointly appear in the cited references of at least a third paper. Small (1973) intended this approach to establish a measure of "the degree of relationship or association between papers as perceived by the population of citing authors". Co-citation analysis has been prominently adopted since the 1970s, especially for its ability to capture shifts in paradigms and schools of thought over time, for sample of papers covering a period of time long enough to let the literature evolve and change direction. Direct citation is the most intuitive approach, linking two papers if one has cited a precedent one. As well as co-citation, direct citation performs better for long time windows to visualize historical connections (Klavans and Boyack, 2017). In terms of accuracy, it has been established that direct citation provides a more accurate representation of the taxonomy of scientific production (Klavans and Boyack, 2017), but for the specific requirements the methodology imposes, it has not gained much success (Boyack and Klavans, 2010).

[14] Our sampled literature starts in 2003 and ends at the moment the research has been done (November 2020), testifying the recent interest of economic literature on the topic

follows:

$$\mathbf{B} = \mathbf{A} \times \mathbf{A^T} \tag{2}$$

where $\mathbf{A}$ is the cited reference bipartite network and $\mathbf{A^T}$ is its transpose. $\mathbf{B}$ is a symmetrical square matrix 151 × 151, where rows and columns are papers included in the sample. Element b_{ij} of matrix $\mathbf{B}$ contains the number of cited articles that paper i and paper j have in common. By construction, the main diagonal will contain the number of references included in each paper (as element a_{ii} defines the number of references that a paper has in common with itself).

The resulting matrix displays an undirected weighted network in which the 151 vertices are the set of papers included in our sample and the edges represent the citation ties between them. An existing tie implies that common reference literature exists between vertex i and j. When two nodes are not linked, the corresponding value of their tie is zero, as they do not share any common reference. Therefore, the network is weighted with the strength of the connections between papers i and j being measured by the weights associated with each tie. To avoid loops, which would be meaningless for our investigation[15], we set the main diagonal to zero. Few ties exceed 20 shared cited references, with a maximum value of 48[16]. It can be argued that the number of references included in an article is not neutral to the resulting tie with any other article. Measuring the correct relatedness of nodes is of primary importance to produce an accurate mapping of literature (Klavans and Boyack, 2006). Citation behaviors of authors may interfere with the observation of core reference literature at the basis of coupled nodes. An author may opt for an extensive approach of citations and include a consistent number of references to display some particular links or details of a paper; authors may also decide for a less inclusive approach and include just essential cited references in the list. In other words, the number of included references in one article may dissolve meaningful information about the ties. Furthermore, specific formats or types of articles lead to broader or narrower bibliographies[17]. To address these concerns, a process of normalization is needed so that data can be corrected for differences in the total number of references. Bibliometric literature has dealt with this issue through the calculation of different *similarity measures*. An accurate overview of the possible measures of similarity is provided in van Eck and Waltman (2009). Overall, such indices aim to determine the similarity between two units according to their co-occurrence (value of association between them, which in our case, is the number of common references in the bibliography) adjusted in different ways for the number of total occurrences of the single units. However, despite the need to correct data for many purposes in citation-based networks and obtain a size-independent measure of association, there is no consensus on which measure is the most appropriate (van Eck and Waltman, 2009): tests of accuracy and coverage proposed by different authors have reached different conclusions (Klavans and Boyack, 2006; van Eck and Waltman, 2009; Sternitzke and Bergmann, 2009). We apply a simple ratio between the observed

[15] It is trivial to observe the value of ties that link a paper with itself, which naturally corresponds to the number of listed references

[16] This number seems very high, but at a closer look, the two papers that register the highest value are two consecutive papers published by the same author (Naudé, 2008, 2010)

[17] For example, a survey of the literature is expected to include a large number of citations, corresponding to the extent of reviewed contributions. Not surprisingly, the highest number of cited references can be found in reviews such as Berlemann and Steinhardt (2017); Bardsley (2014); Castells-Quintana et al. (2018); Auffhammer and Kahn (2018); Millock (2015), including more than a hundred cited references each. On the contrary, articles published in journals in the format of *letters* (i.e. *Economics Letters, Applied Economic Letters*) tend to have an extremely limited number of cited references (for example Ouattara and Strobl (2014) and Khamis and Li (2020) include only 8 and 13 references respectively)

number of commonly shared references and the product of the number of cited references in each of the two coupled papers. It has been defined as a measure of *association strength* (van Eck and Waltman, 2009) and it can be expressed as:

$$b_{ij}^n = \frac{b_{ij}}{b_{ii} b_{jj}} \tag{3}$$

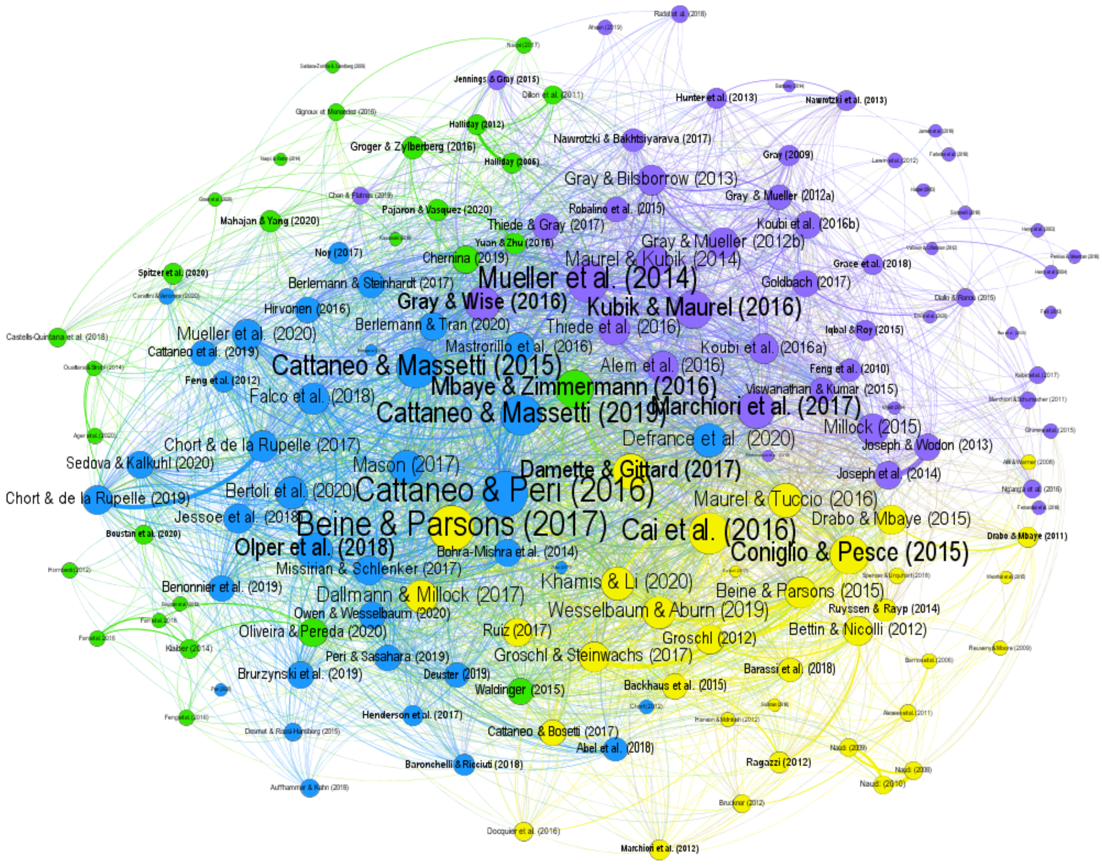
where b_{ij} corresponds to the weights of the tie between i and j in the original bibliographic coupling network; b_{ii} and b_{jj} are respectively the number of cited references included in paper i's bibliography and in paper j's bibliography, which corresponds to the original value on the diagonal. The obtained weighted network will serve to detect communities of papers through their common references and investigate if referring to a certain (group of) paper(s) creates meaningful clusters of items aggregating around certain common characteristics.

3.2 Community Detection

We intend to identify the existence of communities in our network. The assumption is that papers citing the same references aggregate into a group that shares certain features, which could be methodological approach, level of analysis, specific sub-topics of the literature, and outcomes. The extreme heterogeneity of outcomes in this specific literature may be motivated partially by the heterogeneity of the events themselves (type of environmental factor, type of mobility, preexisting conditions in the specific area) or the theoretical and empirical modeling; it may also be motivated by other factors, that can be traced in some patterns linked to the characteristics of single publications. The procedure of community detection is aimed at investigating which are the "forces" that aggregate or disperse papers with each other, primarily through the direct observation of main characteristics, and then running separate MAs on each cluster. Community detection in the bibliographic network is often made through Louvain community detection algorithm (Blondel et al., 2008). In this analysis, a community is thought of as a group of contributions that share common references and form strong common ties with each other, while others have less shared characteristics and structure. The algorithm can detect clusters of contributions with dense interaction with each other and sparse connections with the rest of the network.

The procedure identifies four main clusters. Our network being relatively small allows analyzing the main characteristics of each cluster. Following the full-text screening made in the first step of our threefold approach, we summarized some meaningful indicators about the analysis (such as type - quantitative, qualitative, theoretical, policy, literature review -, level - macro or micro for quantitative and qualitative studies -, unit - country, household, individual, territorial units), the object of the analysis (concerning the type of migration and environmental factors studied and the area) and theoretical and empirical approach (empirical approach and whether it is theory-based, estimation strategy and potential channel investigated). Finally, we recorded a synthetic indicator of the concluding effect of environmental factors on migration patterns: for each paper, we assigned the value "positive", "negative", "not significant" or a combination of the three (in case a paper contains multiple analysis of different migration or environmental factors that lead to different outcomes). Thanks to these indicators we were able to have a picture of the main common characteristics of the papers included in a cluster (Table 3), which will be tested and eventually confirmed in the meta-analysis.

Figure 5: Bibliographic Coupling Network and detected communities



Note: Bibliographic coupling network of 151 documents included in the sample obtained from Scopus, Web of Science, Google Scholar, IDEAS RePEc and previous meta-analyses (Hoffmann et al., 2020; Beine and Jeusette, 2019). Each node represents a paper included in our sample and its size corresponds to its weighted degree. Nodes are tied by links whenever two nodes shares at least one common reference. The thickness of links is given by the association strength of the tie between two nodes (to provide a clear visualization, only nodes with weights higher than the mean are displayed). Colors correspond to communities of belonging of each paper: Cluster 1 is represented in violet, Cluster 2 in green, Cluster 3 in blue and Cluster 4 in yellow. The description of each Cluster is presented below.

The first cluster (Cluster 1) is the most populated (see Table 3), counting 51 papers spanning for the entire period considered (from 2003 to 2020). In terms of type of analysis, it contains the largest variety: as in all clusters, quantitative studies represents the majority (as they are the 76% of the full sample), but this cluster contains also most of the qualitative analyses (10 out of 13) and policy papers (5 out of 7) of the full sample. Published papers are predominant (47 out of 50). Except for few papers, the analysis is mainly carried from a micro perspective, with individuals as units of analysis, based on surveys. Interestingly, most of the micro-level studies included in Beine and Jeusette (2019) can be found in this cluster. Authorship is very concentrated around two main authors, Clark Gray, (co-)authoring 9 papers, and Valerie Mueller, (co-)authoring 4 papers. Many of their co-authors appear in this community, which indeed scores the highest collaboration index of all communities (2.86), much higher than the full sample (2.16). Another important feature is that Cluster 1 includes the micro-level papers with

Table 3: Comparative information about clusters

	Cluster 1	Cluster 2	Cluster 3	Cluster 4
Size	51	28	37	35
included in MA	27	17	21	32
Published	47	24	21	27
Time-span	2003-20	2006-20	2011-20	2006-20
Average citations per document	34.84	18.96	10.89	24.91
Type of paper				
Policy	5	0	0	2
Qualitative	10	1	1	1
Quantitative	32	22	30	32
Review	2	5	4	0
Theoretical	2	0	2	0
Level of analysis				
Macro	4	1	12	30
Micro	39	22	21	4
Not Applicable	8	5	4	1
Unit of analysis				
Country	4	1	12	30
Household	12	5	5	0
Individual	20	7	9	0
Territorial	7	10	7	4
Not applicable	8	5	4	1
included in other MAs				
in Hoffmann et al. (2020)	2	1	4	23
in Beine and Jeusette (2019)	21	5	6	18
Migration				
Both	25	8	18	7
Cross-country	8	7	9	22
Internal (urbanization included)	18	13	10	6
Environmental Factors				
Both	12	2	7	13
Slow-onset events	32	6	26	11
Fast-onset events	7	19	4	11

Note: Sample of academic contributions about migration and environmental factors from Scopus, Web of Science, Google Scholar, IDEAS RePEc, and previous meta-analyses (Hoffmann et al., 2020; Beine and Jeusette, 2019) collected, merged, screened and included by the authors.

the highest global citations (see Table 2): Gray and Mueller (2012b), Feng et al. (2010), Gray and Mueller (2012a), Mueller et al. (2014), Henry et al. (2004), Henry et al. (2003) and Gray (2009). This is also shown by the fact that the number of average citations per document is the highest among all clusters (34.84). Journals are also quite concentrated around a few of them, World Development and Population and Environment mainly. The content of the analyses is mainly focused on climatic change exclusively (precipitation and temperature), while few studies include also natural disasters. All corridors of migration are investigated, with no specific predominance of internal or international migration (which is a characteristic of individual-level studies, mainly based on surveys). Even though the majority of outcomes shows a positive coefficient, that can be translated in finding an active role of environmental factors in pushing migrants out of their origin areas, it is not consensual to every paper: variation among results is high compared to other clusters, most paper finding complex relations between the two phenomena and different directions according to different dimensions. Empirical strategies are often based on discrete-time event history models estimated through multinomial logit. This reflects the approach of the main authors included in this community. A strong accent is put on the importance of the agricultural channel and the thematic of adaptation to the change in environmental conditions.

The second community (Cluster 2) counts 28 papers, mostly published, except for 4 of them (see Table 3). It is composed by mostly quantitative papers, accompanied by 5 literature reviews.

As in the previous cluster, most studies are at a micro level, with all kind of units of analysis and aggregations. Both patterns of migration are explored, but with special attention to urbanization and internal mobility. Contrarily, it seems to put a stronger accent on natural disasters rather than on slow-onset events. The majority of papers in Cluster 2 have been excluded from Beine and Jeusette (2019) (only 5 included, compared to the 21 in Cluster 1) and Hoffmann et al. (2020) (only 1, all others being in Cluster 4). All papers analyzing the impact of different kinds of natural disasters in the U.S. are included in this cluster. Empirical approaches such as the differences-in-difference model and instrumental variable are often used. The papers explore a large variety of potential channels and mechanisms of transmission of the impact of environmental factors on migration (income, agriculture, employment, liquidity constraints), and only in a few cases, a negative direction is found.

The third cluster (Cluster 3) includes the most recent papers: only one paper dates 2011, all other ones are published or issued after 2015 (Table 3). This is part of the reasons why the average citations per document in this cluster is the lowest (10.89) compared to any other cluster. Half of the overall unpublished papers are included in this cluster. In terms of kind of analysis, this cluster appears to be very heterogeneous: even if the micro-level analysis is the majority, 12 papers apply a macro-level analysis on countries. Both cross-country and internal migration are considered, but the majority of them investigate the impact of slow-onset events rather than fast-onset. Many of the analyses are theory-based, especially on classic economic migration theories (Roy-Borjas model, New Economics of Labor Migration), or general or partial equilibrium models. This cluster is also peculiar for the heterogeneity of empirical outcomes, which are often multiple for a single paper: outcomes vary according to the different channels explored, i.e. different levels of agricultural dependency, presence of international aids, level of income. In many cases, environmental factors have been found to be an obstacle to the decision to migrate from an area, or completely neutral. Comparatively, outcomes from this cluster tend to show a complex picture and highlight the many dimensions that may intervene in determining the direction of the impact.

Contrarily to the previous one, Cluster 4 is extremely homogeneous (see Table 3). It contains almost exclusively quantitative (32 out of 35) macro-level studies (30 out of 35). It covers equally slow- and fast-onset events and their impact on mobility. Most importantly, it aggregates 23 of the 30 papers reviewed in Hoffmann et al. (2020), making this cluster very representative and comparable to Hoffmann et al. (2020)'s meta-analysis. Additionally, this community appears to be solid also in terms of theoretical and empirical approach, as micro-founded gravity or pseudo-gravity models are widely used in it (more than half of them uses such models). None of the studies find a negative impact of environmental factors on migration, they mainly estimate positive and significant outcomes, with few not-significant results for specific cases. The most locally cited macro papers are included in this cluster (see Table 2), which also receive high global citations with an average of citations per document of 24.91 (even though lower than Cluster 1).

This description of clusters composition serves as a preliminary investigation of which are the main characteristics linking papers together through their citation behavior. It emerges that stronger links are given by diverse indicators varying across clusters. To test which are the sources of heterogeneity between clusters that aggregate papers within a cluster and their impact on the estimated effect size, in the next section we will use this partitioning to run four separate MAs and compare the conclusions.

4 Meta-analysis

The purpose of our MA is to summarize the results of collected studies and, at the same time, highlight any possible sources of heterogeneity. The analysis is based on four assumptions: (i) our parameter of interest, which we call β, is the effect of climate change on migration; (ii) most researchers believe that β is greater than zero, and this is indeed true; (iii) the sign is not enough for decision-makers; (iv) this has attracted a large literature that has obtained a large number of estimates $\hat{b}$ of β. Each of the 96 selected papers contains one or more equations that estimate the migration effect due to environmental factors. In addition to the characteristics specific to migration itself, the estimated impact on migration can also be distinguished according to different features of environmental factors. Since comparability among studies, and more specifically among estimated βs, is a crucial issue for the MA, we group all collected estimates and conduct two separate analyses according to the type of environmental phenomenon: gradual or slow-onset events and sudden or fast-onset events. To compare the estimates and correctly interpret the synthetic results we need to standardize all collected effect sizes β in a common metric. In this MA the estimates from separate, but similar studies, are converted in partial correlation coefficients (*pcc*):

$$pcc_i = \frac{t_i}{\sqrt{t_i^2 + df_i}}, \tag{4}$$

and its standard error, se_i:

$$se_i = \sqrt{\frac{(1 - pcc_i^2)}{df_i}}. \tag{5}$$

where t_i and df_i are the t-value and the degrees of freedom of the i-th estimate β_i. The *pcc* is commonly used in meta-analysis literature (Doucouliagos, 2005; Stanley and Doucouliagos, 2012; Doucouliagos and Ulubasoglu, 2006; Brada et al., 2021) and allows to analyze within a single framework all available studies on the effects of environmental stressors on migration regardless of the specification or measure of migration used[18]. Summarizing all the different estimates together in a single coefficient raises the question of heterogeneity within the same study and between studies. The summary effect is calculated as follow:

$$\hat{\beta} = \frac{\sum_i^N \hat{b}_i w_i}{\sum_i^N w_i}, \tag{6}$$

where $\hat{b}_i$ are the individual estimates of the effect and weights, w_i, are equal to $(1/se_i^2)$ or $(1/(se_i^2 + \hat{\tau}^2))$ according to the fixed effects model (FEM) and a random-effects model (REM), respectively. The FEM is based on the assumption that the collected effect sizes are homogeneous (the differences observed among the studies are likely due to chance). The REM takes into

[18] The major criticism of the use of the partial correlation is that its distribution is truncated at +1 and -1 and, in some cases, such truncation might cause an asymmetry. (Stanley et al., 2018) suggest as an alternative measure the Fisher's z-transformed correlation effect size. We compute and use it for a robustness check, results do not change sensitively. They are available from the authors upon request.

Table 4: Basic meta-analysis (Fixed and Random effect MA)

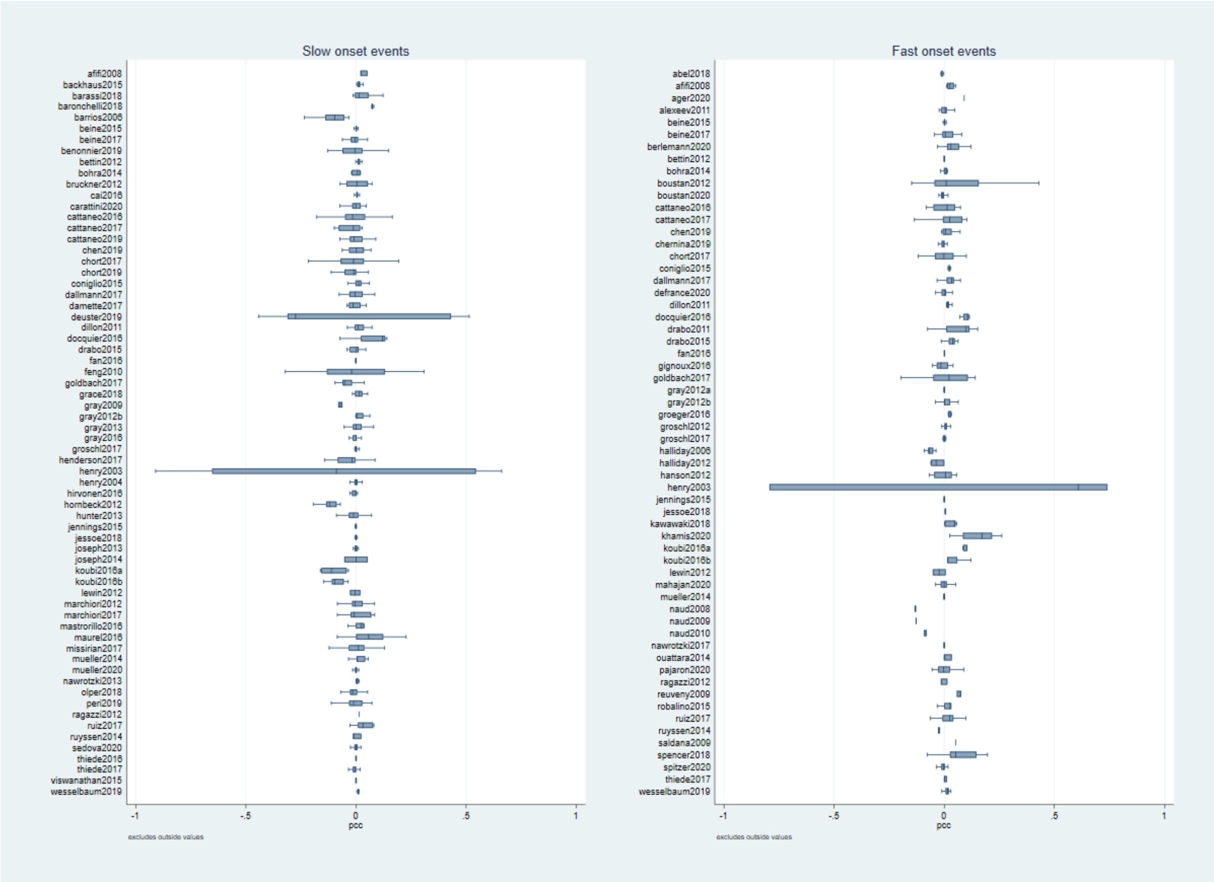
	(1) Model	(2) Averages	(3) Lower bound 95% CI	(4) Upper bound 95% CI	(5) I^2	(6) Q-test p-value	(7) N. of Obs. (N. of studies)
Slow onset effect	FEM	0.0001***	0.0001	0.0001	86.78	0.00	3897
	REM	0.0006	-0.0010	0.0022	99.93	0.00	(66)
- Cluster 1	FEM	0.0001***	0.0000	0.0001	83.15	0.00	932
	REM	-0.0025**	-0.0048	-0.0002	99.97	0.00	(23)
- Cluster 2	FEM	0.0003	-0.0001	0.0008	95.32	0.00	100
	REM	0.0068	-0.0051	0.0186	99.84	0.00	(3)
- Cluster 3	FEM	-0.0037***	-0.0042	-0.0032	77.58	0.00	1814
	REM	-0.0039***	-0.0063	-0.0014	93.58	0.00	(18)
- Cluster 4	FEM	0.0060***	0.0057	0.0064	88.44	0.00	1051
	REM	0.0082***	0.0064	0.0101	94.96	0.00	(22)
Fast onset effect	FEM	0.0021***	0.0018	0.0024	91.42	0.00	2032
	REM	0.0085***	0.0062	0.0107	97.76	0.00	(60)
- Cluster 1	FEM	0.0022***	0.0013	0.0032	86.50	0.00	176
	REM	0.0140***	0.0037	0.0243	98.98	0.00	(13)
- Cluster 2	FEM	-0.0021***	-0.0027	-0.0014	85.84	0.00	789
	REM	-0.0033	-0.0095	0.0029	98.77	0.00	(16)
- Cluster 3	FEM	-0.0004	-0.0009	0.0002	80.19	0.00	409
	REM	0.0028***	0.0008	0.0049	89.04	0.00	(7)
- Cluster 4	FEM	0.0071***	0.0066	0.0077	96.11	0.00	688
	REM	0.0224***	0.0170	0.0278	98.94	0.00	(24)

Note: Basic meta-analysis of collected estimates. Fixed Effect Model and Random Effect Model are reported for overall slow- and fast-onset samples and sub-samples defined by clusters. Averages (2), lower (3) and upper (4) bound of 95% confidence interval. I^2 and Q-test for heterogeneity reported in Columns (4-5); * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

account the heterogeneity among studies and weights incorporate a "between-study heterogeneity", $\hat{\tau}^2$. In the presence of heterogeneity the two models likely find very different results, and it may not be appropriate to combine results. A test of homogeneity of the β_i is provided by referring to the statistic Q to a χ^2-distribution with n - 1 degrees of freedom (Higgins and Thompson, 2002): if the test is higher than the degrees of freedom, the null hypothesis is rejected (and thus there is heterogeneity). Another test commonly used is the I^2 inconsistency index by Higgins and Thompson (2002) describing the percentage of the variability of the estimated effect that is referable to heterogeneity rather than to chance (sample variability). It is interpreted as the proportion of variability due to heterogeneity between studies rather than sampling error. Values range from 0 percent to 100 percent where zero indicates no observed heterogeneity. The results of meta-synthesis of the collected estimates (Table 4) are statistically significant, except for findings of the slow onset effect of paper included in Cluster 2, in which both FEM and REM give statistically insignificant averages. Considering the high heterogeneity in our sample of estimates (see columns 5-6), we should look at the more appropriate random effects results.

The preliminary result of the basic MA is that environmental factors seem to influence migration positively, even if the magnitude is very small and the REM mean is statistically significant only in the case of the fast-onset events. The mean effect by cluster becomes negative in the case of estimates of slow-onset events in Clusters 1 and 3 and for the estimates of fast-onset events in Cluster 2. For a graphical inspection, Figure 6 shows a box plot of the estimates reported in the primary studies; the heterogeneity both between and within studies is substantial.

Figure 6: Box plot of Partial Correlation Coefficients



Note: Box plot of partial correlation coefficients. Panel (1) reports PCC for slow-onset events by study. Panel (2) reports PCC for fast-onset events. PCCs are calculated on coefficients reported in each study included in the sample obtained from Scopus, Web of Science, Google Scholar, IDEAS RePEc, and previous meta-analyses (Hoffmann et al., 2020; Beine and Jeusette, 2019) and coded by the authors.

4.1 Meta-Regression tests of publication selection bias

Different findings of the same phenomenon can be explained in terms of heterogeneity of studies' features, however, the literature also tends to follow the direction consistent with the theoretical predictions causing the so-called publication bias[19]. Meta-regression tests, as the funnel asymmetry test (FAT), allows for an objective assessment of publication bias:

$$pcc_i = \beta_0 + \beta_1 se_i + \epsilon_i \tag{7}$$

Weighted least squares (WLS) corrects the previous equation for heteroskedasticity (Stanley and Doucouliagos, 2017) and it can be obtained dividing by the standard errors:

$$t_i = \frac{pcc_i}{se_i} = \beta_1 + \beta_0 \frac{1}{se_i} + \epsilon_i \tag{8}$$

[19] The publication bias occurs when (i) researchers, referees, or editors prefer statistically significant results and (ii) it is easier to publish results that are consistent with a given theory. However, the consequences of the peer-review process refer more to a general "publication impact" rather than a "bias" (Cipollina and Salvatici, 2010).

Results are used to test for the presence of publication selection ($H_0 : \beta_1 = 0$) or a genuine effect beyond publication selection bias ($H_0 : \beta_0 = 0$). According to the funnel asymmetry–precision estimate test (FAT-PET), in the absence of publication selection the magnitude of the reported effect will vary randomly around the "true" value, β_1, independently of its standard error (Stanley and Doucouliagos, 2012). The use of the variance se_i^2, instead of the standard error, as precision of the estimate gives a better estimate of the size of the genuine effect corrected for publication bias (Stanley and Doucouliagos, 2014). This model is called "precision-effect estimate with standard error" (PEESE) and the WLS version is :

$$t_i = \frac{ppc_i}{se_i} = \beta_1 se_i + \beta_0 \frac{1}{se_i} + \xi_i \tag{9}$$

To take into account the issue of the dependence of study results, when multiple estimates are collected in the same study, the errors of meta-regressions are corrected with the "robust with cluster" option, which adjusts the standard errors for intra-study correlation. Table 5 shows the FAT-PET and PEESE results. We explore publication bias by implementing a full comparison of the FAT-PET and PEESE, through multiple methods for sensitivity analysis and to ensure the robustness of findings. Column (1) of table 5 presents the FAT-PET coefficients, column (2) shows the results of the WLS model to deal with heteroskedasticity, columns (3) and (4) present the results of the panel-random effect model (REM) and multilevel mixed-effect model that treats the dataset as a panel or a multilevel structure.

Table 5: FAT-PET MR model and PEESE correction of publication selection

		(1) WLS	(2) REM	(3) Multilevel Mixed Effect	(4) N. of Obs.
Slow-onset events	Standard Error (FAT): $\hat{\beta}_1$	0.108 (0.144)	0.268 (0.204)	0.260 (0.208)	3897
	Constant (PET): $\hat{\beta}_0$	0.000* (0.000)	-0.000 (0.000)	-0.000 (0.000)	
	PEESE: $\hat{\beta}_0$	0.000** [0.000,0.000]	-0.005 [-0.013,0.003]	-0.004 [-0.011,0.003]	
- Cluster 1	Standard Error (FAT): $\hat{\beta}_1$	-0.337 (0.248)	-0.208 (0.417)	-0.213 (0.407)	932
	Constant (PET): $\hat{\beta}_0$	0.000** (0.000)	0.000 (0.000)	0.000 (0.000)	
	PEESE: $\hat{\beta}_0$	0.000** [0.000,0.000]	-0.001 [-0.020,0.019]	0.004 [-0.017,0.025]	
- Cluster 2	Standard Error (FAT): $\hat{\beta}_1$	0.412 (0.446)	0.042 (0.482)	0.123 (0.488)	100
	Constant (PET): $\hat{\beta}_0$	-0.000 (0.000)	0.000 (0.000)	-0.000 (0.001)	
	PEESE: $\hat{\beta}_0$	0.000** [-0.001,0.002]	-0.001 [-0.019,0.017]	0.006 [-0.010,0.023]	
- Cluster 3	Standard Error (FAT): $\hat{\beta}_1$	0.001 (0.117)	0.825* (0.469)	0.797** (0.357)	1814
	Constant (PET): $\hat{\beta}_0$	-0.004 (0.003)	-0.011** (0.005)	-0.011*** (0.001)	
	PEESE: $\hat{\beta}_0$	-0.004 [-0.009,0.001]	-0.011** [-0.023,0.000]	0.010** [-0.018,-0.002]	

- Cluster 4	Standard Error (FAT): $\hat{\beta}_1$	0.439	0.461	0.460	
		(0.379)	(0.347)	(0.443)	
	Constant (PET): $\hat{\beta}_0$	0.004**	0.005**	0.005***	1051
		(0.001)	(0.002)	(0.002)	
	PEESE: $\hat{\beta}_0$	0.006**	-0.002	-0.002	
		[0.003,0.009]	[-0.021,0.016]	[-0.022,0.018]	
Fast-onset events	Standard Error (FAT): $\hat{\beta}_1$	0.532*	0.755**	0.755**	
		(0.274)	(0.334)	(0.309)	
	Constant (PET): $\hat{\beta}_0$	-0.001	0.001	0.001	2062
		(0.002)	(0.002)	(0.001)	
	PEESE: $\hat{\beta}_0$	0.001	0.012*	0.012*	
		[-0.002,0.005]	[-0.001,0.025]	[-0.000,0.025]	
- Cluster 1	Standard Error (FAT): $\hat{\beta}_1$	0.942**	1.314**	1.329**	
		(0.366)	(0.618)	(0.670)	176
	Constant (PET): $\hat{\beta}_0$	-0.002	-0.001	-0.001	
		(0.002)	(0.001)	(0.003)	
	PEESE: $\hat{\beta}_0$	0.002	-0.012*	0.011	
		[-0.001,0.004]	[-0.000,0.024]	[-0.007,0.030]	
- Cluster 2	Standard Error (FAT): $\hat{\beta}_1$	-0.381	0.095	0.151	
		(0.332)	(0.410)	(0.431)	
	Constant (PET): $\hat{\beta}_0$	-0.000	0.001	0.001	789
		(0.002)	(0.001)	(0.002)	
	PEESE: $\hat{\beta}_0$	-0.002	-0.004	-0.004	
		[-0.007,0.003]	[-0.011,0.003]	[-0.014,0.005]	
- Cluster 3	Standard Error (FAT): $\hat{\beta}_1$	0.283	0.293	0.294	
		(0.394)	(0.715)	(0.372)	
	Constant (PET): $\hat{\beta}_0$	-0.002	0.001	0.001	409
		(0.004)	(0.007)	(0.002)	
	PEESE: $\hat{\beta}_0$	-0.001	0.012**	0.012*	
		[-0.007,0.005]	[0.002,0.023]	[-0.001,0.025]	
- Cluster 4	Standard Error (FAT): $\hat{\beta}_1$	1.877**	1.134**	1.072	
		(0.703)	(0.480)	(0.774)	
	Constant (PET): $\hat{\beta}_0$	-0.003	0.003	0.003	688
		(0.004)	(0.005)	(0.004)	
	PEESE: $\hat{\beta}_0$	0.006**	0.046	0.047**	
		[0.001,0.010]	[-0.028,0.121]	[0.013,0.080]	

Note: FAT, PET and PEESE correction coefficients estimated with Weighted Least Squares (1), Random Effect Model (2) and Multilevel mixed effect model. Overall effect of slow- and fast-onset events reported, along with sub-samples defined by clusters. PCC precision square weights ($1/se_i^2$); robust standard errors clustered by study in parentheses; 95% confidence intervals in brackets; * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Looking at the estimates of the effect of climate change on migration, the FAT coefficients ($\hat{\beta}_1$) are not statistically significant, implying that there is no evidence of publication bias, while the positive and statistically significant PET coefficient ($\hat{\beta}_0$) indicates a genuinely positive slow-onset effect exists, in particular in the case of Cluster 4. Conversely, in the case of Cluster 3 the REM and multilevel mixed-effect model find that, even if in presence of publication bias, the impact on migration is negative. Table 5 provides evidence of publication bias in the literature focusing on the effect of natural disasters on migration. The estimated FAT coefficient is statistically significant in the overall sample, especially due to papers in clusters 1 and 3, and there is insufficient evidence of a genuinely positive effect (accept $H_0 : \hat{\beta}_0$). The PEESE results, however, suggest a significant and positive slow- and fast-onset effect on migration after correcting for publication bias. Our preliminary results between migration and slow- and fast-onset events are positive and significant (though very small in magnitude).

4.2 Multiple Meta-Regression Analysis: econometric results e discussion

We now turn to conditional regressions. The multiple meta-regression analysis (MRA) includes an encompassing set of controls for factors that can integrate and explain the diverse findings in the literature. To capture possible sources of bias among all analyses, we code all differences in the features of the various studies and regressions and include a set of dummies to control for them. Specifically, we code left- and right-hand side characteristics of regressions estimated in the collected papers and generate a set of dummies for paper features, dependent variables, independent variables, sample characteristics, regression characteristics[20].

The overall sample includes both unpublished and published papers, so we add some moderators variables describing different features of the studies that are published. In particular, we introduce a dummy for *Published articles* and a control for the quality of the journal in which the study is published by adding the variable *Publication Impact-factor*. In reporting the main results, some authors emphasize a benchmark regression that produces a preferred estimate, thus we add the dummy *preferred specification* equal to 1 when the reported effect size is obtained from the main specification. Concerning the measure of migration, the dependent variable in the left-hand side of the regression, original studies mainly distinguish migration by *corridor*, which are mainly two, internal and international migration. In this context, we distinguish also a special internal corridor, the one characterized by rural-urban mobility, to investigate the potential impact of an environmental variable on the urbanization process. Whenever the corridor is not specified, the variable is categorized as undefined (which will be the reference category in the estimation). Dependent variables differ also in terms of *measurement* of the phenomenon: specifically, we separate measures that express flows from those expressing stocks. The first category includes both studies that use flows (or an estimation of flows) and rates of migration. The second category captures those cases in which migration is measured as stock of migrants at the destination. The reference category is direct measures, which mainly captures whether migration has occurred or not (typically dummy variables used on survey-based samples equal to 1 when the individual migrates and 0 otherwise). We also include information about countries of origin and destination of migrants. *Origins* are categorized by macro-regions: Africa, Asia, Europe, Latin America and Caribbean, Middle East and North Africa and North America. The reference category is "world", identified whenever origin countries are not specified (typically in multi-country settings). *Destinations* are categorized by level of income. The choice of this categorization is led by the aim to identify differences in the possibility to choose a destination. Categories are divided into high, higher-middle, lower-middle and low income.

The specific object of the study is the impact of environmental variables on migration, thus on the right-hand side of the regression a proxy of the environmental change is included. Slow-onset events are typically defined as gradual modifications of temperature, precipitation and soil quality. Respectively, three dummies *temperature, precipitation* and *soil degradation* are created. Each of these phenomena is measured in different ways, and the use of a specific kind of measurement is relevant for the outcome. Both temperature and precipitation have been measured in levels (simple level or trend of temperature/precipitation); deviation, as the difference between levels and long-run averages; and anomalies, mostly calculated as the ratio of the difference between the level and the long-run mean and its standard deviation. Soil degradation includes events such as desertification, soil salinity, or erosion. Additionally, we

[20]The complete description of coded variables is available in Supplementary materials, section A.1

also code the time lag considered concerning the time units of the dependent variable: whenever the period considered corresponds to the same time-span as the dependent variable the lag is zero, while it takes values more than zero for any additional period before the dependent variable time-span. The second battery of coded variables refers to fast-onset events, which can be also defined as natural hazards or extreme events. The main classification of fast-onset events reflects the one reported in Section 2: *geophysical* (earthquakes, mass movements, volcanic eruptions), *meteorological* (extreme temperature, storms - cyclones, typhoons, hurricanes, tropical storms, tornadoes), *hydrological* (floods and landslides) and *climatological* (droughts or wildfires). Fast-onset events also differ in the way they are measured. Possible measures are: occurrence (when the measure is a dummy capturing if the disaster happened or not), frequency (the count of events occurred in the area), intensity (i.e. Richter scale for earthquakes, wind speed for tornadoes, etc.), duration (length of the occurrence of the event) and losses (when the disaster is measured in terms of the affected population, number of deaths or injured people, number of destroyed houses or financial value of the damaged goods). As for slow-onset events, we code a continuous variable capturing the time lag of the event concerning the dependent variable. A dummy capturing whether the coefficient refers to multiple disasters is also included.

Characteristics of the sample are one of the main sources of heterogeneity. The level of the analysis varies considerably from paper to paper, as we include both micro-and macro-level studies. we code variables capturing both the specific unit of analysis and the source of the data. Typically micro-level studies uses data coming from *censuses* or *surveys* where *households* or *individuals* are the units of analysis. *Country-level* studies usually take the source of their data from *official statistics*. Other kinds of sampling are included in the reference group (for example small territorial aggregates such as districts, provinces, or grid cells). We also code a variable capturing the time span of the analysis, subtracting the last year of observation from the first one. The role of econometric approaches may have an impact on resulting outcomes. Beine and Jeusette (2019) emphasized in their work the importance of methodological choices, with differentiated results depending on estimation techniques. First of all, we code a *panel* dummy to capture whether the structure of data and related estimation techniques has an impact. Furthermore, we distinguish *Poisson* estimations that include the Pseudo Poisson Maximum Likelihood (PPML) estimator and Negative Binomial Models; *linear* estimators, both Ordinary Least Squares (OLS), linear probability models and maximum likelihood models; conventional *Instrumental Variables* (IV) estimators, two-stage least squares (2SLS), and other cases of estimators as Generalized Method of Moments (GMM) used to control for endogeneity; and finally, *logit* which comprises multinomial logit models. Any other estimator (i.e. Tobit, panel VAR) are less frequent and grouped in a category *other estimators* used as the reference group.

Theoretically, the impact of environmental variables on migration may be mediated, channeled, or transmitted through other phenomena that can be controlled for or interacted with. Most of models investigating general migration determinants usually controls for several possible determinants to recover the effect of the specific objective variable, with all potential other factors being controlled for. The majority of these additional controls are suggested by theoretical models and then introduced in the empirical model. Furthermore, methodological approaches in our sample are found to often include interaction terms to specifically address the combined effect of an environmental variable with other potential factors. Thus, we introduce two groups of variables, *controls* and *interacted terms*, categorized both to capture factors or channels such as income, agriculture, conflicts, political stability, cultural or geographical factors, (a full description of the categories can be found in the Supplementary materials). Among the list of controls, we also include a dummy that captures whether both slow- and fast-onset events are included in the regression.

Table 6 shows the results of the multiple MRA on the literature in slow-onset events (precipitation, temperature and soil quality) in which potential biases are filtered out sequentially by the addition, in a stepwise manner, of statistically significant controls[21]. Column (1) presents results for the whole sample of studies estimating the impact of climatic variations on migration, columns (2) to (5) show the results of papers grouped by clusters to highlight how specific features characterizing the cluster influence the magnitude of the estimated effect. The results are unfolded below.

Table 6: MRA Results for slow-onset events

	(1) All	(2) Cluster 1	(3) Cluster 2	(4) Cluster 3	(5) Cluster 4
Constant (PET): $\hat{\beta}_0$	-0.011***	-1.040***	0.959***	-0.031***	0.102***
	(0.003)	(0.264)	(0.010)	(0.008)	(0.009)
Standard Error (FAT): $\hat{\beta}_1$	-0.205*	-4.939**	-29.959***	0.099	-0.671***
	(0.119)	(1.894)	(0.264)	(0.273)	(0.190)
Paper features					
- Preferred specification		-0.001**			
		(0.000)			
- Published article					-0.008***
					(0.002)
- Publication Impact-factor		0.024**			
		(0.009)			
Corridor					
- Internal	0.002***	0.002***		-0.009***	0.012**
	(0.001)	(0.000)		(0.002)	(0.005)
- International				-0.010***	
				(0.001)	
- Urbanisation	0.002***	0.002***			
	(0.001)	(0.000)			
Measurement					
- Flows	-0.016***	1.565***			
	(0.004)	(0.481)			
Region of origin					
- Asia	0.008**				
	(0.003)				
- Europe	0.033***	-0.332***			0.010***
	(0.004)	(0.083)			(0.002)
- LAC				0.096***	-0.012***
				(0.017)	(0.002)
- North America	-0.021***				
	(0.004)				
Destination					
- High income		-0.000*		-0.049***	
		(0.000)		(0.012)	
- Upper-middle income		-0.000***		-0.049***	
		(0.000)		(0.012)	
- Lower-middle income		0.000***		0.004***	
		(0.000)		(0.001)	
Precipitation measures					
- levels	-0.000**	0.000***	-0.924***	-0.007***	-0.002*

[21] Results of specifications that control for all moderator variables are available upon request.

	(1)	(2)	(3)	(4)	(5)
	(0.000)	(0.000)	(0.009)	(0.002)	(0.001)
- deviation		0.000***		-0.008**	
		(0.000)		(0.004)	
- anomaly		0.002**			
		(0.001)			
Time lag	-0.000***	-0.000***			
	(0.000)	(0.000)			
Temperature measures					
- levels		0.000***	-0.924***		
		(0.000)	(0.009)		
- deviation	0.000***	0.000***	-0.410***		
	(0.000)	(0.000)	(0.005)		
- anomaly		-0.005***		-0.012***	
		(0.001)		(0.001)	
Time lag	-0.000***	-0.000***	0.021***		
	(0.000)	(0.000)	(0.000)		
Soil Degradation		0.011***		-0.055***	
		(0.003)		(0.002)	
Sample features					
Time span	-0.000***			-0.002***	
	(0.000)			(0.000)	
Source of data					
- Census	0.016***	-0.331**		0.076***	-0.089***
	(0.002)	(0.140)		(0.012)	(0.005)
- Official statistics		0.397***			
		(0.096)			
- Research data	-0.007**	0.257**			
	(0.003)	(0.103)			
Unit of analysis					
- Household		1.256***		0.052***	
		(0.362)		(0.005)	
- Individual	-0.015***	1.051***			
	(0.004)	(0.287)			
- Country level	0.014***	-0.856**		0.079***	-0.098***
	(0.004)	(0.311)		(0.019)	(0.009)
Estimation:					
- Panel	0.019***	0.066**		0.042***	
	(0.004)	(0.024)		(0.006)	
- Poisson		-0.514**			
		(0.219)			
- OLS and ML	0.010***		-0.017***		0.011***
	(0.003)		(0.000)		(0.002)
- IV	0.041***				0.044***
	(0.011)				(0.011)
Controls:					
- Slow and fast included				-0.032***	
				(0.008)	
- Income	0.004***	0.170**	0.004***		
	(0.001)	(0.065)	(0.000)		
- Conflict		0.249***			
		(0.063)			
- Political stability		-0.130***			0.012***
		(0.040)			(0.002)
- Population	0.005**			0.031***	0.009***
	(0.002)			(0.008)	(0.002)
- Diaspora		-0.156**			
		(0.074)			
- Past migration		-0.090**	0.007***		
		(0.042)	(0.000)		
- Poverty		0.096**			-0.011***
		(0.039)			(0.002)
- Culture		0.436**			
		(0.173)			
- Agriculture	0.004***	-0.461**			
	(0.001)	(0.193)			
- Labour					

- Urban	-0.013***	0.265**		-0.016***	
	(0.002)	(0.111)		(0.004)	
- International aids	-0.025***			-0.036***	
	(0.008)			(0.003)	
Interacted terms (channels):					
- Agriculture			-0.055***		0.003*
			(0.000)		(0.001)
- International aid	0.023*			0.034***	
	(0.013)			(0.000)	
- Culture	-0.006***				-0.006***
	(0.001)				(0.002)
- Destination	0.012***				
	(0.002)				
- Poverty				-0.058***	
				(0.011)	
- Income and agriculture	0.029***			0.024***	
	(0.005)			(0.004)	
- Education	-0.000***	-0.000***			
	(0.000)	(0.000)			
- Environment	-0.000***	-0.000***		0.003*	
	(0.000)	(0.000)		(0.001)	
- Income		-0.003**		-0.018***	
		(0.001)		(0.004)	
- Origin	-0.000***	-0.000***		-0.046***	
	(0.000)	(0.000)		(0.005)	
- Past migration	-0.013***	-0.007***			
	(0.003)	(0.000)			
- Political stability	-0.037***				-0.047***
	(0.008)				(0.002)
- Population	-0.019***			-0.028***	
	(0.006)			(0.008)	
- Urban	0.011***			0.021***	
	(0.004)			(0.001	
PEESE Correction: β_0	-0.012***	-0.783***	0.655***	-0.030***	0.079***
	[-0.018,-0.006]	[-1.155,-0.411]	[0.582,0.729]	[-0.038,-0.022]	[0.062,0.097]
N. of Obs.	3897	932	100	1814	1051
N. of Studies	66	23	3	18	22

Note: Stepwise regression of overall sample (1) and sub-samples defined by clusters (2-5) for slow-onset events. Estimates shown represent significant coefficients obtained through a stepwise procedure (not reported when not significant). Controls are grouped by paper features, dependent variable, independent variable, sample and regression characteristics. PCC precision square weights ($1/se_i^2$); robust standard errors clustered by study in parentheses; 95% confidence intervals in brackets; * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Column (1) refers to the overall sample and shows a coefficient of the main variable of interest ($\hat{\beta}_0$) negative and statistically significant, implying that climatic variations may decrease incentives for migration by exacerbating credit constraints of potential migrants. Looking at results for different clusters (columns 2-5) such negative effect is generated by studies that are included in clusters 1 and 3. The MRA of papers in clusters 2 and 4, instead, gives positive and statistically significant PET coefficients ($\hat{\beta}_0$) implying that climate changes induce people to migrate. Concerning the FAT-test, the intercept ($\hat{\beta}_1$) might deviate from zero confirming the presence of publication bias: the peer-review process seems to particularly affect the magnitude of the estimated effect of studies in all clusters except for Cluster 3.

Most of the papers included in the MRA for slow-onset events are published (52 articles out of 66), indeed the estimated coefficients of controls for published articles are useful to evaluate if the peer-review process exerts some influence on reported results in the collected studies. In Cluster 3 estimates obtained by the *Preferred specification* tend to be slightly lower while articles published in journals with higher impact factors report lower estimates of the impact of slow-onset events on migration. In Cluster 4, instead, results of *Published articles* are lower, even if the mean effect of this group of studies remains positive.

From the other sets of controls emerges that specific features of studies included in the MRA differently explain the diversity in the results within clusters. The positive coefficients of controls for corridors such as *Internal* and *Urbanization* state that people respond to adverse climatic change with increased internal migration. The only exception is for studies included in Cluster 3, this is the most heterogeneous cluster of most recent papers, where heterogeneous approaches (micro-and macro-level and type of migration) lead to a large heterogeneity in outcomes, varying according to different channels explored. Findings obtained when mobility is measured by *Flows* seem to be lower in the overall sample. In macroeconomic literature, usually, the measurement of migration is a stock variable, since it is generally easier to find and measure the number of foreign citizens born or resident in a country at any given time. Data on flow variables and migration rates, or the number of people who have moved from an origin to a destination in a specific period, are less available, and analyses often rely on estimates and computations of this data. Therefore, the opposite sign of the coefficient of the variable *Flows* in Cluster 1 is not surprising since this cluster collects all micro-level studies (where the migration variable refers to movements of individuals as a unit, based on surveys).

Controls for how the climatic phenomenon is measured, *Precipitation measures* and *Temperature measures*, seem to differently affect the heterogeneity of results and, in many cases, the estimated coefficients are statistically significant but very close to zero.

The estimated coefficients of dummies for country groups included in our multiple MRA indicate how results from analyses focusing on specific regions of origin differ. In particular, positive coefficients of controls *Asia* and *Europe* support the idea that the results of analyses that focus on the migration from these regions are likely to be positive (with exception of Cluster 1), while if the people move from a country in the region of *North America* the impact of climate changes on migration is lower and can be negative. The climate impact on migration from *LAC* (Latin America and the Caribbean) countries are higher in Cluster 3 (where the PET coefficient is negative) and lower in Cluster 4 (where the PET coefficient is positive).

Regarding the heterogeneity produced by the fact that studies use different sources of data for migration, we add dummies for sources used. All estimated coefficients of this set of controls are statistically significant in Cluster 1: the use of different databases might influence the wide variety of findings. Effect sizes in Cluster 2, instead, are not affected by the source of data used.

Since it is natural to expect the adjustment of migratory flows in response to climate change is not instantaneous, especially in the case of gradual phenomena, most of the studies use a panel structure with macroeconomic focus and attempt to assess the impact of changes in climatic conditions on human migratory flows in the medium-long term. Microeconomic analyses mostly use cross-section data to explain causal relationships between specific features of individuals, collected through surveys and censuses, and various factors determining the migration by isolating the net effect of the environment. Analyses at *Individual* level tend to capture a more negative impact of climate changes on migration, whereas analyses at *Country* level tend to find a more positive effect. As already said, for micro-level analyses in Cluster 1 controls related to sample characteristics have opposite signs. Looking at dummies for the estimation techniques, our evidence suggests that the diversity in the effects sizes is in part explained by differences in techniques. In particular positive and significant coefficients are found for controls as *OLS and ML* estimators for cross-section analyses, same for panel studies that use *Panel* estimation techniques, and Instrumental Variables (*IV*) or GMM estimators to correct for endogeneity. Micro-economic analyses (Cluster 1) use more disaggregated data, while the high presence of zeros in the dependent variable is treated with a *Poisson* estimator, which tends to produce lower estimates.

Many authors highlight the importance of variables of political, economic, social and historical nature, in influencing the impact of climatic anomalies on migration processes, emphasizing the role of important channels of transmission of the environmental effect to migrations. We include in the multiple MRA a set of dummies for *Controls* included in the estimation of the model of migration and dummies for *Channels* through which the climatic event determines migration phenomena. The idea is that studies based on the same theoretical framework tend to include the same set of control variables or interacted terms and we find that many of these controls may positively and negatively affect the effect size of climate changes on migration.

Table 7 shows the results of the MRA for fast-onset events, or rather natural disasters, more or less related to climate change, which appear as destructive shocks of limited duration and for which the ability to predict is reduced.

Table 7: MRA Results for fast-onset events

	(1) All	(2) Cluster 1	(3) Cluster 2	(4) Cluster 3	(5) Cluster 4
Constant (PET): $\hat{\beta}_0$	0.044**	-0.127***	3.147***	-0.508***	0.419***
	(0.021)	(0.032)	(0.091)	(0.038)	(0.030)
Standard Error (FAT): $\hat{\beta}_1$	0.997***	-1.506	-0.097	6.410***	1.070
	(0.279)	(1.399)	(0.116)	(0.961)	(0.783)
Paper features					
- Preferred specification				0.001***	
				(0.000)	
- Published articles		0.145***	0.936***		
		(0.004)	(0.056)		
- Publication Impact-factor	0.002**	0.015***	-0.475***		0.048*
	(0.001)	(0.004)	(0.007)		(0.026)
Corridor					
- Internal				0.043***	-0.021**
				(0.005)	(0.008)
- International			0.004***	0.041***	
			(0.001)	(0.005)	
- Urbanization			0.003***		
			(0.000)		
Measurement					
- Flows		0.322***	-3.199***	-0.240***	-0.355***

		(0.027)	(0.296)	(0.042)	(0.072)
- Stock			-0.087***		-0.357***
			(0.012)		(0.071)
Region of Origin					
- Africa	-0.015**	-0.003**	0.346***	0.212***	
	(0.007)	(0.001)	(0.106)	(0.044)	
- Asia			-0.773***		
			(0.145)		
- Europe		-0.340**	2.114***		
		(0.156)	(0.313)		
- LAC		-0.034***	0.974**	0.030***	
		(0.002)	(0.380)	(0.001)	
- North America	-0.023**		1.827***		
	(0.009)		(0.332)		
Destination					
- High income			-4.148***		-0.003*
			(0.181)		(0.002)
- Upper-middle income				-0.003*	
				(0.001)	
- Lower-middle income		-0.002***	-0.002***	0.021***	-0.020***
		(0.000)	(0.000)	(0.000)	(0.004)
Type of event					
- Geophysical			-0.054***	-0.107***	
			(0.002)	(0.006)	
- Meteorological	0.004**		-0.063***	-0.146***	
	(0.002)		(0.006)	(0.006)	
- Hydrogeological	0.005**	0.006**	-0.054***	-0.109***	0.006**
	(0.002)	(0.002)	(0.002)	(0.006)	(0.003)
- Climatological			-0.065***	-0.077***	
			(0.006)	(0.006)	
Time lag			0.002***		
			(0.000)		
Measurement					
- Frequency		0.031***	-0.023***	0.556***	
		(0.000)	(0.000)	(0.026)	
- Intensity			1.137***	0.493***	
			(0.265)	(0.026)	
- Occurrence			0.024***	0.474***	
			(0.000)	(0.009)	
- Duration		0.368***		0.584***	
		(0.057)		(0.029)	
Sample					
Time span	0.000*	0.014***	0.030***	-0.001*	
	(0.000)	(0.003)	(0.005)	(0.000)	
Source of data					
- Census			-0.005***		
			(0.000)		
- Official statistics		-0.127**	0.002***		0.152*
		(0.044)	(0.000)		(0.085)
- Research data					
- Survey			-3.360***		
			(0.052)		
Unit of analysis					
- Household		-0.197***	-0.910***	0.757***	
		(0.064)	(0.027)	(0.067)	
- Individual			0.121***		
			(0.032)		
- Country level					-0.230*
					(0.116)
Estimation					
- Panel	-0.034***	-0.621***	0.788***		-0.116*
	(0.011)	(0.103)	(0.059)		(0.059)
- Poisson				-0.003***	0.058***
				(0.000)	(0.010)
- OLS and ML	-0.027**	-0.037***			0.036***

	(0.012)	(0.003)			(0.011)
- IV	-0.066***	-0.037***	0.830***		0.058*
	(0.019)	(0.003)	(0.043)		(0.031)
- Logit	-0.023*				
	(0.012)				
Controls					
- Slow and fast included	-0.016*				
	(0.009)				
- Income			0.008***	-0.009***	0.094*
			(0.000)	(0.000)	(0.049)
- Conflict	0.018***				-0.061*
	(0.005)				(0.033)
- Political stability	0.017***	0.029***	0.002***		0.097*
	(0.005)	(0.001)	(0.000)		(0.048)
- Population		0.394***	0.001*	0.008***	-0.036**
		(0.076)	(0.001)	(0.000)	(0.017)
- Diaspora	-0.028***	-0.296***	-0.043***		
	(0.010)	(0.024)	(0.001)		
- Past migration					-0.127***
					(0.037)
- Poverty	-0.015**	-0.032**	-0.001***		
	(0.006)	(0.014)	(0.000)		
- Geography		-0.095***	-0.006***		
		(0.021)	(0.000)		
- Agriculture			0.002*	0.008***	
			(0.001)	(0.001)	
- Labor					-0.084*
					(0.047)
- Urban				-0.016***	
				(0.000)	
- International aids			-0.001***	-0.030***	0.107**
			(0.000)	(0.004)	(0.047)
Interacted terms (channels)					
- Agriculture	0.005**		0.007***	-0.005***	-0.027***
	(0.002)		(0.002)	(0.001)	(0.004)
- International aid	-0.031***				-0.039***
	(0.005)				(0.001)
- Culture	0.019**	0.015***			0.026***
	(0.008)	(0.001)			(0.004)
- Destination		-0.023*			
		(0.011)			
- Diaspora			0.004**		
			(0.001)		
- Poverty			0.004***	0.008***	
			(0.001)	(0.000)	
- Education		0.034***			
		(0.001)			
- Environment				0.015***	
				(0.000)	
- Geography			0.025***		
			(0.001)		
- Income		-0.005***	0.010***		-0.014***
		(0.000)	(0.001)		(0.001)
- Past migration	0.016***	0.014***	0.020***		
	(0.006)	(0.001)	(0.000)		
- Political stability	-0.013***		-0.000***		
	(0.004)		(0.000)		
- Urban				0.038***	-0.342***
				(0.000)	(0.026)
PEESE Correction: β_0	0.047**	-0.138***	2.938***	-0.464***	0.443***
	[0.004,0.091]	[-0.200,-0.077]	[2.637,3.238]	[-0.468,-0.460]	[0.390,0.495]
N. of Obs	2062	176	789	409	688
N. of Studies	60	13	16	7	24

Note: Stepwise regression of overall sample (1) and sub-samples defined by clusters (2-5) for fast-onset events. Estimates shown represent significant coefficients obtained through a stepwise procedure (not reported when not significant). Controls are grouped by paper features, dependent variable, independent variable, sample and regression characteristics. PCC precision square weights ($1/se_i^2$); robust standard errors clustered by study in parentheses; 95% confidence intervals in brackets; * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

The coefficient of $\hat{\beta}_0$, is positive and statistically significant in the overall sample and in clusters 2 and 4, providing evidence of an increase of migration due to sudden natural hazards. It is worth noting that papers in Cluster 2 (column 3) mainly focus on fast-onset events and the summarized effect size is positive and very high. On the other side, the summarized effect of papers in clusters 1 and 3 is negative and statistically significant.

Results show evidence of publication bias for the overall sample and in Cluster 3, with $\hat{\beta}_1$ statistically significant signaling that the reported effect is not independent of its standard error. The significant and positive coefficient found for the published dummy confirms that there is a general *Publication Impact*, so the peer-review process seems to affect the magnitude of the estimated effect, especially in clusters 1 and 2. Articles published in journals with higher *Impact-factor* get higher estimates of the effects of natural disasters on migration, with exception of published articles in Cluster 2, suggesting that editors prefer to publish results that have a positive but more limited effect. Natural disasters affect domestic and international migration flows. The positive coefficients of the group of controls related to the type of migration, in clusters 2 and 3 confirm that people respond to natural disasters with any kind of mobility. Specifically in Cluster 2 natural disasters increase both *Internal* and *Urbanization* migration, while studies in Cluster 3 find a greater effect on *Internal* and *International* movements of people. In Cluster 4, instead, estimates of the impact of natural disasters are lower in the case of *Internal* migration. *Hydrological* events have a greater impact on migration, the estimated coefficient is statistically significant in all clusters; if the fast-onset event refers to *Geophysical*, *Meteorological* and *Climatological* disasters the effect on migration is lower.

The severity of natural disasters, such as hurricanes, landslides, or floods, affects regional agricultural production and it also has direct effects on employment and income in the agricultural sectors of the affected regions pushing people to migrate. However, if on the one hand natural disasters, such as droughts, floods, and storms, push individuals to move to find new sources of income or livelihood, on the other hand, natural disasters such as earthquakes, tsunamis, or hurricanes cause losses to populations that might lead people into a poverty trap, with potential migrants not having the resources to finance the trip. This effects, already highlighted by the literature, seems to be confirmed. Also in this literature, indeed, various controls and transmission channels analyzed in the original empirical models have a role in determining heterogeneity in results.

5 Conclusions

Environmental change and human migration will continue to characterize the global system in the years to come. The analysis offered in the paper sheds some new light on the very heterogeneous results in the estimates of the existing relationship between the two phenomena reported in empirical economic essays in the last twenty years.

The sample collected through a systematic review of the literature, the bibliometric analysis, and the community detection on the citation-based network of essays, highlights the absence of a uniform and cohesive literature. The too many different characteristics in terms of object of analysis, methodology and mediating covariates renders the meta-analytic average effect estimates just a first approximation of the quantitative evidence of the literature. The small, positive, and significant effect of slow- and rapid-onset variables on migration, can barely be considered a consensual outcome. The high level of heterogeneity in the four clusters of papers that compose the economic literature on environmental migration tells us that the contributions in each cluster are conditionally converging towards a different average effect, indicating that the estimates obtained by the meta-analysis on the entire sample must be examined taking into account the specificities of every group of studies.

All this calls for a group-by-group analysis of the link between environmental change and migration, and a greater effort by scholars and institutions in validating existing studies.

References

Aria, M. and Cuccurullo, C. (2017). bibliometrix: An r-tool for comprehensive science mapping analysis. *Journal of Informetrics*, 11(4):959–975.

Auffhammer, M. and Kahn, M. (2018). The farmer's climate change adaptation challenge in least developed countries. *Handbook of Environmental Economics*, 4:193–229.

Bardsley, D. (2014). Limits to adaptation or a second modernity? responses to climate change risk in the context of failing socio-ecosystems. *Environment, Development and Sustainability*, 17(1):41–55.

Barrios, S., Bertinelli, L., and Strobl, E. (2006). Climatic change and rural-urban migration: The case of sub-saharan africa. *Journal of Urban Economics*, 60(3):357–371.

Beine, M. and Jeusette, L. (2019). A meta-analysis of the literature on climate change and migration. IZA Discussion Papers 12639, Institute of Labor Economics (IZA).

Beine, M. and Parsons, C. (2015). Climatic factors as determinants of international migration. *Scandinavian Journal of Economics*, 117(2):723–767.

Beine, M. and Parsons, C. R. (2017). Climatic Factors as Determinants of International Migration: Redux. *CESIFO ECONOMIC STUDIES*, 63(4):386–402.

Berlemann, M. and Steinhardt, M. (2017). Climate change, natural disasters, and migration-a survey of the empirical evidence. *CESifo Economic Studies*, 63(4):353–385.

Berlemann, M. and Tran, T. (2020). Climate-related hazards and internal migration empirical evidence for rural vietnam. *Economics of Disasters and Climate Change*, 4(2):385–409.

Blondel, V., Guillaume, J.-L., Lambiotte, R., and Lefebvre, E. (2008). Fast unfolding of communities in large networks. *Journal of Statistical Mechanics: Theory and Experiment*, 2008(10).

Bohra-Mishra, P., Oppenheimer, M., and Hsiang, S. (2014). Nonlinear permanent migration response to climatic variations but minimal response to disasters. *Proceedings of the National Academy of Sciences of the United States of America*, 111(27):9780–9785.

Boyack, K. and Klavans, R. (2010). Co-citation analysis, bibliographic coupling, and direct citation: Which citation approach represents the research front most accurately? *Journal of the American Society for Information Science and Technology*, 61(12):2389–2404.

Brada, J. C., Drabek, Z., and Iwasaki, I. (2021). Does investor protection increase foreign direct investment? a meta-analysis. *Journal of Economic Surveys*, 35(1):34–70.

Cai, R., FENG, S., Oppenheimer, M., and Pytlikova, M. (2016). Climate variability and international migration: The importance of the agricultural linkage. *Journal of Environmental Economics and Management*, 79:135–151.

Castells-Quintana, D., Lopez-Uribe, M., and McDermott, T. (2018). Adaptation to climate change: A review through a development economics lens. *World Development*, 104:183–196.

Cattaneo, C. and Massetti, E. (2019). Does harmful climate increase or decrease migration? evidence from rural households in nigeria. *Climate Change Economics*, 10(4).

Cattaneo, C. and Peri, G. (2016). The migration response to increasing temperatures. *JOURNAL OF DEVELOPMENT ECONOMICS*, 122:127–146.

Cipollina, M. and Salvatici, L. (2010). Reciprocal trade agreements in gravity models: A meta-analysis. *Review of International Economics*, 18(1):63–80.

Coniglio, N. and Pesce, G. (2015). Climate variability and international migration: An empirical analysis. *Environment and Development Economics*, 20(4):434–468.

Doucouliagos, C. (2005). Publication bias in the economic freedom and economic growth literature. *Journal of Economic Surveys*, 19(3):367–387.

Doucouliagos, C. and Ulubasoglu, M. A. (2006). Economic freedom and economic growth: Does specification make a difference? *European journal of political economy*, 22(1):60–81.

Drabo, A. and Mbaye, L. (2015). Natural disasters, migration and education: An empirical analysis in developing countries. *Environment and Development Economics*, 20(6):767–796.

Feng, S., Krueger, A., and Oppenheimer, M. (2010). Linkages among climate change, crop yields and mexico-us cross-border migration. *Proceedings of the National Academy of Sciences of the United States of America*, 107(32):14257–14262.

Findley, S. (1994). Does drought increase migration? a study of migration from rural mali during the 1983-1985 drought. *International Migration Review*, 28(3):539–553.

Gignoux, J. and Menéndez, M. (2016). Benefit in the wake of disaster: Long-run effects of earthquakes on welfare in rural indonesia. *Journal of Development Economics*, 118:26–44.

Gray, C. (2009). Environment, land, and rural out-migration in the southern ecuadorian andes. *World Development*, 37(2):457–468.

Gray, C. and Mueller, V. (2012a). Drought and population mobility in rural ethiopia. *World Development*, 40(1):134–145.

Gray, C. and Mueller, V. (2012b). Natural disasters and population mobility in bangladesh. *Proceedings of the National Academy of Sciences of the United States of America*, 109(16):6000–6005.

Gray, C. and Wise, E. (2016). Country-specific effects of climate variability on human migration. *Climatic Change*, 135(3-4):555–568.

Halliday, T. (2006). Migration, risk, and liquidity constraints in el salvador. *Economic Development and Cultural Change*, 54(4):893–925.

Halliday, T. (2012). Intra-household labor supply, migration, and subsistence constraints in a risky environment: Evidence from rural el salvador. *European Economic Review*, 56(6):1001–1019.

Henry, S., Boyle, P., and Lambin, E. (2003). Modelling inter-provincial migration in burkina faso, west africa: The role of socio-demographic and environmental factors. *Applied Geography*, 23(2-3):115–136.

Henry, S., Schoumaker, B., and Beauchemin, C. (2004). The impact of rainfall on the first out-migration: A multi-level event-history analysis in burkina faso. *Population and Environment*, 25(5):423–460.

Higgins, J. P. and Thompson, S. G. (2002). Quantifying heterogeneity in a meta-analysis. *Statistics in medicine*, 21(11):1539–1558.

Hirsch, J. (2005). An index to quantify an individual's scientific research output. *Proceedings of the National Academy of Sciences of the United States of America*, 102(46):16569–16572.

Hoffmann, R., Dimitrova, A., Muttarak, R., Cuaresma, J. C., and Peisker, J. (2020). A meta-analysis of country-level studies on environmental change and migration. *Nature Climate Change*, 10(10):904–912.

Hornbeck, R. (2012). The enduring impact of the american dust bowl: Short- and long-run adjustments to environmental catastrophe. *American Economic Review*, 102(4):1477–1507.

Jennings, J. and Gray, C. (2015). Climate variability and human migration in the netherlands, 1865–1937. *Population and Environment*, 36(3):255–278.

Kawawaki, Y. (2018). Economic analysis of population migration factors caused by the great east japan earthquake and tsunami. *Review of Urban and Regional Development Studies*, 30(1):44–65.

Kessler, M. M. (1963a). Bibliographic coupling between scientific papers. *American documentation*, 14(1):10–25.

Kessler, M. M. (1963b). An experimental study of bibliographic coupling between technical papers. *IEEE Transactions on Information Theory*, 9(1):49–51.

Khamis, M. and Li, X. (2020). Environment matters: new evidence from mexican migration. *Applied Economics Letters*, 27(3):168–173.

Klavans, R. and Boyack, K. (2006). Identifying a better measure of relatedness for mapping science. *Journal of the American Society for Information Science and Technology*, 57(2):251–263.

Klavans, R. and Boyack, K. (2017). Which type of citation analysis generates the most accurate taxonomy of scientific and technical knowledge? *Journal of the Association for Information Science and Technology*, 68(4):984–998.

Koubi, V., Spilker, G., Schaffer, L., and Bernauer, T. (2016). Environmental stressors and migration: Evidence from vietnam. *World Development*, 79:197–210.

Liberati, A., Altman, D. G., Tetzlaff, J., Mulrow, C., Gøtzsche, P. C., Ioannidis, J. P., Clarke, M., Devereaux, P. J., Kleijnen, J., and Moher, D. (2009). The prisma statement for reporting systematic reviews and meta-analyses of studies that evaluate health care interventions: explanation and elaboration. *Journal of clinical epidemiology*, 62(10):e1–e34.

Marchiori, L., Maystadt, J.-F., and Schumacher, I. (2012). The impact of weather anomalies on migration in sub-saharan africa. *Journal of Environmental Economics and Management*, 63(3):355–374.

Millock, K. (2015). Migration and environment. *Annual Review of Resource Economics*, 7(1):35–60.

Mueller, V., Gray, C., and Kosec, K. (2014). Heat stress increases long-term human migration in rural pakistan. *Nature Climate Change*, 4(3):182–185.

Mueller, V., Sheriff, G., Dou, X., and Gray, C. (2020). Temporary migration and climate variation in eastern Africa. *WORLD DEVELOPMENT*, 126.

Naudé, W. (2008). Conflict, Disasters, and No Jobs: Reasons for International Migration from Sub-Saharan Africa. WIDER Working Paper Series RP2008-85, World Institute for Development Economic Research (UNU-WIDER).

Naudé, W. (2010). The determinants of migration from sub-saharan african countries. *Journal of African Economies*, 19(3):330–356.

Ouattara, B. and Strobl, E. (2014). Hurricane strikes and local migration in us coastal counties. *Economics Letters*, 124(1):17–20.

Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., Shamseer, L., Tetzlaff, J. M., Akl, E. A., Brennan, S. E., et al. (2021). The prisma 2020 statement: an updated guideline for reporting systematic reviews. *Bmj*, 372.

Rao, N., Singh, C., Solomon, D., Camfield, L., Sidiki, R., Angula, M., Poonacha, P., Sidibe, A., and Lawson, E. T. (2020). Managing risk, changing aspirations and household dynamics: Implications for wellbeing and adaptation in semi-arid Africa and India. *WORLD DEVELOPMENT*, 125.

Small, H. (1973). Co-citation in the scientific literature: A new measure of the relationship between two documents. *Journal of the American Society for Information Science*, 24(4):265–269.

Spitzer, Y., Tortorici, G., and Zimran, A. (2020). International migration responses to natural disasters: Evidence from modern europe's deadliest earthquake. Technical report, National Bureau of Economic Research, Inc.

Stanley, T. D. and Doucouliagos, H. (2012). *Meta-regression analysis in economics and business*, volume 5. routledge.

Stanley, T. D. and Doucouliagos, H. (2014). Meta-regression approximations to reduce publication selection bias. *Research Synthesis Methods*, 5(1):60–78.

Stanley, T. D. and Doucouliagos, H. (2017). Neither fixed nor random: weighted least squares meta-regression. *Research synthesis methods*, 8(1):19–42.

Stanley, T. D., Doucouliagos, H., and Steel, P. (2018). Does ict generate economic growth? a meta-regression analysis. *Journal of Economic Surveys*, 32(3):705–726.

Sternitzke, C. and Bergmann, I. (2009). Similarity measures for document mapping: A comparative study on the level of an individual scientist. *Scientometrics*, 78(1):113–130.

Thiede, B., Gray, C., and Mueller, V. (2016). Climate variability and inter-provincial migration in south america, 1970–2011. *Global Environmental Change*, 41:228–240.

Thijs, B., Zhang, L., and Glänzel, W. (2015). Bibliographic coupling and hierarchical clustering for the validation and improvement of subject-classification schemes. *Scientometrics*, 105(3):1453–1467.

van Eck, N. J. and Waltman, L. (2009). How to normalize cooccurrence data? an analysis of some well-known similarity measures. *Journal of the American Society for Information Science and Technology*, 51(8):1635–1651.

Weinberg, B. (1974). Bibliographic coupling: A review. *Information Storage and Retrieval*, 10(5-6):189–196.

A Appendix: List of Articles

Table 8 lists the 151 papers included in the reviewed sample.

Author(s)	Title	Year	Published	Cluster
Abel et al.	*Climate, conflict and forced migration*	2018		C3
Afifi and Warner	*The impact of environmental degradation on migration flows across countries*	2008		C4
Ager et al.	*How the 1906 San Francisco earthquake shaped economic activity in the American West*	2020	x	C2
Ahsan et al.	*Climate-induced migration impacts on social structures and justice in Bangladesh*	2019	x	C1
Alem et al.	*Migration as an adaptation strategy to weather variability: an instrumental variables probit analysis*	2016		C1
Alexeev et al.	*Weather-related disasters and international migration*	2011		C4
Aufhammer and Kahn	*The farmers climate change adaptation challenge in least developed countries*	2018	x	C3
Backhaus et al.	*Do climate variations explain bilateral migration? A gravity model analysis*	2015	x	C4
Barassi et al	*Climate anomalies and migration between Chinese provinces 1987-2015*	2018	x	C4
Bardsley	*Limits to adaptation or a second modernity responses to climate change risk in the context of failing socio-ecosystems*	2014	x	C1
Baronchelli and Ricciuti	*Climate change, rice production, and migration in Vietnamese households*	2018		C3
Barrios et al.	*Climatic change and rural-urban migration the case of Sub-Saharan Africa*	2006	x	C4
Beine and Parsons	*Climatic factors as determinants of international migration*	2015	x	C4
Beine and Parsons	*Climatic factors as determinants of international migration (redux)*	2017	x	C4
Benonnier et al.	*Climate change, migration, and irrigation*	2019		C3
Berlemann and Steinhardt	*Climate change natural disasters and migration: a survey of the empirical evidence*	2017	x	C3
Berlemann and Tran	*Climate-related hazards and internal migration empirical evidence for rural Vietnam*	2020	x	C3
Bertoli et al.	*Weather shocks and migration intentions in Western Africa: insights from a multilevel analysis*	2020		C3
Bettin and Nicolli	*Does climate change foster emigration from less developed countries? Evidence from bilateral data*	2012		C4
Bhargava	*Climate change demographic pressures and global sustainability*	2019	x	C3
Bohra-Mishra et al.	*Non-linear permanent migration response to climatic variations but minimal response to disasters*	2014	x	C3
Boustan et al.	*Moving to higher ground: migration response to natural disasters in the early twentieth century*	2012	x	C2
Boustan et al.	*The effect of natural disasters on economic activity in U.S. counties a century of data*	2020	x	C2
Brückner	*Economic growth, size of the agricultural sector, and urbanization in Africa*	2012	x	C4
Burzynski et al.	*Climate change, inequality, and human migration*	2019		C3
Cai et al.	*Climate variability and international migration the importance of the agricultural linkage*	2016	x	C4
Carattini and Veronesi	*Trust, temperature fluctuations, and asylum applications*	2020		C3
Castells-Quintana et al.	*Adaptation to climate change a review through a development economics lens*	2018	x	C2
Cattaneo and Massetti	*Migration and climate change in rural Africa*	2015		C3
Cattaneo and Peri	*The migration response to increasing temperatures*	2016	x	C3
Cattaneo and Bosetti	*Climate-induced international migration and conflicts*	2017	x	C4
Cattaneo and Massetti	*Does harmful climate increase or decrease migration evidence from rural households in Nigeria*	2019	x	C3
Cattaneo et al.	*Human migration in the era of climate change*	2019	x	C3
Chen and Flatnes	*Credit access, migration, and climate change adaptation in rural Bangladesh*	2019		C1
Chernina	*Natural shocks and migration decisions: the case of Kyrgyzstan*	2019		C2
Chort	*New insights into the selection process of Mexican migrants. What can we learn from discrepancies between intentions to migrate and actual moves to the U.S.?*	2012		C3
Chort and de la Rupelle	*Managing the impact of climate change on migration: evidence from Mexico*	2017		C3
Chort and de la Rupelle	*Managing the impact of climate on migration: evidence from Mexico*	2019		C3
Coniglio and Pesce	*Climate variability and international migration: an empirical analysis*	2015	x	C4
Dallmann and Millock	*Climate variability and interstate migration in India*	2017	x	C4
Damette and Gittard	*Climate change and migrations: remittances as a buffer?*	2017	x	C4
Defrance et al.	*Is migration drought-induced in Mali? An empirical analysis using panel data on Malian localities over the 1987-2009 period*	2020		C3
Desmet and Rossi-Hansberg	*On the spatial economic impact of global warming*	2015	x	C3
Deuster	*Climate change, education and mobility in Africa*	2019		C3
Diallo and Renou	*Climate change and migration the emerging structure of a scientific field and the process of public policy formulation*	2015	x	C1
Dillon et al.	*Migratory responses to agricultural risk in Northern Nigeria*	2011	x	C2
Docquier et al.	*Emigration and democracy*	2016	x	C4
Drabo and Mbaye	*Climate change, natural disasters and migration: an empirical analysis in developing countries*	2011		C4
Drabo and Mbaye	*Natural disasters, migration and education: an empirical analysis in developing countries*	2015	x	C4
Erwin et al.	*Inter-sectionality shapes adaptation to social-ecological change*	2020	x	C1
Falco et al.	*Climate change, agriculture and migration: a survey*	2018		C3

Fan et al.	*Does extreme weather drive inter-regional brain drain in the U.S. evidence from a sorting model*	2016	x	C2
Fan et al.	*Climate change migration and regional economic impacts in the United States*	2018	x	C2
Farbotko et al.	*Transformative mobilities in the pacific promoting adaptation and development in a changing climate*	2018	x	C1
Felli	*Managing climate insecurity by ensuring continuous capital accumulation climate refugees and climate migrants*	2013	x	C1
Feng et al.	*The perils of modelling how migration responds to climate change*	2016		C2
Feng et al	*Linkages among climate change, crop yields and Mexico-U.S. cross-border migration*	2010	x	C1
Feng et al.	*Climate change, crop yields, and internal migration in the United States*	2012		C3
Fernández et al.	*Climate change-induced migration in Morocco*	2018	x	C1
Galizzi	*Demographic explosion in Sub-Saharan Africa subsistence agriculture and the problem of migrants*	2017	x	C4
Ghimire et al.	*Flood-induced displacement and civil conflict*	2015	x	C1
Gignoux and Menéndez	*Benefit in the wake of disaster long-run effects of earthquakes on welfare in rural Indonesia*	2016	x	C2
Goldbach	*Out-migration from coastal areas in Ghana and Indonesia: the role of environmental factors*	2017	x	C1
Grace et al	*Examining rural Sahelian out-migration in the context of climate change: an analysis of the linkages between rainfall and out-migration in two Malian villages from 1981 to 2009*	2018	x	C1
Gray	*Environment, land, and rural out-migration in the Southern Ecuadorian Andes*	2009	x	C1
Gray and Mueller	*Natural disasters and population mobility in Bangladesh*	2012	x	C1
Gray and Mueller	*Drought and population mobility in rural Ethiopia*	2012	x	C1
Gray and Bilsborrow	*Environmental influences on human migration in rural Ecuador*	2013	x	C1
Gray and Wise	*Country-specific effects of climate variability on human migration*	2016	x	C1
Gröger and Zylberberg	*Internal labor migration as a shock coping strategy evidence from a typhoon*	2016	x	C2
Groen et al.	*Storms and jobs the effect of hurricanes on individuals employment and earnings over the long term*	2020	x	C2
Gröschl	*Climate change and the relocation of population*	2012		C4
Gröschl and Steinwachs	*Do natural hazards cause international migration?*	2017	x	C4
Halliday	*Migration, risk, and liquidity constraints in El Salvador*	2006	x	C2
Halliday	*Intra-household labour supply, migration, and subsistence constraints in a risky environment: evidence from rural El Salvador*	2012	x	C2
Hanson and McIntosh	*Birth rates and border crossings: Latin American migration to the U.S., Canada, Spain and the U.K.*	2012	x	C4
Harper	*Population-environment interactions European migration population composition and climate change*	2013	x	C1
Henderson et al.	*Has climate change driven urbanization in Africa*	2017	x	C3
Henry et al.	*Modelling inter-provincial migration in Burkina Faso, West Africa: the role of socio-demographic and environmental factors*	2003	x	C1
Herny et al.	*The impact of rainfall on the first out-migration: a multi-level event-history analysis in Burkina Faso*	2004	x	C1
Hirvonen	*Temperature changes, household consumption, and internal migration: evidence from Tanzania*	2016	x	C3
Hornbeck	*The enduring impact of the American dust bowl: short- and long-run adjustments to environmental catastrophe*	2012	x	C2
Hunter et al.	*Rainfall patterns and U.S. Migration from rural Mexico*	2013	x	C1
Iqbal and Roy	*Climate change agriculture and migration evidence from Bangladesh*	2015	x	C1
Jamero et al.	*In-situ adaptation against climate change can enable relocation of impoverished small islands*	2019	x	C1
Jennings and Gray	*Climate variability and human migration in the Netherlands, 1865-1937*	2015	x	C1
Jessoe et al.	*Climate change and labour allocation in rural Mexico evidence from annual fluctuations in weather*	2018	x	C3
Joseph and Wodon	*Is internal migration in Yemen driven by climate or socio-economic factors?*	2013	x	C1
Joseph et al.	*Is climate change likely to lead to higher net internal migration? The republic of Yemen's case*	2014		C1
Kabir et al.	*Seasonal drought thresholds and internal migration for adaptation lessons from northern Bangladesh*	2017	x	C1
Kawawaki	*Economic analysis of population migration factors caused by the Great East Japan earthquake and tsunami*	2018	x	C2
Khamis and Li	*Environment matters: new evidence from Mexican migration*	2020	x	C4
Klaiber	*Migration and household adaptation to climate a review of empirical research*	2014	x	C2
Koubi et al.	*The role of environmental perceptions in migration decision-making: evidence from both migrants and non-migrants in five developing countries*	2016	x	C1
Koubi et al.	*Environmental stressors and migration evidence from Vietnam*	2016	x	C1
Kubik and Maurel	*Weather shocks agricultural production and migration evidence from Tanzania*	2016	x	C1
Lewin et al.	*Do rainfall conditions push or pull rural migrants evidence from Malawi*	2012	x	C1
Mahajan and Yang	*Taken by storm: hurricanes, migrant networks, and U.S. immigration*	2020	x	C2
Marchiori and Schumacher	*When nature rebels international migration, climate change and inequality*	2011	x	C1
Marchiori et al.	*The impact of weather anomalies on migration in Sub-Saharan Africa*	2012	x	C4
Marchiori et al.	*Is environmentally induced income variability a driver of human migration?*	2017	x	C1
Mason	*Climate change and migration a dynamic model*	2017	x	C3
Mastrorillo et al.	*The influence of climate variability on internal migration flows in South Africa*	2016	x	C3
Maurel and Zaneta	*Climate variability and migration: evidence from Tanzania*	2014		C1

Maurel and Tuccio	*Climate instability, urbanisation and international migration*	2016	x	C4
Mbaye and Zimmermann	*Natural disasters and human mobility*	2016	x	C2
Millock	*Migration and environment*	2015	x	C1
Missirian and Schlenker	*Asylum applications respond to temperature fluctuations*	2017	x	C3
Mueller et al.	*Heat stress increases long-term human migration in rural Pakistan*	2014	x	C1
Mueller et al.	*Temporary migration and climate variation in Eastern Africa*	2020	x	C3
Naqvi	*Deep impact geo-simulations as a policy toolkit for natural disasters*	2017	x	C2
Naqvi and Rehm	*A multi-agent model of a low income economy simulating the distributional effects of natural disasters*	2014	x	C2
Naudé	*Conflict, disasters, and no jobs: reasons for international migration from Sub-Saharan Africa*	2008		C4
Naudé	*Natural disasters and international migration from Sub-Saharan Africa*	2009	x	C4
Naudé	*The determinants of migration from Sub-Saharan African countries*	2010	x	C4
Nawrotzki et al.	*Do rainfall deficits predict U.S.-bound migration from rural Mexico? Evidence from the Mexican census*	2013	x	C1
Nawrotzki and Bakhtsiyarava	*International climate migration: evidence for the climate inhibitor mechanism and the agricultural pathway*	2017	x	C1
Ng'ang'a et al.	*Migration and self-protection against climate change a case study of Samburu county Kenya*	2016	x	C1
Noy	*To leave or not to leave climate change exit and voice on a pacific island*	2017	x	C3
Oliveira and Pereda	*The impact of climate change on internal migration in Brazil*	2020	x	C2
Olper et al.	*Climate change, agriculture and migration: is there a causal relationship?*	2018		C3
Ouattara and Strobl	*Hurricane strikes and local migration in U.S. coastal counties*	2014	x	C2
Owen and Wesselbaum	*On thresholds in the climate-migration relationship*	2020	x	C3
Pajaron and Vasquez	*Weathering the storm weather shocks and international labour migration from the Philippines*	2020	x	C2
Pan	*Protections from natural disasters as local public goods migration and local adaptations*	2020	x	C3
Peri and Sasahara	*The impact of global warming on rural-urban migrations: evidence from global big data*	2019		C3
Perkiss and Moerman	*A dispute in the making: a critical examination of displacement, climate change and the Pacific islands*	2018	x	C1
Pismennaya et al.	*Impact of climate change on migration from Vietnam to Russia as a factor of transformation of geopolitical relations*	2015	x	C1
Radel et al	*Toward a political ecology of migration land labour migration and climate change in northwestern Nicaragua*	2018	x	C1
Ragazzi	*Climate change and migration: a gravity model approach*	2012		C4
Rao et al.	*Managing risk changing aspirations and household dynamics implications for well-being and adaptation in semiarid Africa and India*	2020	x	C1
Reuveny and Moore	*Does environmental degradation influence migration? Emigration to developed countries in the late 1980s and 1990s*	2009	x	C4
Robalino et al.	*The effect of hydro-meteorological emergencies on internal migration*	2015	x	C1
Ruiz	*Do climatic events influence internal migration? Evidence from Mexico*	2017		C4
Ruyssen and Rayp	*Determinants of intra-regional migration in Sub-Saharan Africa 1980-2000*	2014	x	C4
Saldaña-Zorrilla and Sandberg	*Impact of climate-related disasters on human migration in Mexico: a spatial model*	2009	x	C2
Sedova and Kalkuhl	*Who are the climate migrants and where do they go evidence from rural India*	2020	x	C3
Simonelli	*Migration and climate change*	2018	x	C1
Spencer and Urquhart	*Hurricane strikes and migration: evidence from storms in Central America and the Caribbean*	2018	x	C4
Spitzer et al.	*International migration responses to natural disasters: evidence from modern Europe's deadliest earthquake*	2020		C2
Suliman	*Rethinking about civilizations the politics of migration in a new climate*	2016	x	C4
Thiede et al.	*Climate variability and inter-provincial migration in South America, 1970-2011*	2016	x	C1
Thiede and Gray	*Heterogeneous climate effects on human migration in Indonesia*	2017	x	C1
Valsson and Ulfarsson	*Mega-patterns of global settlement typology and drivers in a warming world*	2012	x	C1
Viswanathan and Kumar	*Weather, agriculture and rural migration: evidence from state and district level migration in India*	2015	x	C1
Waldinger	*The effects of climate change on internal and international migration: implications for developing countries*	2015		C2
Weinthal et al.	*Securitizing water climate and migration in Israel, Jordan and Syria*	2015	x	C4
Wesselbaum and Aburn	*Gone with the wind: international migration*	2019	x	C4
Wyett	*Escaping a rising tide sea level rise and migration in Kiribati*	2014	x	C1
Yuan and Zhu	*Shock and roam migratory responses to natural disasters*	2016	x	C2
Zhou	*Climate change health and migration in urban China*	2011	x	C3