



Geographical imbalances and divides in the scientific production of climate change knowledge



Maya Pasgaard^{a,*}, Bo Dalsgaard^b, Pietro K. Maruyama^{b,c}, Brody Sandel^d, Niels Strange^{b,e}

^a University of Copenhagen, Faculty of Science, Department of Geosciences and Natural Resource Management, Øster Voldgade 10, DK-1350 Copenhagen K, Denmark

^b Center for Macroecology, Evolution and Climate, Natural History Museum of Denmark, University of Copenhagen, Universitetsparken 15, DK-2100, Denmark

^c Programa de Pós-Graduação em Ecologia, Universidade Estadual de Campinas (UNICAMP), Cx. Postal 6109, CEP: 13083-970, Campinas, SP, Brazil

^d Department of Bioscience, Aarhus University, Ny Munkegade 114, DK-8000 Aarhus C, Denmark

^e University of Copenhagen, Faculty of Science, Department of Food and Resource Economics, Denmark

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ABSTRACT

Studies on scientific production of climate change knowledge show a geographical bias against the developing and more vulnerable regions of the world. If there is limited knowledge exchange between regions, this may deepen global knowledge divides and, thus, potentially hamper adaptive capacities. Consequently, there is a need to further understand this bias, and, particularly, link it with the exchange of knowledge across borders. We use a world-wide geographical distribution of author affiliations in >15,000 scientific climate change publications to show that (1) research production mainly takes place in richer, institutionally well-developed countries with cooler climates and high climate footprints, and (2) the network of author affiliations is structured into distinct modules of countries with strong common research interests, but with little knowledge exchange between modules. These modules are determined mainly by geographical proximity, common climates, and similar political and economic characteristics. This indicates that political-economic, social and educational-scientific initiatives targeted to enhance local research production and collaborations across geographical-climate module borders may help diminish global knowledge divides. We argue that this could strengthen adaptive capacity in the most vulnerable regions of the world.

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1. Introduction

The scientific community provides increasing evidence that climate change impacts are unevenly distributed across the globe. Many regions with a high risk of negative impacts from climate change are in the less developed and low adaptive capacity countries (IPCC, 2012; Richardson et al., 2009), but scientific research on climate change has a skewed focus on the more developed and less vulnerable regions of the world (Pasgaard and Strange, 2013; Rosenzweig et al., 2007). The distribution of scientific research may be driven by underlying economic, demographic, and institutional factors. For instance, spending on science and climate change research increases with the wealth and educational level of the country (Ho-Lem et al., 2011; Karlsson et al., 2007), and institutional governance characteristics influence

the production of research in general (Karlsson et al., 2007; Moustakas and Karakassis, 2009; Pasgaard and Strange, 2013). Notably, a lack of governance and economic performance of a country may indirectly negatively affect its research output, including the production of scientific publications (Karlsson et al., 2007). This may result in a lack of a sufficient climate change knowledge base in developing and vulnerable regions, limit the understanding of the response of natural and managed systems to climate change (Rosenzweig et al., 2007), and therefore limit adaptive capacity (Karlsson et al., 2007; Kiparsky et al., 2006). In addition, exchange of knowledge among researchers appears critical for reducing global knowledge divides (Karlsson et al., 2007). Thus, to advance the discussion on how to address challenges associated with climate change, there is a need to better understand the geographical imbalances in climate change knowledge production and its exchange between nations and regions, including why it has emerged and persists.

Here we present a comprehensive bibliometric and network analysis of a decade of scientific climate change publications in

* Corresponding author.

E-mail address: mapa@ign.ku.dk (M. Pasgaard).

order to identify gaps in production and exchange of knowledge across the world. Bibliometric analysis has been used in environmental science to study which authors, journals or countries contribute within a given field (Aksnes and Hessen, 2009; Fu et al., 2010; Kahn, 2011; Karlsson et al., 2007; Ma and Stern, 2006). Such studies have addressed the link between climate change research and certain knowledge domains (resilience, vulnerability and adaptation) (Janssen et al., 2006), as well as unequally distributed knowledge on adaptation strategies, as reflected by a lack of aquatic research published by developing countries on adaptation to climate change (van der Zaag et al., 2009). A few studies also analyzed published research within a given field in relation to geographic, social and economic characteristics of the corresponding author's affiliated country (Moustakas and Karakassis, 2009; Pasgaard and Strange, 2013). These studies suggest that the number of publications is linked with the economic activity of the publishing country, the consuming behavior and lifestyle of the citizens in the publishing country, and the relationship of the citizens with the particular environment and its resources (Moustakas and Karakassis, 2009).

However, as for other types of systems which may be interpreted as networks across geographical units, such as the world-wide air transportation network (Guimera et al., 2005) or bird distributions across islands (Dalsgaard et al., 2014), a more holistic network view would allow a deeper understanding of the geographical structure and exchange of scientific knowledge production. Specifically, modularity analysis provides an analytical tool to quantify sub-groups within networks (Dalsgaard et al., 2014; Yarime et al., 2010), such as geographical regions of strong collaboration between countries. This type of analysis require detailed data on co-authors in order to determine the extent to which authors are locally or externally based, and the extent to which multiple authorships involve shared research interests among academics in different countries. In the present study, we analyze a comprehensive dataset of >15,000 climate change publications (published between 1999 and 2010, see Supplementary information), in which all author affiliations of all individual publications are separated into one of a total of 197 countries.

We show that production of climate change knowledge is biased away from developing, more vulnerable regions of the world with warmer climates and low climate footprints, and that in these regions, relatively few authors are based in the country being studied. Furthermore, the global network of climate change publications is structured into modules of countries with a common research interest; these modules are associated mainly with geographical proximity, common climate, politics and trade, but unrelated to cultural and linguistic ties. We conclude that the geographical imbalance in scientific research production on climate change, and the modular structure of research interests, delimits the potential exchange of knowledge on climate change. Future initiatives of a political, economic, social and educational-scientific character may increase knowledge exchange beyond geographical and climatic boundaries, which, especially if targeted to promote collaborations across geographical-climate module borders, would help diminish global knowledge divides and strengthen adaptive capacity in the most vulnerable parts of the world.

2. Methods

2.1. Data collection and affiliation data

In order to analyze the global geographic distribution and production of climate change knowledge, three types of data were collected: case country publications, the number of publications concerning climate change for a specific country; first author

publications, the number of publications by first authors based in a specific country; and co-authorships, the number of times an author country occurred in each publication. The overall methodological approach of searching and reviewing climate change publications follow guidelines for systematic reviews (Davies and Pullin, 2007; Pullin and Stewart, 2006) adapted to the purpose of this study (for detailed description of methods, see Supplementary information).

We investigate how knowledge production (measured by publications) and the flow of climate change knowledge among those who produce it vary with country-level demographical, geographical, economical, educational, institutional, and environmental variables. The count regression models and network analysis are presented in the subsequent sections.

These models included a range of variables designed to capture each of these aspects. We expect that countries that are most susceptible to climate change, such as countries with high mean annual temperatures (MAT) (Pasgaard and Strange, 2013) and low mean annual precipitation (MAP) are more likely to be studied and exchange knowledge. We use gridded data for MAT and MAP between 1960 and 1990 (Hijmans et al., 2005; WorldClim, 2015). To describe spatial proximity, we used the longitude and latitude of each country's capital as predictors. Small Island States are included as a dummy variable (AOSIS, 2015). We expect that small island states, which in general are considered more climatic sensitive than other locations, will be more studied (Pasgaard and Strange, 2013). However, the research effort on climate change could also be tied with the economic situation of the country (Ho-Lem et al., 2011). More wealthy countries with high gross national income (World Bank, 2015a) would be more likely to invest in climate change research. They may also represent high carbon dioxide emitters, and we would expect that countries that are large carbon dioxide emitters (EIA, 2015) may have an incentive to invest in climate change research compared to low emitters (Pasgaard and Strange, 2013). We used country data on the total carbon dioxide emission from energy consumption to test for such a relationship. We include data on country membership in the World Trade Organization (WTO, 2015), which may represent countries with wealthier inhabitants and a higher environmental carbon footprint. To test for this we use the share of exports of gross domestic product (World Bank, 2015b) as an indicator of the degree of openness towards the rest of the world (Neumayer, 2002). Other studies have demonstrated that a number of institutional governance characteristics could be determining (either directly or indirectly) research production (Ho-Lem et al., 2011; Moustakas and Karakassis, 2009). Other studies have demonstrated that research output may be indirectly negatively affected by a lack of governance and economic performance (Karlsson et al., 2007). Chowdhury (2004) found that democracy can have significant impact on state capacity to cope with corruption and crises. Hence, we hypothesize that countries with higher democracy scores (Center for Systemic Peace, 2015) may have higher adaptive capacity and a stronger focus on research into climate change impacts, adaptation and mitigation (Karlsson et al., 2007; Kiparsky et al., 2006; Pasgaard and Strange, 2013). Furthermore, the value of research may depend on press freedom and the likelihood of research being disseminated to the public. If civil freedom, as well as the ability of researchers, journals, newspapers and other media to communicate with the general public, is low then adaptive capacity could be weakened (Pahl-Wostl, 2009). We therefore tested if the number of publications and exchange of knowledge were positively related to the freedom of the press (RSF, 2015). The cultural background of countries may influence the willingness of individuals to cooperate (Gächter et al., 2010). We use religious and cultural values (World Values Survey, 2008) to test if countries of similar cultural backgrounds are

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