nature climate change

ARTICLES

PUBLISHED ONLINE: 7 SEPTEMBER 2015 | DOI: 10.1038/NCLIMATE2782

Patterns of authorship in the IPCC Working Group III report

Esteve Corbera[1]*, Laura Calvet-Mir[2], Hannah Hughes[3†] and Matthew Paterson[4]

The Intergovernmental Panel on Climate Change (IPCC) has completed its Fifth Assessment Report (AR5). Here, we explore the social scientific networks informing Working Group III (WGIII) assessment of mitigation for the AR5. Identifying authors' institutional pathways, we highlight the persistence and extent of North–South inequalities in the authorship of the report, revealing the dominance of US and UK institutions as training sites for WGIII authors. Examining patterns of co-authorship between WGIII authors, we identify the unevenness in co-authoring relations, with a small number of authors co-writing regularly and indicative of an epistemic community's influence over the IPCC's definition of mitigation. These co-authoring networks follow regional patterns, with significant EU–BRICS collaboration and authors from the US relatively insular. From a disciplinary perspective, economists, engineers, physicists and natural scientists remain central to the process, with insignificant participation of scholars from the humanities. The shared training and career paths made apparent through our analysis suggest that the idea that broader geographic participation may lead to a wider range of viewpoints and cultural understandings of climate change mitigation may not be as sound as previously thought.

The IPCC is widely accepted as the authoritative voice of scientific knowledge on climate change. However, what is often missing in the popular depiction of the IPCC as a scientific collaborative endeavour is a reflection on the array of social processes involved in its assessments. Thus, alongside the institutionalized scientific practices for writing, reviewing and revising the reports, there are social processes and scientific conventions for selecting authors and recognizing authoritative knowledge. These social conventions privilege certain institutional affiliations and pre-existing patterns of scientific collaboration and are tightly coupled with economic resources and political power.

Twenty years of social science research into the IPCC has identified two ongoing biases within the organization and its assessment reports: the disparity in participation between Northern countries and the global South, and a hierarchy in disciplinary knowledge[1]. As the organization recognized during its First Assessment Report (FAR), unequal participation impacts the legitimacy of the IPCC process and the authority of its assessment products, with countries reluctant to accept assessments of climate change when their expert involvement is limited[2–6]. Disciplinary biases, on the other hand, constrain how climate change is known and acted on, with only certain forms of knowledge and expertise authorized to construct a problem with global implications[7,8]. Given the hegemonic status of the IPCC within the production of climate change knowledge, exploring questions of participation and scientific legitimacy remains an important task.

Earlier insights on these issues have been largely qualitative in nature, providing detailed descriptions of the establishment of the organization and identifying the North–South divide structuring the Panel and authorship of IPCC assessments[2,3,9–11]. Further research identified the scientific interests shaping the construction of climate change as a global political issue, highlighting the dominance of global climate models in Working Group I's (WGI) conceptualization of climate change, and the natural sciences more broadly across the three WGs (refs 7,8,12–15). More recently, a variety of statistical techniques have been employed to quantify the disciplinary and geographic bias within the IPCC and environmental science research more broadly[16–19]. The paucity of the social sciences has been of particular concern to those critical of the IPCC's technical and managerial framings of the issue and seeking to broaden social understandings of the climate change problem[7,8,20].

Here we contribute to these studies by applying for the first time social network analysis to the writing team of WGIII's contribution (that is, Mitigation of Climate Change) to the AR5. Although previous studies have illuminated the disciplinary biases within WGIII, there has been no detailed analysis of the actors authoring the report—the patterns of training, disciplinary backgrounds and institutions connecting this group of actors. Exploring these patterns provides evidence on how disparities between Northern countries and the global South structure the authorship of WGIII's assessment, and may facilitate a deepened understanding of the controversy surrounding governments' acceptance and approval of the final reports[21].

Nuanced northern domination

Figure 1 represents the network of countries involved in the WGIII AR5 writing process, showing the patterns of connection between countries through the key moments in an author's career trajectory, including the country they undertook their PhD and current country of work. These patterns reveal a more complex picture than a simple North–South divide. The figure indicates the existence of a US- and UK-based dominance in authors' careers, identifying them as principal training sites for scientists involved in the production of the WGIII AR5. Previous studies have highlighted the US and UK dominance in the authorship of the report and identified statistically

[1]Universitat Autònoma de Barcelona, Institute of Environmental Science and Technology, Edifici ICTA-ICP, c/de les Columnes s/n, Bellaterra, Barcelona 08193, Spain. [2]Universitat Oberta de Catalunya, Internet Interdisciplinary Institute, Av. Carl Friedrich Gauss, 5 Castelldefels, Barcelona 08860, Spain. [3]Via Roma 36, Mezzolombardo, 38017 Trentino, Italy. [4]University of Ottawa, School of Political Studies, 120 University Avenue, Ottawa K1N 6N5, Canada. †Present address: Department of Politics and International Relations, Cardiff University, Law Building, Museum Avenue, Cardiff CF10 3AX, UK. *e-mail: esteve.corbera@uab.cat

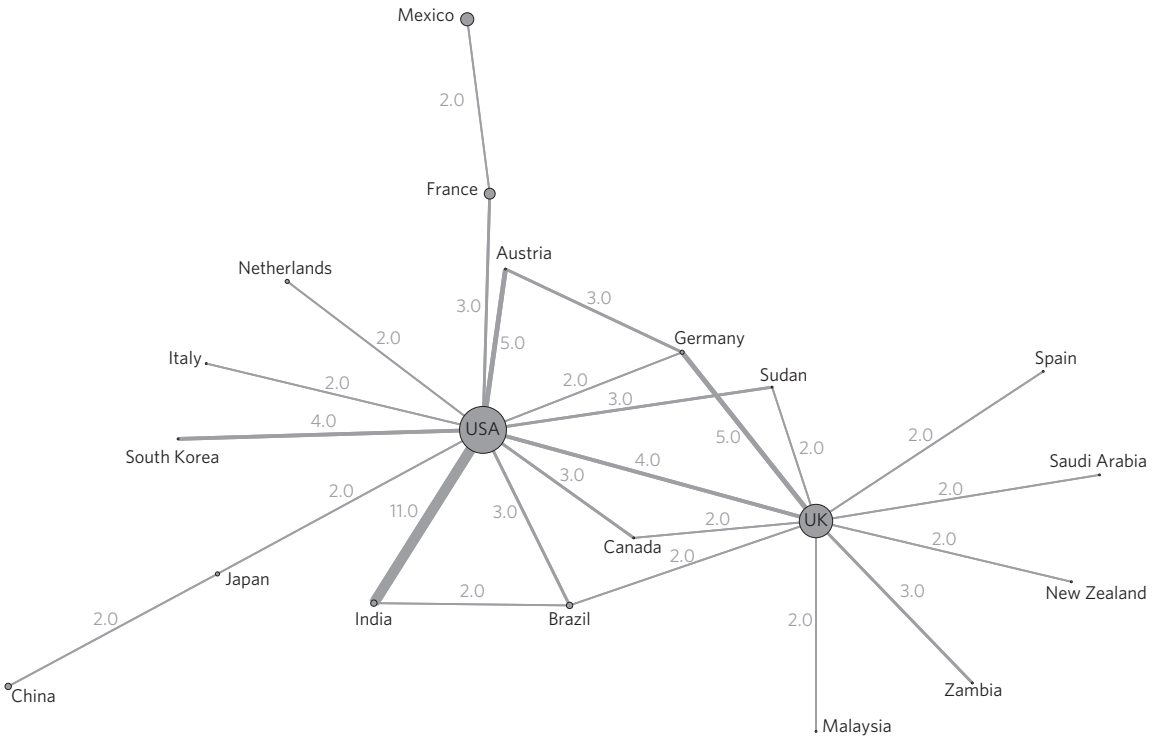

Figure 1 | Two-degree network of countries in which IPCC authors worked and studied. Lines indicate at least 2 authors connecting each country. Node size indicates the betweenness score and thus centrality in the network (see Methods). The number on each line, as well as line thickness, indicates the number of authors connecting each pair of countries. Data used to construct this figure can be found in columns D, E, G, and I of the 'CV Data' table in the Supplementary Database.

significant drivers of this, including per capita GDP (gross domestic product), English-speaking status, and levels of tertiary education[17]. The historic role these countries had in the development of early scientific interest in climate change and the establishment of the IPCC is also likely to be a factor[12,13,22,23].

However, the statistical dominance identified in the network of countries is significantly higher than the number of authors the USA and the UK have in WGIII. According to the IPCC's own figures, the USA has 19% of authors in the population (51/273), the UK only 6% (17/273) and developing countries (combined with economies in transition countries) 43% (117/273; ref. 24). In contrast, the centrality of the USA and the UK, as measured by betweenness score, is very strong and outstrips the next most central countries (see Methods and Supplementary Database).

The findings also show that the USA and the UK are connected to rather different subsets of countries, with relatively little overlap in countries connected to both. This suggests that the USA and UK have distinct sets of professional and institutionalized networks, at least among IPCC-involved scientists. Notably, these connections do not seem to follow obvious geopolitical patterns, such as histories of colonialism for the UK and hemispheric dominance for the USA. The USA and UK have thus a 'globalized' dominance of scientific networks, with the UK in particular training IPCC authors in far greater numbers than there are UK-based Lead Authors in WGIII.

Countries in the global South demonstrate significant variation in terms of their connections across the North–South divide. Overall, BRICS (Brazil, Russia, India, China and South Africa) countries dominate the numerical participation of developing country authors in the IPCC, but the single strongest link between two countries is between the USA and India. In contrast, Chinese and Russian authors are noticeably marginalized from the core of the network relative to Brazil and India, which probably reflects the relative strength of these countries' own universities and research centres. China is connected only to Japan (in contrast China has 15/273, or 5.5% of authors in the writing team, only two fewer than the UK) and Russia disappears entirely from the two-degree network.

Patterns of institutional influence

Another way of exploring the network of AR5 WGIII authors is through the institutions in which authors have worked and studied. Table 1 shows the top 30 institutions ranked by their betweenness scores. The analysis again reveals the dominance of US- and UK-based institutions but also identifies, perhaps surprisingly, the disproportionate role that international organizations play in connecting up the network, despite the fact that only 7% of authors work in international organizations (18/273). The World Bank is the most connected institution in the network, followed by the University of California at Berkeley, and with the UNFCCC (United Nations Framework Convention on Climate Change), UNEP (United Nations Environment Programme), FAO (Food and Agriculture Organization of the United Nations) and the International Institute for Applied Systems Analysis (IIASA), an international research institute, all in the top ten. This suggests that at some point in their career, substantial numbers of IPCC authors pass through these institutions in some capacity, a dynamic that is not captured effectively in the country network (although the relative prominence of Austria is an effect of IIASA being located there) and indicates that these institutions have an influential coordinating role in climate mitigation and policy research.

This institutional dynamic is further illuminated when the institutional network is combined with the co-authoring network (see 'Individual dominance and regional patterns' for more details). Figure 2 shows the institutional network of the 'top 20' authors in the co-authoring network (that is, the 20 with the highest betweenness scores). The figure shows only the largest single cluster of the network among these 20, which involves 13 of them. It highlights the centrality of IIASA, the IAEA (International Atomic Energy

Table 1 | Top 30 institutions by betweenness score.

Institution	Country	Betweenness score
World Bank	INT	45680.918
University of California, Berkeley	USA	34781.469
International Institute for Applied Systems Analysis	INT	28260.313
Harvard University	USA	24528.729
University of Cambridge	UK	19284.412
United Nations Framework Convention on Climate Change	INT	15010.749
Massachusetts Institute of Technology	USA	13015.785
Food and Agriculture Organisation	INT	11924.348
University College London	UK	11612.026
United Nations Environment Programme	INT	11448.463
Carnegie Mellon University	USA	9391.656
Stanford University	USA	8613.510
University of Oxford	UK	8120.635
University of Pennsylvania	USA	7881.373
University of York	UK	7264.178
Universidade Federal do Rio de Janeiro	BRA	6832.559
University of Tokyo	JAP	6682.641
University of London	UK	6424.277
University of Leeds	UK	5884.000
European Commission	INT	5403.873
Universidad Nacional Autónoma de Mexico	MEX	5387.752
Organisation for Economic Co-operation and Development	INT	5047.919
Princeton University	USA	5016.771
World Resources Institute	USA	4818.724
Boston University	USA	4660.375
Fondazione Eni Enrico Mattei	IT	4402.986
University of Illinois	USA	4195.032
University of Kent	UK	4135.000
University of Surrey	UK	4123.000
IPCC	INT	4085.808

Betweenness scores and location of top 30 most frequent institutions associated with IPCC WGIII AR5 authors. INT; international.

Authority), the PNNL (Pacific Northwest National Laboratory) and Stanford University in constituting the key connections between the main WGIII AR5 authors of the co-authoring network. International or national (specifically US) research laboratories, more than universities, act as critical linkages in the co-authoring network. This suggests that there are a relatively small number of institutions through which key members of the co-authoring network pass, and through which institutionalized collaboration in IPCC-related climate change knowledge production is organized.

This network effectively has two subparts, one Austrian–German cluster of institutions, and another US one. According to IPCC affiliation, half of the top 20 authors' group are represented by the USA (5 authors) and Austria (5). No other country has more than one author in this group. The role of IIASA and IAEA is central to the Austrian dominance. The UK is much less important in this network than to the overall network of individuals, so although it may serve as a country training a large number of WGIII scientists, it does not seem to play a key role in organizing research collaboration between authors. The role of the Technical Support Unit (TSU), based in Potsdam, Germany, and the WGIII bureau in author selection is likely to contribute to the predominance of central European authors in the AR5 'top 20' co-authoring network. The TSU supports the WGIII bureau in ensuring chapter teams have the relevant expertise to fulfil the government-approved report outline. Members of the TSU and the WGIII co-chairs may rely on their own networks and encourage colleagues to participate during government nomination and to fill remaining gaps in expertise once country nomination is complete.

Individual dominance and regional patterns

Exploring further the co-authoring network within WGIII enables us to think about pre-existing and ongoing patterns of collaboration amongst authors. As noted above, there are a small number of authors co-authoring regularly with one another, who are central to the network. Whereas the mean betweenness score for authors is 312, the median is 11, indicating a highly skewed distribution with a relatively small number of high betweenness individuals and most authors on the margins of the network. Taking a closer look at these 'top 20' indicates that although overall 73% of AR5 WGIII authors were new to the process[24], 85% of these 20 individuals have been in a previous assessment, and half of them have contributed to three of the five assessment cycles (see 'Top 20 IPCC Part Analysis' tab of the Supplementary Database). This might suggest that there are a small number of WGIII authors whose careers have become structured around the IPCC's assessments process and in producing papers oriented towards the reports.

At the same time, the co-authoring network of the 'top 20' authors (Fig. 3) indicates that the writing collaborations of these individuals extend across the WGIII team, and are indicative of regional patterns of climate change research collaborations. Figure 3 is a two-degree network, with each line indicating that two authors have co-authored at least two papers together. The network shows that European researchers (largely excluding UK researchers) dominate the co-authoring network, and that their collaborations are as much with BRICS authors as US ones. This concentration of co-authoring among a small number of authors seems to reflect research funding criteria and institutionalized incentives to collaborate across EU boundaries and with developing and emerging economies. The network's existence may be indicative of a core group within the AR5 WGIII writing team, composed of a small group of authors regularly co-authoring with each other and regularly contributing to the IPCC's constructions of mitigation. However, further research is required to illuminate the dynamics of this group and to determine its fit with existent concepts that aim to capture the authority and influence of scientific networks, such as 'epistemic community', 'core set' or 'invisible college'[25–27]. This inference is reinforced by the understanding that these authors also come from a narrow range of disciplines—all either economists or engineers.

Disciplinary dominance

Turning to gender and disciplinary make-up, women represent 18% (50/273) of AR5 WGIII authors, and only two women appear in the 'top 20' co-authoring network. In line with an analysis of the Third Assessment Report[16] (TAR), trained economists are dominant in the report, followed by engineers, and then by scholars trained in energy studies, mathematics and physics. Trained economists and engineers represent 49% of the authors for whom we were able to get data for their highest academic training (125/253), whereas 15% (39/253) were trained as social scientists. This pattern is more marked among the 35 Coordinating Lead Authors (CLAs), among which 14% are female and 58% are trained as economists or engineers. Only 3 CLAs have been trained in social sciences other than economics (that is, political science, geography and law), and none in the humanities. This is significant because CLAs, along with WG bureau and TSU members, make up the drafting team for the Summary for Policymakers (SPM), which constitutes the document

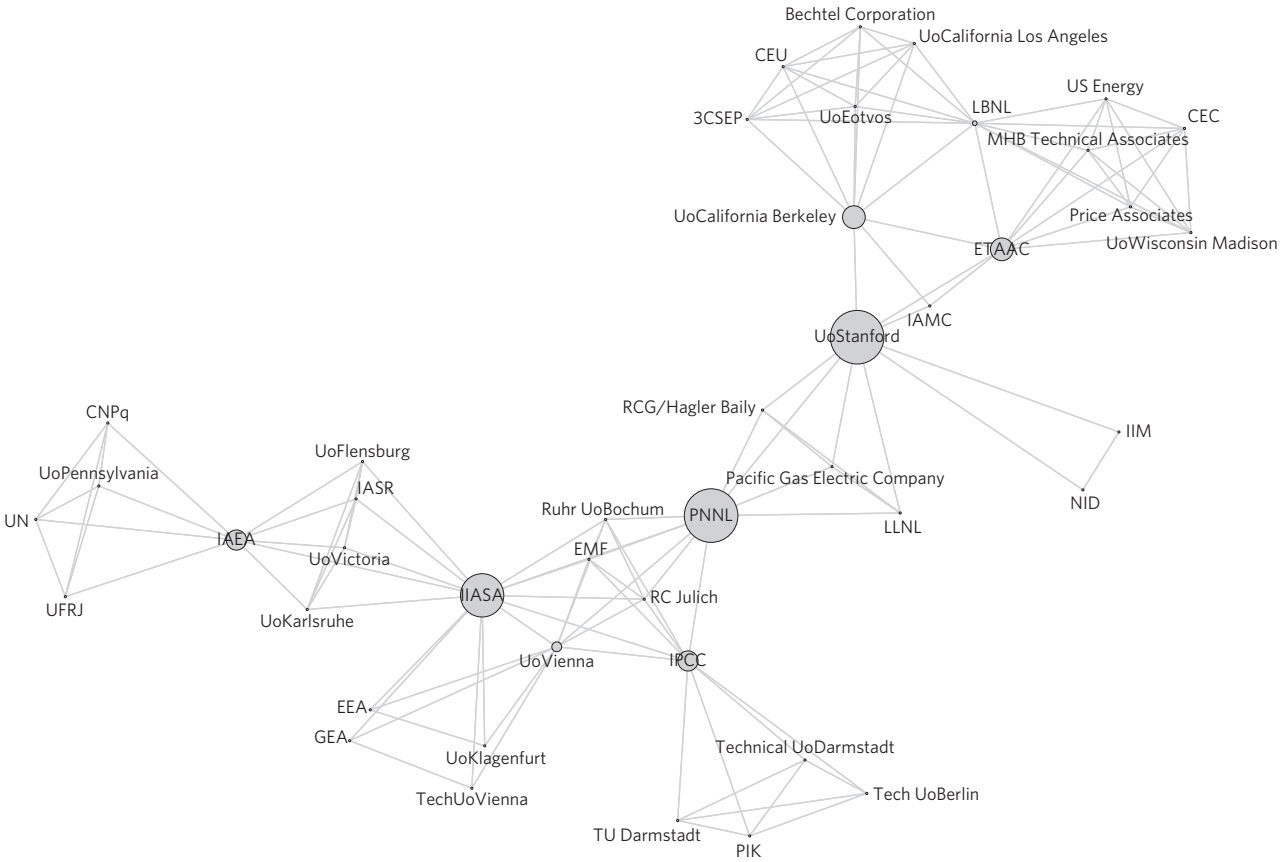

Figure 2 | Institutional network of top 20 authors in co-authoring network, principal component alone. Links between institutions (nodes) indicate that they are connected by at least one of the top 20 authors' career paths. Node size indicates the betweenness score within this network. Some nodes have been moved slightly from their mathematically determined location to enable visibility of the label. Data used to construct this figure can be found in 'Top 20 Institutions Analysis' tab of the Supplementary Database. For a list of abbrevations see the 'Institutions Acronyms' tab of the Supplementary Database.

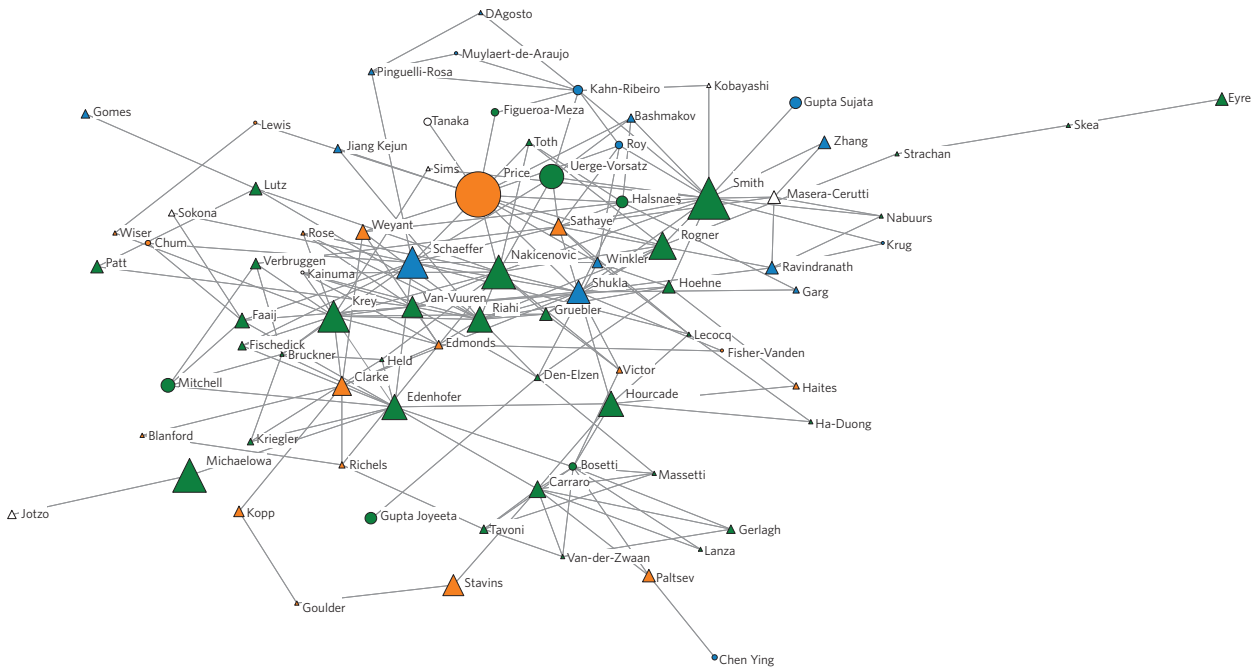

Figure 3 | Two-degree co-authoring network with world regions. Lines between nodes indicate that they have co-authored at least two papers—single collaborations are excluded. Node size indicates the betweenness score. Shape indicates gender (triangle, men, circle, women). Colour indicates the world's region, attributed according to their IPCC representing country (green, Europe; orange, North America; blue, BRICS countries; other regions in white). Some nodes have been moved slightly from their mathematically determined location to enable visibility of the label. Data used to construct this figure can be found in the 'CV Data' and the 'Co-Authoring Patterns Analysis' tabs of the Supplementary Database.

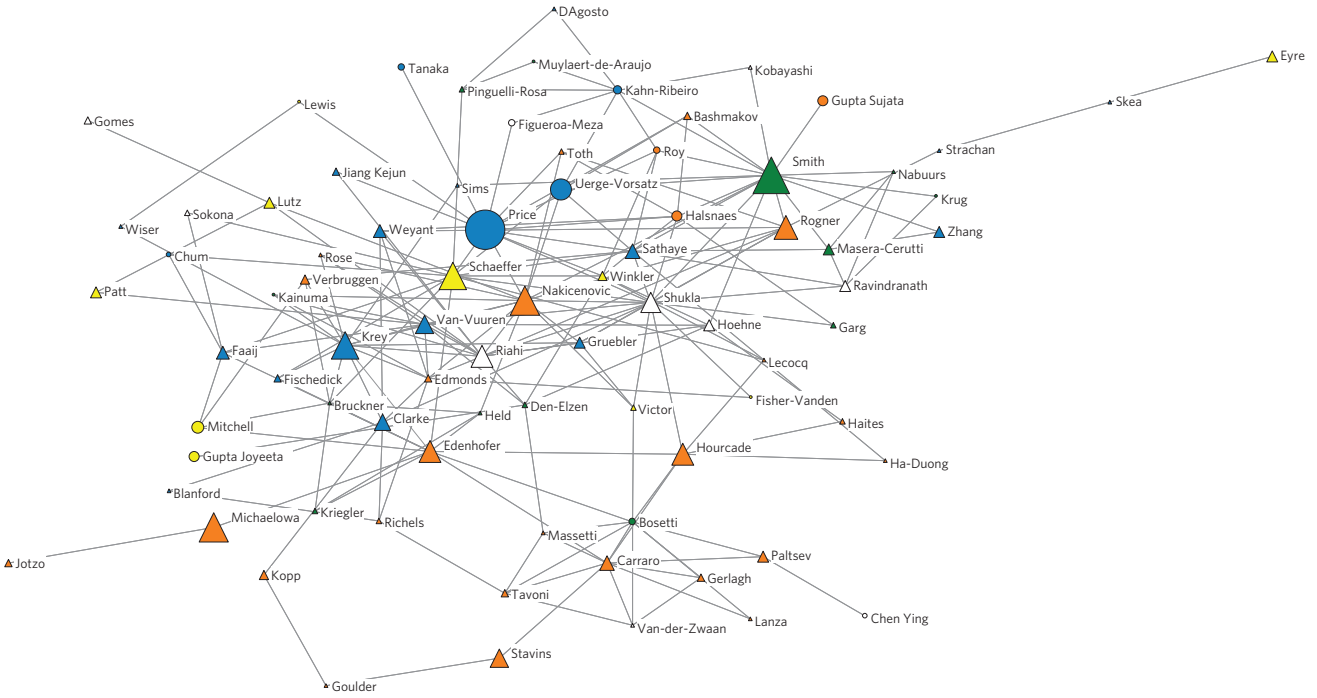

Figure 4 | Two-degree co-authoring network with academic disciplines. Lines indicate that the two authors co-authored at least two articles together. Node size indicates the betweenness score. Shape indicates gender (triangle, men, circle, women). Colour indicates the author's academic discipline (blue, engineering; green, physical, natural and applied sciences; orange, economics; yellow, social sciences; other disciplines in white). Data used to construct this figure can be found in the 'DegreeDisciplines Analysis' and the 'Co-Authoring Patterns Analysis' tabs of the Supplementary Database.

through which the main findings of the assessment are distilled for wider social and political attention.

We also analysed authors' academic 'disciplines', taking into account their highest educational qualification and contribution to one or various research fields (see Methods). This enabled greater sensitivity to deviations in authors' career pathways and avoided equating the highest academic qualification to the author's current research orientation. The results amplify the dominance of economics and engineering-based disciplinary backgrounds, representing 56% of the authors' sample. Sixteen per cent of all contributing authors have well-defined disciplinary backgrounds on physical, natural and applied sciences, and 4% on environmental sciences or related degrees with multiple climate mitigation research foci. Social science scholars represent 22% of this sample, and only 2% are trained in the humanities (see Supplementary Fig. 1).

Figure 4 shows the two-degree co-authoring network with our academic disciplines codes overlaid to see if and how authors cluster along disciplinary lines. It also shows the number of co-authorships between nodes and thus the strength of the collaborative relationship. It can be observed that the core of the co-authoring network is composed of multidisciplinary teams dominated by engineers (blue) and economists (orange), with one physical scientist (Smith, green) well connected to this network. This scientist, in a one-degree network (see Supplementary Figs 2 and 3), seems strongly linked to a larger cluster of other physical scientists, most of whom worked on one specific chapter—chapter 11 on Agriculture, Forestry and Land Use or AFOLU—suggesting strong coordination between a group of closely connected researchers who have been able to join the IPCC to work on these issues. In disciplinary terms, Fig. 4 also suggests that engineers are slightly dominant over economists and, when explored in relation to WGIII AR5 chapters, chapters 5, 6, 7 predominate in the co-authoring network. These are the large modelling chapters (drivers of emissions, transformation pathways, energy systems) that are at the 'heart' of the mitigation report. To the extent there is an epistemic community as suggested above, Fig. 4 depicts the episteme informing the knowledge production of this community.

A harmonized understanding of mitigation

There are three key messages that can be distilled from our analysis. First, despite historical improvements in the relative participation of scientists from the global South, those who have participated in WGIII are mostly trained in northern institutions, overwhelmingly in the USA and UK. In addition, some countries in the global South, notably India and Brazil, are more connected to the core of the IPCC research network than others. Second, there are clear patterns in the authors' network showing the importance of specific international organizations in shaping the field of climate mitigation policy research as represented in the IPCC, and suggestive of the existence of a core network of researchers whose careers are centred on the IPCC and the research represented within it. Third, scholars from the humanities remain marginalized from the IPCC's assessment of climate mitigation in comparison with economists, engineers and applied scientists. These issues can be further investigated and tested exploring the IPCC as a social network across all three working groups and across the five assessment reports since 1990, as well as through interviews and ethnographic research[28].

The shared institutional pathway identified may indicate why WGIII's contribution to the AR5 met with reluctant acceptance in the governments' approval session[29]. Although geographic representation has increased, our analysis makes apparent that actors and institutions in the North continue to play a dominant role in constructing the IPCC's assessment of mitigation and thus their influence on the UNFCCC process. These findings combined might also suggest why the WGIII AR5 presents a fairly strong harmonization of views, compared with the diversity one finds across the social sciences of climate change more broadly, and explain why WGIII finds it difficult to effectively incorporate many important questions into its discourse, notably questions of justice or governance, because the disciplines dominating the WGIII author team do not have these

questions at their core and frame important questions narrowly. For example, referring to 'behavioural change' instead of 'consumption practices' ignores important insights from disciplines (in this case sociology) that remain largely excluded from the process[30].

The conclusion of our analysis, however, is not necessarily that incorporating these broader perspectives would produce a 'better harmonization' of views within the IPCC mitigation reports because the Panel's capacity to produce a 'consensus' might be dependent precisely on these exclusions. Rather, broadening the geographical and disciplinary basis of participation in the IPCC may help unearth the key conflicts and choices to be made in climate change mitigation policy, between different values and interests. This might in turn enable the IPCC to increase its policy usefulness by emphasizing the important political choices societies confront as they respond to climate change, particularly mitigation. Changes in the author team composition and the effects on the report's contents of a broader disciplinary engagement would thus probably not make the approval process of the SPM any easier in the future. However, the mitigation report and its ensuing SPM might well become more legitimate and encompassing to more countries and scientific audiences[21].

Methods

Methods and any associated references are available in the online version of the paper.

Received 1 April 2015; accepted 3 August 2015; published online 7 September 2015

References

1. Hulme, M. & Mahoney, M. What do we know about the IPCC? *Prog. Phys. Geogr.* **34,** 705–718 (2010).
2. Agrawala, S. Context and early origins of the intergovernmental panel on climate change. *Climatic Change* **39,** 605–620 (1998).
3. Agrawala, S. Structural and process history of the intergovernmental panel on climate change. *Climatic Change* **39,** 621–642 (1998).
4. Biermann, F. Institutions for scientific advice: Global environmental assessments and their influence in developing countries. *Glob. Gov.* **8,** 195–219 (2002).
5. Hughes, H. Bourdieu and the IPCC's symbolic power. *Glob. Environ. Polit.* (in the press).
6. Kandlikar, M. & Sagar, A. Climate change research and analysis in India: An integrated assessment of a south–north divide. *Glob. Environ. Change* **9,** 119–138 (1999).
7. Demeritt, D. The construction of global warming and the politics of science. *Ann. Assoc. Am. Geogr.* **91,** 307–37 (2001).
8. Shackley, S. & Wynne, B. Global Climate Change: The mutual construction of an emergent science-policy domain. *Sci. Public Policy* **22,** 218–230 (1995).
9. Lahsen, M. in *Earthly Politics: Local and Global in Environmental Governance* (eds Jasanoff, S. & Martello, M. L.) Ch. 6, 151–172 (MIT Press, 2004).
10. Siebenhuner, B. The changing role of nation states in international environmental assessments—the case of the IPCC. *Glob. Environ. Change* **13,** 113–123 (2003).
11. Skodvin, T. *Structure and Agent in the Scientific Diplomacy of Climate Change: An Empirical Case Study of Science-Policy Interaction in the Intergovernmental Panel on Climate Change* (Kluwer Academic, 2000).
12. Boehmer-Christiansen, S. Britain and the international panel on climate change: The impacts of scientific advice on global warming Part II: The domestic story of the British response to climate change. *Environ. Polit.* **4,** 175–196 (1995).
13. Edwards, P. N. Global climate science, uncertainty and politics: Data-laden models, model-filtered data. *Sci. Cult.* **8,** 437–472 (1999).
14. Hulme, M. Geographical work at the boundaries of climate change. *Trans. Inst. Br. Geogr.* **33,** 5–11 (2007).
15. Miller, C. in *States of Knowledge: The Co-Production of Science and Social Order* (ed. Jasanoff, S.) Ch. 3, 46–66 (Routledge, 2004).
16. Bjurström, A. & Polk, M. Physical and economic bias in climate change research. A scientometric study of IPCC third assessment report. *Climatic Change* **108,** 1–22 (2011).
17. Ho-Lem, C., Zerriffi, H. & Kandlikar, M. Who participates in the Intergovernmental Panel on Climate Change and why: A quantitative assessment of the national representation of authors in the Intergovernmental Panel on Climate Change. *Glob. Environ. Change* **21,** 1308–1317 (2011).
18. Karlsson, S., Srebotnjak, T. & Gonzales, P. Understanding the north–south knowledge divide and its implications for policy: A quantitative analysis of the generation of scientific knowledge in the environmental sciences. *Environ. Sci. Policy* **10,** 668–684 (2007).
19. Vasileiadou, E., Heimeriks, G. & Petersen, A. C. Exploring the impact of IPCC assessment reports on science. *Environ. Sci. Policy* **14,** 1052–1061 (2011).
20. Yearley, S. Sociology and climate change after Kyoto: What roles for social science in understanding climate change? *Curr. Sociol.* **57,** 389–405 (2009).
21. Victor, D. Climate change: Embed the social sciences in climate policy. *Nature* **520,** 27–29 (2015).
22. Hart, D. M. & Victor, D. G. Scientific Elites and the making of United-States-policy for climate-change research, 1957–74. *Soc. Stud. Sci.* **23,** 643–680 (1993).
23. Hecht, A. D. & Tirpak, D. Framework agreement on climate-change—a scientific and policy history. *Climatic Change* **29,** 371–402 (1995).
24. IPCC *Selection of Lead Authors (CLA and LA) and Review Editors for The IPCC Fifth Assessment Report (AR5)* (IPCC, 2010); http://www.ipcc.ch/meetings/bureau-sessions/bureau41rep.pdf
25. Haas, P. M. (ed.) *Knowledge, Power and International Policy Coordination. Special Issue* Vol. 46 (International Organization, 1992).
26. Collins, H. M. Public experiments and displays of virtuosity: The core-set revisited. *Soc. Stud. Sci.* **18,** 715–748 (1988).
27. Crane, D. *Invisible Colleges: Diffusion of Knowledge in Scientific Communities* (Univ. Chicago Press, 1972).
28. Hulme, M. & Mahoney, M. Climate panel is ripe for examination. *Nature* **502,** 604 (2013).
29. Edenhofer, O. & Minx, J. Mapmakers and navigators, facts and values. *Science* **345,** 36–37 (2014).
30. Shove, E. Beyond the ABC: Climate change and theories of social change. *Environ. Plan. A* **42,** 1273–1285 (2010).

Acknowledgements

The authors acknowledge the assistance provided by M. Calvet-Mir in data collection and J. L. Molina in data analysis. E.C. and L.C.-M. acknowledge the financial support of the Biodiversa Framework Project INVALUABLE: Values, Markets, and Policies for Biodiversity and Ecosystem Services (PRI-PIMBDV-2011-1072). E.C. has also received support from the Spanish Research, Development and Innovation Secretariat through a 'Ramón y Cajal' research fellowship (RYC-2010-07183).

Author contributions

E.C. and M.P. had the original idea for the article. L.C.-M. and M.P. developed the social network analysis for training and co-authoring patterns. E.C. analysed the authors' disciplinary backgrounds. H.H. provided important background concerning the existing literature on the sociology of the IPCC, and contributed to data collection and analysis. M.P. and E.C. developed the first draft of the article, and all four authors extensively revised and edited the text. E.C. completed and edited the final version of the article and all Supplementary Information.

Additional information

Supplementary information is available in the online version of the paper. Reprints and permissions information is available online at www.nature.com/reprints. Correspondence and requests for materials should be addressed to E.C.

Competing financial interests

The authors declare no competing financial interests.

Methods

We focused specifically on the Working Group (WG) III writing team for the IPCC Fifth Assessment Report (AR5), dedicated to overview the most recent research related to climate change mitigation. Two of us were Lead Authors in the full report, which was officially published in September 2014 (the Summary for Policy Makers and the full report chapters are available at http://www.mitigation2014.org). WGIII vice-chairs and co-chairs and a scientific supporting team unit, who are part of what is known as the Technical Support Unit (TSU), edit the final report. Each of its chapters is produced by two Coordinating Lead Authors (CLAs) who steer and contribute to the writing-up process, a team of Lead Authors (LAs) who lead the writing-up, a few Contributing Authors (CAs) who provide specific material, and two or three Review Editors (REs).

We collected data on all CLAs and LAs, as well as the vice-chairs and co-chairs of WGIII (that is, a total of 273 members) on the basis of their most recent curriculum vitae (CV) ('CV Data' tab in the Supplementary Database). CVs were obtained from institutional, personal and social network websites, and authors for whom this was not available were asked directly by email for their CV. We gathered information on author name, gender, chapter in which they participated, their role in the chapter, the country they represented in the IPCC, as well as where they work at present or had worked in the past, where they got their PhD (or highest educational qualification), and any other country of citizenship. We also analysed career trajectories, specifically employment history in academic and non-academic institutions. We employed acronyms to codify most institutions ($N = 705$, with 606 acronyms) and we coded numerically the other data gathered. Gender was coded as 0 or 1 for female or male respectively. Countries were coded using pre-defined country groupings, namely: Europe (1); Eastern Europe (except Russia and EU countries) (2); USA/Canada (3); Others OECD (Organisation for Economic Co-operation and Development) (4); BRICS (5); Latin America (except Brazil) (6); Sub-Saharan Africa (except South Africa) (7); MENA (Middle East and North Africa) (8); South and South East Asia (9); and Oceania (10). The author's role in each chapter was coded giving numbers to each pre-defined IPCC role, namely Coordinating Lead Author (1); Lead Author (2); Review Editor (3); Co-Chair (4); and Vice-Chair (5). Authors' academic disciplines include Economics (1); Engineering (2); Environmental Sciences (3); Humanities (4); Physical, Natural & Applied Sciences (5); and Social Sciences (6) (see correspondent tabs in Supplementary Database).

We recorded the discipline of their PhD or highest academic qualification on the basis of their own personal description in the CV or relevant websites, and identified the authors' research fields and overall academic disciplines (see 'DegreeDisciplines' and 'ResFields AcadDisciplines' tabs in Supplementary Database). In doing so, we first recorded the PhD or highest degree title, as stated on the CV, but grouped similar degree titles to reduce observations. Second, on the basis of a preliminary round of CV analyses, we defined a number of research fields that IPCC AR5 authors have contributed to during their academic career, informed by their CV statements, their publication record or related web pages. Third and finally, we used the information on PhD or highest academic qualification, combined with the research fields, to infer an academic discipline for each author (Supplementary Table 2 and Supplementary Fig. 1). Authors for whom we were not able to find data on their PhD degree or highest qualification were treated as missing data for both PhD degree and academic discipline, except for two central authors (Shukla and Riahi) for whom we attributed the disciplinary background on the basis of their peer-reviewed publications and their own description in personal websites.

We developed this three-step approach for analysing authors' disciplines to enable greater sensitivity to multidisciplinary careers, and to avoid equating authors' PhD training with their current research field. However, this proved challenging because many authors had studied climate change mitigation issues from a variety of disciplines and epistemologies. Indeed, one conclusion to be drawn from an effort to code IPCC authors according to disciplinary boundaries is that many authors involved in this field work across traditional disciplinary divides in ways that make such an assessment difficult.

We also examined the authors' publication record, identifying how many publications each author had co-authored with other WGIII authors, according to the peer-reviewed journal articles and books noted in the available versions of their respective CVs rather than on those present in scientific databases (for example, Scopus, Web of Knowledge; see 'Co-Authoring Patterns Analysis' tab in Supplementary Database). Finally, we analysed how many 'top 20' authors had participated in the author teams of previous WGII and WGIII IPCC assessments (AR4, TAR, SAR and FAR) (see 'Top 20 IPCC Part Analysis' in Supplementary Database).

We used social network analysis to analyse our data, following examples of similar applications of this research tool in environmental governance studies[31,32]. Social network analysis is a methodological tool that enables exploration of the structure of a social group or network by examining patterns of connections between the group or network elements (often called 'nodes'). It is possible to measure the centrality of a particular node within the network (for example, individual, institution, country) by examining the number of direct connections of such a node with other nodes—so-called 'degree'—or by examining the extent to which a given node appears among the indirect links (that is, how node A is connected to node B not directly, but rather indirectly through node C or nodes D and E) that connect the rest of the nodes—so-called 'betweenness'—(see below).

We employed the software UCInet6-Netdraw[33] to develop three different types of informative network: one showing the patterns of connection between countries using the key moments in an author's career trajectory, including the country they undertook their PhD and current country of work; one for authors' co-authoring patterns; and one for the institutions through which the most collaborative authors have passed. We calculated each individual centrality measure (that is, 'betweenness') for the three networks. Betweenness centrality indicates the number of times that actor rests on the geodesic (shortest path) between two actors. If an actor rests between many other actors in the network, then this actor has the chance to withhold or distort information she or he receives, thereby influencing the whole network. The notion of betweenness centrality is related to that of a 'broker', because this is an individual who rests between disconnected others or segments of the network. The notion of a 'broker' comes from Ron Burt's notion of a 'structural hole', which refers to the existence of a gap in the social network between disconnected others[34]. Brokers can fill these structural holes and gain advantage for themselves and the entire network. Typically, these structural holes are measured through betweenness[35].

Some methodological limitations suggest taking our results with caution but do not invalidate our findings. First, we were unable to find complete CV data for all authors (see 'Missing Data' tab in Supplementary Database). However, for most of these cases, we were able to retrieve key information from the IPCC's web page (that is, IPCC representing country, chapter, authorship role and current institution), and using other authors' CVs (for publications). As highlighted earlier, we did not find data on the highest academic training degree for 20 authors, even after email contact, and thus they were not included in our analysis of research fields and disciplinary background. We also lacked data on employment history (beyond current institution) of another 47 authors, including eight of the former group, but we do not think this skews the institutional influence results because we are still covering the career trajectory of more than 82% of the authors.

Second, the fact that we determined authors' collaborative patterns through the number of peer-reviewed articles and books appearing in their CVs might have probably reduced the number of joint publications identified, and it might have also underplayed the importance of other connections taking place through consultancy contracts or collaborative activities other than co-publishing. However, these connections are likely to be partially reflected through the analysis of country and institution-based networks, for instance, if two IPCC authors got to know each other through an organization of work or study, despite not publishing together.

Third, we acknowledge that the attribution of an academic discipline to each author is subjective, but when grounded on the author's research fields and complemented with the discipline of their highest academic qualification, it serves as effective data on disciplinary expertise across authors. In this regard, and to ensure consistency in judgement, only one of us undertook the analysis of CVs, academic qualifications, research fields and academic discipline. Subsequently, 50 observations were randomly selected for crosscheck and analysed by other team members. When discordance was found, the attribution of research fields and academic discipline was attributed based on consensus. Despite these caveats, our study remains relevant because it highlights connection patterns between authors in a systematic way and confirms relations found in similar studies using different methods. In the future, it will be worth exploring connections between writing teams of WGIII over several reports, as well as investigating disciplinary divides within and co-authoring networks across WGI and WGII, respectively.

References

31. Bodin, O. & Prell, C. (eds) in *Social Networks and Natural Resource Management. Uncovering the Social Fabric of Environmental Governance* Ch. 14, 347–373 (Cambridge Univ. Press, 2011).
32. Rantala, S. *Knowledge and Brokerage in REDD+ Policy Making: A Policy Network Analysis of the Case of Tanzania* Working Paper No. 201203 (Sustainability Science Program, Harvard University, 2012).
33. Borgatti, S. P., Everett, M.-G. & Freeman, L. C. *Ucinet for Windows: Software for Social Network Analysis* (Analytic Technologies, 2010).
34. Burt, R. S. *Structural Holes: The Social Structure of Competition* (Harvard Univ. Press, 1992).
35. Brass, D. J. in *Research in Politics and Society* (eds Moore, G. & Whitt, J. A.) 295–323 (JAI, 1992).