International Journal of Petroleum and Gas Engineering Research, 7 (1), 109-116, 2024
Print ISSN: ISSN 2514-9253
Online ISSN: ISSN 2514-9261
Website: https://www.eajournals.org/
Publication of the European Centre for Research Training and Development-UK

Cross-border CO_2 Transport Decreases Public Support for Carbon Capture and Storage

Obianuju Ogochukwu Ndibueze

University of Lagos
Department of Mechanical Engineering

doi: https://doi.org/10.37745/ijpger.17v7n1109116 Published May 05, 2024

Citation: Ndibueze O.O. (2024) Cross-border CO2 Transport Decreases Public Support for Carbon Capture and Storage, *International Journal of Petroleum and Gas Engineering Research*, 7 (1), 109-116

ABSTRACT: *Carbon Capture and Storage (CCS) of CO2 has become indispensable to reach net-zero targets. Investments into cross-border CO2 transport infrastructure are considered essential to the cost-efficiency of a CCS strategy. We conduct multifactorial vignette experiments in four European countries and Canada to disentangle the impact of cross-border CO2 transport on individuals' acceptance and fairness evaluations of CCS. We find its perceived unfairness to clearly hinder public acceptance of CCS.*

KEYWORDS: cross-border CO2, transport decreases, public support, carbon capture, storage

INTRDOCUTION

As critical milestones in the fight against Climate Change are missed, pressures are mounting to use all available technology options to reduce atmospheric CO21. This includes carbon removal using Carbon Capture and Storage (CCS), a set of technologies aimed at capturing CO2 directly at the point of emission and subsequently transporting it to underground reservoirs for permanent storage. The indispensability of CCS technology is acknowledged by different actors, among others in Europe and North America2,3,4. For example, the European Union (EU) expects that "hundreds of millions of tonnes CO2 annually" are captured and stored by the second half of this century. To use CSS in a cost-efficient way, the EU emphasises the need for alliances that invest into cross-border CO2 transport infrastructure for linkingemission sources and sinks through supply chains5,6,7. Yet, previous research has shown that the European and North American public hold overall negative attitudes towards CCS8,9,10,11 that imply strong preferences for storing only CO2 emissions of domestic origin12,13,14. If this position manifests, existing
policy plans for cost-efficient CCS and the public acceptance of CCS would move even further apart.

Against this background, we employ a multifactorial vignette experiment to uncover public acceptance with a focus on the perceived fairness of cross-border CO2 transport in five countries. Expanding onprevious research14,15,16,17, our experimental design allows us to disentangle the relative importance of attributes of CSS implementation, including cross-border CO2 transport, for acceptance and fairness evaluations. Online surveys (see Methods) were conducted in Canada, Germany, Netherlands, Norway, and UK, that differ in the stage of their public discourse and implementation of CSS. In each country, between 988 and 1,021 citizens evaluated six potential scenarios of CCS implementation in

their country. Scenarios experimentally varied seven attributes including factors discussed in the literature for their ability to affect public perceptions and acceptance of energy development11,18,19: implementation body, proximity to respondents' place of residence, CO2 mitigative capacity, geographical origin of CO2 emissions, extent of public consultation in CCS approval, extent of information provision regarding CCS seismicity risks, and compensation of affected communities by the CCS operator. In each scenario, the CO2 origin was expressed as either coming exclusively from domestic sources or a combination of domestic and imported CO2 from one of the five countries included in the study. Subsequently, participants each time responded to two questions on 11-point scales (-5 to + 5), "How acceptable is this

CCS development to you?" and "How fair is the proposed storage of CO2 from domestic and if applicable imported emissions to you?".Figure 1 depicts the distribution of 30,918 fairness evaluations across the five countries irrespective of the vignette attributes combinations but accounting for the origin of the CO2. For all countries it reveals a slightly positive fairness evaluation of the implementation of CCS when only domestic emissions are concerned. Among domestic only scenarios, UK citizen are most supportive (mean = 0.55, CI 0.38/0.72), followed by Canadians (mean = 0.40, CI 0.22/0.57), the Norwegian public (mean = 0.24, CI 0.07/0.41), and Germans (mean = 0.16, CI -0.01/0.32). Dutch citizens are the least supportive (mean = 0.07, CI -0.09/0.23). In all countries evaluations become negative when only CCS scenarios with cross-border CO2 imports are considered, where especially the peak for the lowest fairness value is noteworthy. Regarding scenarios with cross-border CO2 imports, the Norwegian public is most supportive (mean = -0.13, CI -0.21/-0.05), followed by UK citizen (mean = -0.27, CI -0.35/-0.19), Germans (mean = -0.52, CI -0.59/-0.45), and Canadians (mean = -0.53, CI -0.61/-0.45). Again, Dutch citizens are the least supportive (mean = -0.63, CI
-0.70/-0.55). All differences in means between domestic only and domestic plus cross-border CO2 import scenarios are statistically significant (two-sided t-tests with $p < 0.0001$, see suppl. material, Table S1). Differences range between 0.93 (CI 0.73/1.12) for Canada and 0.37 (CI 0.18/0.56) for Norway. The overall negative fairness scores for CO2 imports add important statistical evidence, for example, on the future of a European CO2 transport infrastructure that exists in EU framework planning but does notreflect the state of public perceptions of CCS development in the different countries3,13.

To further disentangle the fairness perceptions of cross-border CO2 transport from the effects of other attributes of CSS implementation, we estimated random intercept regression models of vignette ratings on the vignette scenario attributes (Methods, suppl. material Tables S2 and S3). The results depicted in Fig. 2 confirm that across all countries CCS scenarios involving CO2 imports are perceived as less fair than the storage of only domestic CO2. Effect sizes are larger than for any other CCS attribute ranging from − 0.3 scale points for CO2 imports from the Netherlands to Norway to -1.1 scale points for imports from Germany to Canada. Noteworthy, the cross-Atlantic transport of CO2, i.e., from Canada to Europe and vice versa, is only rated least fair in Germany and the Netherlands, but not in Canada, Norway, and UK. While the EU Commission classifies cross-border transport of CO2 as a Project of Common Interest (PCI) essential to the Union's climate policy objectives20 citizens in four countries (and Canadians) summarily reject the notion of cooperation on CO2 transport. In other words: for the citizens in all five countries cross-border transport of CO2 is a non-starter no matter whether its perceived fairness or effects on CCS acceptance are concerned (see suppl. material Table S3).

As expected, attributes deemed to increase public involvement positively affect evaluations of CCS for fairness in Fig. 2, and acceptance (Appendix). Our results clearly show that consulting the public during the CCS approval process11,21, providing transparency through information sharing on the seismic and CO2 leakage risks of CCS22,23 matter irrespective of the country studied. Acceptance and perceived

fairness evaluations also benefit from increasing geographical distances to a proposed CSS development that together with the psychological distance might enforce the NIMBY phenomenon24. Interestingly, neither the potential mitigative contribution of CCS to CO2 removal nor the type of implementing body,
and thus possible differences in public trust between CCS stakeholder groups11,19 appear to matter to views on CCS on either side of the Atlantic.

In line with the literature on energy development18,25, the provisions of direct compensating economic benefits to citizens does lift both fairness perceptions and acceptance. However, on the question of whether compensation may be able to directly settle the negativity of CO2 imports, model results are unanimous. Magnitudes of interaction effects between CO2 import origins and citizen financial incentives are largely insignificant (see suppl. material, Table S4). Admittedly a niche case, Canadians would tolerate German CO2 imports given financial incentives, but the positive effect is far from offsetting the overall negative fairness assessment of importing CO2 for CCS. As such, we find that local compensation schemes alone are unable to successfully offset the multitude of current intertwined public concerns over the procedural and distributive fairness and likelihood of tangible economic and wider benefits of a large- scale commercial implementation of CCS11,26.

Considering the growing scientific and, following with some delay, political consensus that CCS is essential for any climate strategy to meet net-zero by 2050, our results outline substantial challenges for decision makers. Societal opposition grounded in the strongly perceived unfairness of CO2 imports is hindering support for CSS. This result stands against the emerging view that cross-border transport is indispensable to cost-efficient climate solutions using CCS. Even if decision makers were to consider procedural and distributive justice concerns, including financial compensation, no single measure alone valued positively by citizens in the five countries is sufficiently compensating for the negative effects of CO2 imports. Therefore, to engage the public with the objective of shifting perceptions and acceptance of CCS, well-designed combinations of consultation and transparent risk communication measures appear to be the most mutable policy approach. Without public consent, the goal of significant and long-term decarbonisation of carbon intensive sectors using CCS as part of net-zero strategies could quickly become another missed milestone.

METHODS

Date Collection

The study was implemented with quota representative samples of the general public in Germany (n = 1,124), the Netherlands (n = 1,000), Norway (n = 1,009), the UK (n = 1,021), and Canada (n = 988) in December of 2022. The experiment was administered by online survey provider SurveyEngine via proprietary software. Respondents were recruited through survey panel providers in each country with sample quotas for age, gender, education, and household income to assure representation. Successful completions received small monetary incentive from SurveyEngine for their participation. An accompanying two-wave survey instrument was designed to measure public attitudes and preferences around climate mitigative technologies with an emphasis on CSS and its potential induced seismicity risks.The vignette experiment was designed to elicit respondents' ratings of six CCS implementation scenarios described by seven experimental attributes expressed at varying levels (reference levels in italics): (1) CCS implementation (industry consortium, a government-industry partnership, your national government); (2) proximity to the respondent's place of residence (up to 50km, between 50km to 100km, more than 100km); (3) mitigative capacity (equivalent to the emissions of 5%, 10%, or 20% of all households in respondents' state of residence; (4) geographical

origin of CO2 emissions (domestic emissions only, domestic and imported emissions). The origin of CO2 imports was expressed in terms of a CCS facility that will "store domestic emissions and CO2 imported from X", with X being one of Germany, the Netherlands, Norway, the UK, or Canada. As countries cannot import from themselves, Poland was substituted for a European country and the USA in case of Canada. (5) extent of public consultation (no consultation, relevant NGOs only, several formats at community, state and national level); (6) extent of information provision regarding seismicity risks (no information, online at approval stage only, as long as the project runs), (7) compensation by the CCS operator (no financial compensation, preferential contracts for businesses in the host community, direct financial compensation for citizens in the host community).

Before entering the experiment, respondents were provided with a brief introduction and explanation of the vignette approach in their language. This was followed by a mandatory information screen that provided a neutral definition of CCS together with a visualization of the process of capturing, transporting, and storing CO2. This information was also available "on demand" during the experiment. Respondents were then asked to rate each of six vignette CCS implementation scenarios on an 11-point scale, from − 5 to + 5, in terms of "How acceptable is this CCS development scenario to you?" and "How fair is the proposed storage of CO2 from domestic and if applicable imported emissions to you?" These rating questions present the dependent variable in the models discussed in the main text.

Based on the seven attributes expressed in three or six levels the full factorial experimental design contains 8,748 unique vignettes. Using an orthogonal fractional factorial design (foldover) allowing for two-way attribute interactions resulted in a perfectly orthogonal and level balanced experimental design comprised of 144 vignettes. Each respondent was shown six randomly drawn vignettes (without replacement). With a total of 5,142 respondents across the five countries each CCS vignette was rated approximately 35 times resulting in a total of 30,852 evaluations of the perceived fairness and overall acceptance of hypothetical CCS implementation scenarios. To investigate the question of perceived fairness of cross-border transport of CO2 emissions for CCS and overall public acceptance of CCS technology we estimate a series of random intercept models that regress participants' vignette ratings on vignette scenario attributes at their respective levels (suppl. material, Tables S2, S3, S4). In contrast to simple OLS models, our random effects model specifications account for the nested structure of vignette ratings at the respondent level and the presumed heterogeneity in respondents' evaluation of CCS27. To test whether the attribute "direct financial compensation for citizens in the host community" is able to improve fairness perceptions of CO2 imports for CCS, the models include interactions effects of CO2 origin country and the financial compensation attribute (e.g. "XX_financ"). We estimate all models using the Random-effects GLS regression (xtreg) command in Stata 15.

Declaration

Human Subject Research

Human subjects' approval for the survey-experimental research study was granted by the Human Research Ethics Board (Pro00123473) at the University of Alberta, Canada. Informed consent was obtained from all research participants prior to entering the study. All methods were performed in accordance with the relevant guidelines and regulations.

Reporting summary

Further information on the research design is available based on reasonable request to the authors.

Data Availability

The dataset analysed for this study will be made available upon publication of the manuscript.

REFERENCES

I. PCC. 2022. Climate Change 2022: Mitigation of Climate Change. IPCC Sixth Assessment Report, Working Group III: Mitigation of Climate Change. Summary for Policymakers, 48 p. Available at: . Accessed: Aug 20, 2023.
2. European Commission (2023): Investment needs assessment and funding availabilities to strengthen EU's Net-Zero technology manufacturing capacity. Commission Staff Working Document. European Commission. Brussels. Available at: single-market- economy.ec.europa.eu/publications/staff-working-document-investment-needs-assessment-and- funding-availabilities-strengthen-eus-net_en. Accessed: September 15, 2023.
3. Clean Air Taskforce (CATF) 2022. A Policy Framework for Carbon Capture and Storage in Europe. Available at: . Accessed June 6, 2023.
4. International Energy Agency (IEA). 2020. Special report on carbon capture utilisation and storage. CCUS in clean energy transitions. Paris, France, International Energy Agency, 174 pp. Available at: . Accessed June 9, 2023.
5. d'Amore, F., Carmelo Romano, M., Bezzo, F. 2021. Optimal design of European supply chains for carbon capture and storage from industrial emission sources including pipe and ship transport. International Journal of Greenhouse Gas Control, 109, 103372. doi.org/10.1016/j.ijggc.2021.103372.
6. Fuss, S., Canadell, J.G., Ciais, P., Jackson, R.B., Jones, C.D., Lyngfelt, A., Peters, G.P., and Van Vuren, D.P. 2020. Moving toward Net-Zero emissions requires new alliances for carbon dioxide removal. One Earth, 3, 145–149. doi.org/10.1016/j.oneear.2020.08.002.
7. Zero Emissions Platform (ZEP). 2019. Business models for commercial CO2 transport and storage Delivering large-scale CCS in Europe by 2030. ZEP report on Business Models for Commercial CO2 Transport and Storage. Available at: https://zeroemissionsplatform.eu/wp-content/uploads/ZEP- report-on-Business-Models-for-Commercial-CO2-Transport-and-Storage.pdf. Accessed July 28, 2023.
8. Akerboom S., Waldmann S., Mukherjee A., Agaton C., Sanders M., Kramer, G.J. 2021. Different This Time? The Prospects of CCS in the Netherlands in the 2020s. Frontiers.in Energy Research. 9, 644796. doi.org/10.3389/fenrg.2021.644796.
9. Pianta, S., Rinscheid, A., Weber, E.U. 2021. Carbon Capture and Storage in the United States: Perceptions, preferences, and lessons for policy. Energy Policy, 151, 112149. doi.org/10.1016/j.enpol.2021.112149.
10. Arning, K., Offermann-van Heek, J., Linzenich, A., Kaetelhoen, A., Sternberg, A., Bardow, A., Ziefle, M. 2019. Same or different? Insights on public perception and acceptance of carbon capture and storage or utilization in Germany. Energy Policy 125, 235e249. doi.org/10.1016/j.enpol.2018.10.039.
11. Whitmarsh, L., Xenias, D. Jones, C.R. 2019. Framing effects on public support for carbon capture and storage. Palgrave Communications, 5(17). doi.org/10.1057/s41599-019-0217-x.
12. Merk, C., Liebe, U., Meyerhoff, J., Rehdanz, K. 2023. German citizens' preference for domestic carbon dioxide removal by afforestation is incompatible with national removal potential. Nature Communications Earth and Environment, 4, 100. doi.org/10.1038/s43247-023-00713-9.
13. Merk, C., Andersen, G., Nordø, Å.D., Helfrich, T. 2023. Carbon Capture and Storage - Publics in five countries around the North Sea prefer to do it on their own territory. Kiel Working Paper, 2252. Available at: . Accessed: Sept 5, 2023.
14. Merk, C. Dyrnes Nordø, Å., Andersen, G., Martin Lægreid, O., Tvinnereim, E. 2022. Don't send us your waste gases: Public attitudes toward international carbon dioxide transportation and storage in Europe, Energy Research & Social Science, 87, 102450. doi.org/10.1016/j.erss.2021.102450.
15. Lokuge, N., Phillips, J., Anders, S., van der Baan, M. 2023. Human-induced seismicity and the public acceptance of hydraulic fracturing: A vignette experiment. The Extractive Industries and Society, 15, 101335. doi.org/10.1016/j.exis.2023.101335.
16. Lutzke, L. and Árvai, J. 2021. Consumer acceptance of products from carbon capture and utilization. Climatic

Change 166 (15). doi.org/10.1007/s10584-021-03110-3.
17. Dütschke, E., Wohlfarth, K., Höller, S., Viebahn, P., Schumann, D., Pietzner, K. 2016 Differences in the public perception of CCS in Germany depending on CO2 source, transport option and storagelocation. International Journal of Greenhouse Gas Control, 53, 149–159. doi.org/10.1016/j.ijggc.2016.07.043.
18. Buck. H.J. 2021. Social science for the next decade of carbon capture and storage, The Electricity Journal, 34(7), 107003. doi.org/10.1016/j.tej.2021.107003.
19. Cox, E., Spence, E., Pidgeon, N. 2020. Public perceptions of carbon dioxide removal in the United States and the United Kingdom. Nature Climate Change.10, 744–749. doi.org/10.1038/s41558-020- 0823-z.
20. European Commission. 2021. Candidate PCI projects in cross-border carbon dioxide (CO2) transport networks. Consultation on the list of candidate Projects of Common Interest in cross-border carbon dioxide (CO2) transport networks. Available at: energy.ec.europa.eu/consultations/consultation-list- candidate-projects-common-interest-cross-border-carbon-dioxide-co2-transport_en#reference- documents. Accessed: July 24, 2023.
21. Dunphy, N.P., Velasco-Herrejón, P., Lennon, B., Smith, A.L. 2022. Engaging effectively with public(s) in the realization of CCS projects. Proceedings of the 16th Greenhouse Gas Control Technologies Conference (GHGT-16), Lyon, France. Available at: papers.ssrn.com/sol3/papers.cfm?abstract_id = 4286313. Accessed: Sept 4, 2023.
22. Haemmerli, L. and Stauffacher, M. 2020. The Neglected Role of Risk Mitigation Perception in the Risk Governance of Underground Technologies—The Example of Induced Seismicity. International Journal of Disaster Risk Science, 11, 630–639. doi.org/10.1007/s13753-020-00298-3.
23. Trutnevyte, E. and Ejderyan, O. 2018. Managing geoenergy-induced seismicity with society. Journal of Risk Research, 21(10) 1287–1294. doi.org/10.1080/13669877.2017.1304979.
24. Braun, C. 2017. Not in My Backyard: CCS Sites and Public Perception of CCS. Risk Analysis, 37(12), 2264–2275. doi.org/10.1111/risa.12793.
25. Boudet, H. 2019. Public perceptions of and responses to new energy technologies Nature Energy, 4, 446–455. doi.org/10.1038/s41560-019-0399-x.
26. Krevor, S., de Coninck, H., Gasda, S.E., Singh Ghaleigh, N., de Gooyert, V., Hajibeygi, H., Juanes, R., Neufeld, J., Roberts, J.J., Swennenhuis, F. 2023. Subsurface carbon dioxide and hydrogen storage for a sustainable energy future. Nature Reviews Earth and Environment, 4, 102–118. doi.org/10.1038/s43017-022-00376-8.

International Journal of Petroleum and Gas Engineering Research, 7 (1), 109-116, 2024
Print ISSN: ISSN 2514-9253
Online ISSN: ISSN 2514-9261
Website: https://www.eajournals.org/
Publication of the European Centre for Research Training and Development-UK

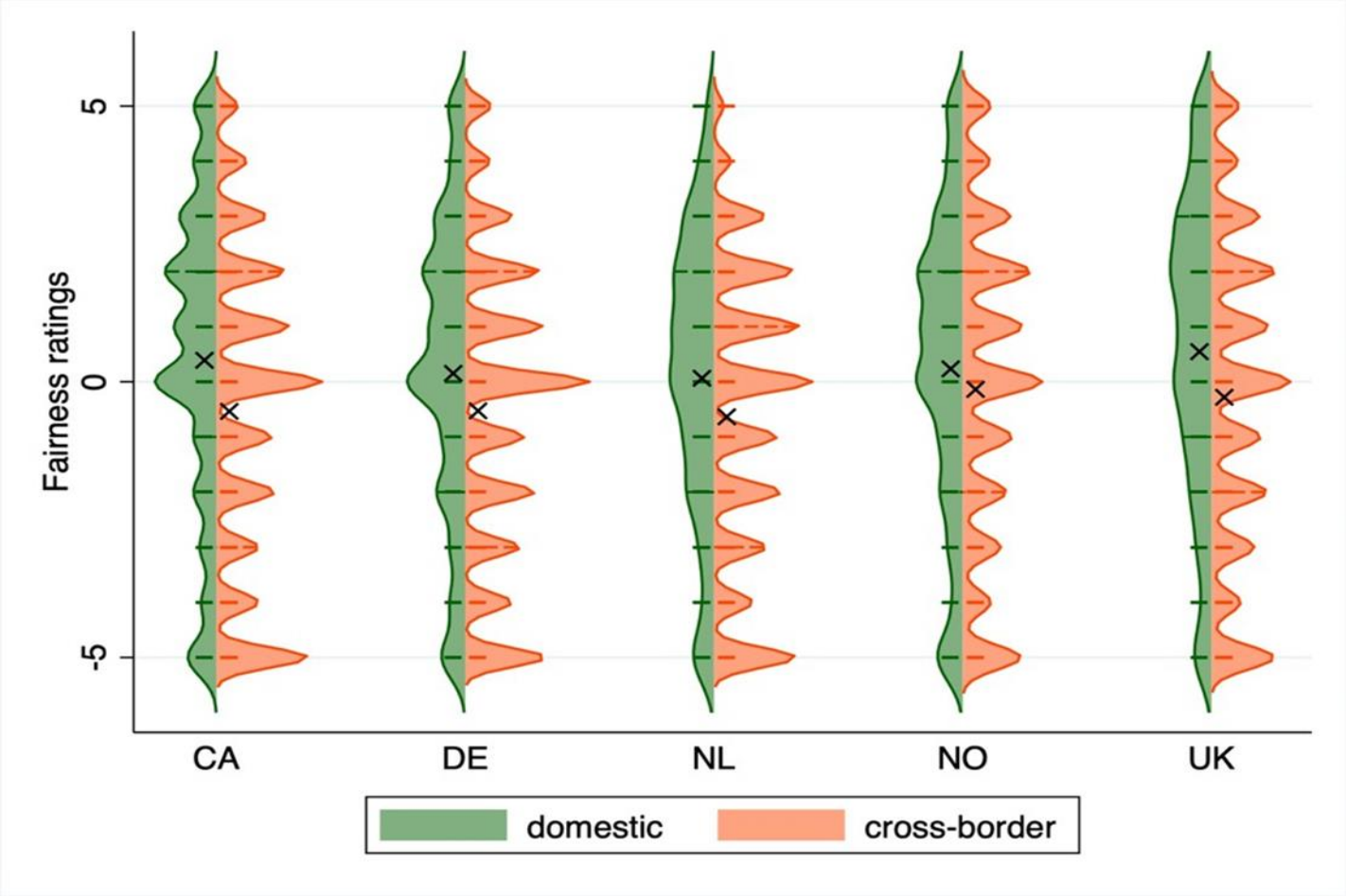

Figure 1

Violin plots of fairness ratings of CCS implementation scenarios by CO_2 emissions origin. Crosses (x) mark mean scenario evaluations, vertical axis. (Canada n = 5,988, Germany n = 6,744, Netherlands n = 6,000, Norway n = 6,054, UK n = 6,126).

International Journal of Petroleum and Gas Engineering Research, 7 (1), 109-116, 2024
Print ISSN: ISSN 2514-9253
Online ISSN: ISSN 2514-9261
Website: https://www.eajournals.org/
Publication of the European Centre for Research Training and Development-UK

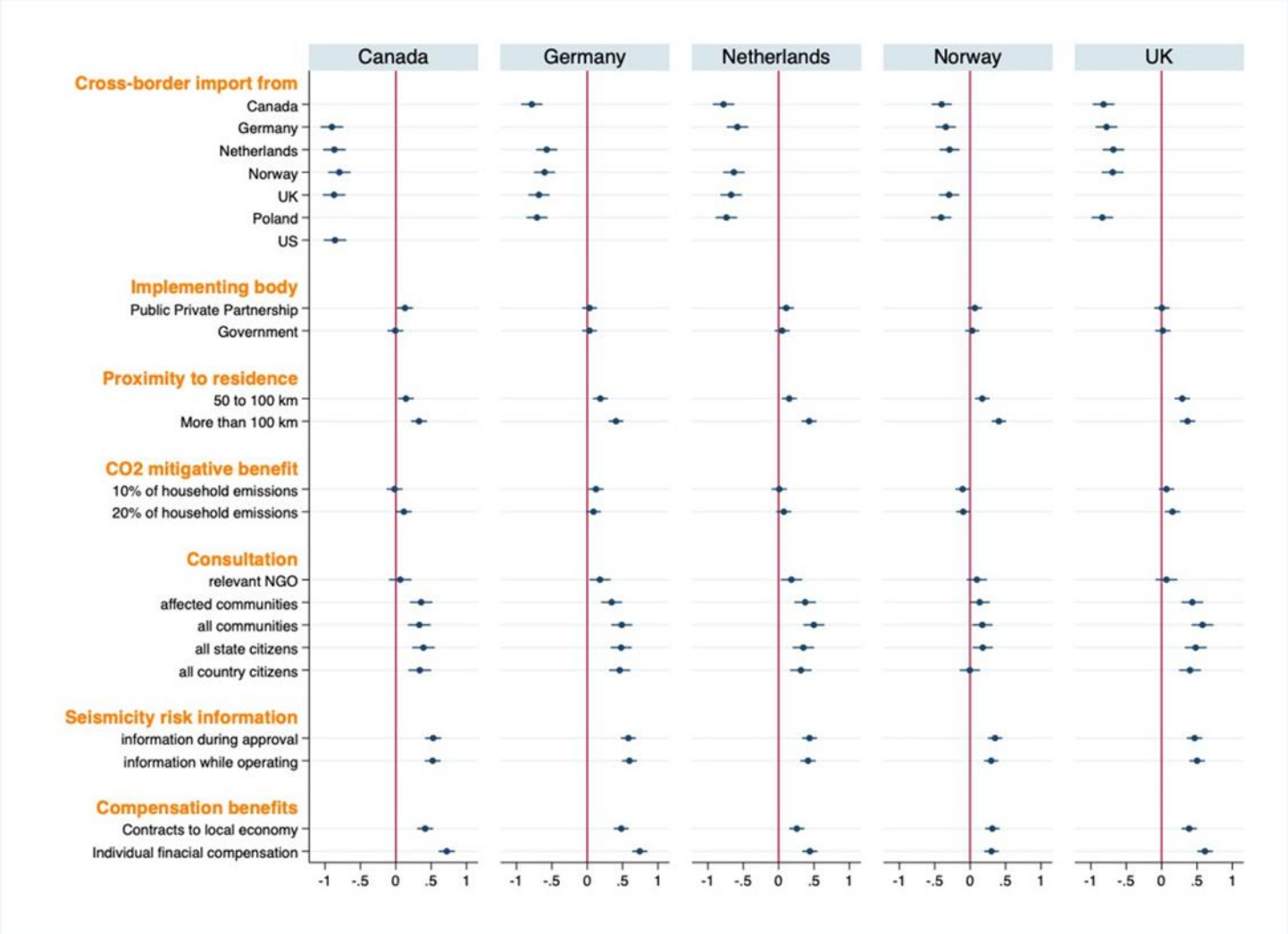

Figure 2

Random effects model results of CCS implementation attributes on citizens' vignette ratings based on perceived fairness.

Note: Dots indicate magnitudes of marginal effect estimates of attribute levels with 95% confidence intervals. Reference levels for attribute effects: industry consortium for implementing body; up to 50km for proximity to residence; 5% for CO2 mitigative benefit; no consultation for extent of public consultation; no information for seismicity risk information; no financial compensation for compensation benefits. n = 5,988 for Canada; n = 6,744 for Germany; n = 6,000 for Netherlands; n = 6,054 for Norway; n = 6,126 for UK.

International Journal of Petroleum and Gas Engineering Research, 7 (1), 109-116, 2024
Print ISSN: ISSN 2514-9253
Online ISSN: ISSN 2514-9261
Website: https://www.eajournals.org/
Publication of the European Centre for Research Training and Development-UK

International Journal of Petroleum and Gas Engineering Research, 7 (1), 109-116, 2024
Print ISSN: ISSN 2514-9253
Online ISSN: ISSN 2514-9261
Website: https://www.eajournals.org/
Publication of the European Centre for Research Training and Development-UK

International Journal of Petroleum and Gas Engineering Research, 7 (1), 109-116, 2024
Print ISSN: ISSN 2514-9253
Online ISSN: ISSN 2514-9261
Website: https://www.eajournals.org/
Publication of the European Centre for Research Training and Development-UK

International Journal of Petroleum and Gas Engineering Research, 7 (1), 109-116, 2024
Print ISSN: ISSN 2514-9253
Online ISSN: ISSN 2514-9261
Website: https://www.eajournals.org/
Publication of the European Centre for Research Training and Development-UK