Don't send us your waste gases:
Public attitudes toward international carbon dioxide transportation and storage in Europe

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Abstract
Large-scale deployment of Carbon Capture and Storage (CCS) is part of the pathways for limiting global warming to 1.5°C and yet, negative public perceptions of CCS have challenged the realization of several projects in Europe over the last decade. This study is the first to look at the effect of exporting or importing CO_2 on public perceptions. We conducted a fractional factorial survey experiment in Germany and Norway varying the nationality of the CO_2 source and of the storage site of a hypothetical CCS project. We find that respondents from both countries do not evaluate offshore and onshore storage differently but otherwise we find substantial differences between countries. Norwegian respondents react to the experimental manipulation: despite an overall more positive attitude toward CCS, they evaluate a project where foreign sourced CO_2 is stored in Norway substantially more negatively compared to a project where domestically sourced CO_2 is stored in Norway. By contrast, German respondents are not affected by the variation of the nationality of emissions or the storage site. We connect this finding to construal level theory, arguing that Germans are more psychologically distanced from CCS than Norwegians due to differences in general familiarity with CCS and the political support for CCS; this makes them less sensitive to our experimental manipulation. The uncovered decrease in public support for CCS when CO_2 is exported from Germany to Norway challenges the feasibility of the current plans of Northern European states for a CO_2 transport and storage infrastructure.

Keywords: Public perception; CCS; CO_2 storage; international cooperation; Norway; Germany; acceptability

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1. Introduction

Carbon capture and storage (CCS) is an important element in the scenarios for limiting global warming to 1.5°C. According to the IPCC's illustrative model pathways, 550-1017 Gt CO_2 would have to be stored by the end of the century [1]. This includes CCS for the mitigation of residual emissions from sources like waste incineration or cement production and at varying scales negative emissions from the combination of bio-energy generation combined with CCS. Today about 40 million t of CO_2 are captured [2]. An IPCC [3] special report on CCS from 2005 assessed storage in depleted oil and gas fields as a well-understood technology and enhanced oil recovery as economically feasible. Fifteen years later, CCS with the explicit aim to mitigate emissions has not yet moved beyond the level of demonstration projects. Main barriers for large-scale deployment are found in the economic, political and societal sphere: the costs along the entire value chain have not yet been assessed, which renders commercialization uncertain and leaves public acceptability unclear. Both factors have potentially negative effects on the political support for CCS [4,5].

However, after a period of stalemate, the International Energy Agency [2] sees new momentum building up with changes in international law and new investments into CCS development. Following the initiative of Norway and the Netherlands, the London Protocol was amended to allow cross-border transportation and storage of CO_2. The European Commission has identified several projects for cross-border CO_2 transportation as Projects of Common Interest (PCI) to accelerate infrastructure development [6]. This opens up the possibility to establish a cross-border market for CO_2 storage in Europe. One of the PCIs is the Northern Lights project where Norway, in their second phase of the project starting in 2025, plans to import CO_2 from capture sites in Scotland, Belgium, Germany, Sweden and England and to store it in the North Sea.[7] CO_2 captured at industrial sites in Europe will be collected by ship, offloaded at an onshore site and then sent by pipeline to an offshore injection site in the North Sea. Within the next decade the goal is to set up a European system of CO_2 transport and storage, paving the way for cost reductions and substantial scale-up of CCS. The geological storage sites for CO_2 are unevenly distributed across countries. In European CCS strategies the North Sea is identified as the largest share of European offshore storage potential – with about 56 Gt CO_2 on Norwegian territory and around 78 Gt CO_2 on British territory. [2]

We studied two countries, Germany and Norway, which have in common a commitment to the Northern Lights project but have very different preconditions when it comes to the support for CCS among the public and politicians. While there has been a push across party lines for the development of CCS for decades in Norway and the public has been supportive, German public opposition led to German CO_2 storage projects being essentially forbidden by law in 2016 [8].

Public perceptions of CCS

In general, the level of awareness of CCS in the public is low [9–11], the exception being Norwegian respondents who in previous studies have reported relatively high levels of awareness [12]. Despite the wide-spread ignorance, the lack of public acceptance, especially of onshore storage [10] has been a major barrier to the development of CCS in Europe in the past. The support for CCS is relatively high in Norway [12,13], whereas it is low in Germany [14]. The German government's plans to use CCS for emission abatement hinge for the time being on the feasibility of exporting CO_2 for storage [15], while Norwegian plans for up-scaling depend on the import of CO_2 for storage. It is, however, unclear how the aspect of importing or exporting, respectively, influences the public's perceptions of the technology.

We conducted the first survey experiment to assess the effect of the nationality of emissions and of the storage site for the acceptability of CCS among German and Norwegian laypeople. More specifically, we wanted to find out whether perceptions of CCS would vary depending on the factors (1) onshore/offshore storage, (2) foreign/domestic sourcing of CO_2, and (3) storage on foreign/domestic territory. Our experimental treatment varies the spatial and psychological distance from the CO_2-source and the storage site, in terms of nationality and location. The mental construction of psychological distance as defined by construal-level theory is influenced by temporal, spatial, and social distance in addition to how hypothetically a situation or an event is perceived. The four dimensions are largely interrelated. A higher psychological distance leads to more abstract thinking and lowers risk perception; objects are evaluated more globally only using core characteristics [16,17].

A review of studies on public acceptability of CCS suggests effects of national culture [18–20], religious faith [21], perceived risks and benefits [22–25], trust [9,24–27], education [28], knowledge about CO_2 [29,30], perceived naturalness [31], values/emotions [32,33], and communicative framing [34,35] on the support for CCS. Despite the practical relevance of the question, there is – to the best of our knowledge – no study on the influence of the nationality of emissions or the storage site on perceptions, yet. There is, however, a substantial body of work on the effects of geographical proximity to CCS infrastructure.

The findings on the influence of geographical proximity to CCS sites on acceptability are mixed. Several studies find that the spatial proximity to proposed or current CCS facilities is important [12,36–39]. Among others, Krause et al. [38] find that 21.3 % of initial proponents of a hypothetical CCS site became more negative toward it after the project was framed as being promoted in their neighbourhood. In a US study, the probability of voting for CCS increased along the distance of the facility to residential areas [40]. Combining survey data on public perceptions of CCS with data on the exact locations of all potential CCS sites, Braun (2017) shows that respondents that live close to a potential CCS site have significantly lower acceptance rates than those that do not. To avoid this NUMBY (Not Under My Backyard) effect, political authorities have focused their efforts on offshore storage over the last decade [41]. Thus, our first hypothesis reads as follows:

H1: Offshore storage is evaluated more positively compared to onshore storage.

Still, past results on CCS perceptions do not fully support such a hypothesis. There are only small differences in the perceptions of geological onshore and offshore CO_2 storage. Studies have shown either a small positive effect for offshore storage [42,43] or no substantial difference [44,45].

Exporting CO_2 for storage to other countries could be perceived more positively, as NUMBY reactions should not occur, as the storage site is geographically and thus psychologically more distant. But especially in large countries, people might actually not live close to a domestic storage site. In addition to an implicit spatial proximity, specifying the nationality of a storage site could also result in differences in the psychological distance between domestic and foreign storage sites. Thus, storage on foreign territory might be evaluated more positively in comparison to domestic – spatially and psychologically closer – storage because the risk of being affected by leakage is lower. Based on these insights, we establish the following second hypothesis that only focuses on the perception of storage neglecting any additional influence of the nationality of emissions:

H2: Storage on domestic territory is evaluated more negatively compared to storage on foreign territory.

Studies furthermore show that public attitudes vary depending on the part of the CCS value chain citizens live close to. Whitmarsh et al. [12] find different levels of CCS acceptability for CO_2 capture and storage sites: Proximal communities are more positive toward carbon capture than the general public, reporting a degree of YIMBYism (Yes, In My Backyard) around proposed capture facilities, while they also find the expected NUMBY effect among citizens living close to proposed storage sites. Acceptability of the CO_2 source increases when it is not a fossil-fuel power plant but a bioenergy or biogas power plant [31,46,47]; this even partially offsets the NUMBY effect [46]. As it is the storage part of the value chain that is identified as inducing most risk to the system in terms of leakage, this distinction in perceptions makes sense. It remains, however, unclear whether the more positive perception of capture facilities compared to storage sites is also connected to a belief that proximal facilities should reduce their CO_2 emissions and contribute to mitigation. The differences in past findings might also highlight that NIMBY/NUMBY-framings are used in politically contested situations to downplay concerns by local communities that are directly affected and that the framing oversimplifies more complex social concerns [48–50].

One study indicates that positive expectations about the contribution of CCS to climate change mitigation lead to more positive evaluations of the technology [41]; people see the mitigation of CO_2 emissions as a main benefit of CCS [10] and a stronger concern about climate change leads to more favourable views of CCS [9]. These findings may be well-aligned with the perceptions of international burden sharing rules: people think that states should be held accountable for their (historic) emissions, i.e., the polluter pays principle [51,52]. While this framing of accountability narrowly focuses on financial payments, it might also speak to broader concerns about universal justice and responsibility. Transboundary transport of CO_2 can be compared to the export of nuclear or chemical wastes [53]. Even though CO_2 is neither toxic, radioactive nor explosive, it is often perceived as waste [54]. Shipping CO_2 to other countries for long-term storage could therefore raise concerns about multinational justice as it shifts (intergenerational) risks and burdens from one country to another [53]. We thus formulate H3 about the differentiated effect of the source of emissions on the perceptions of CO_2 storage on domestic territory:

H3: Storage of domestically sourced CO_2 on domestic territory is evaluated more positively compared to (i) an unspecified source and compared to (ii) foreign sourced CO_2.

It implies that people would perceive domestic storage more positively because it means that domestic CO_2 emissions are taken care of, while perceptions are more negative when other countries export their CO_2 and thus the responsibility for their emissions to other countries. H3 extends beyond the aspect of spatial distance in H1 and H2 adding the social distance of the benefit of the mitigation of national emissions and of taking responsibility for them.

Regions or people in Germany that are more familiar with the oil and gas sector or large industrial installations have been found to be more open toward CCS demonstration projects [55]. Wong-Parodi and Ray [56] found that positive experiences with the natural gas sector like benefits for the community positively influenced the local perceptions of CCS. At the same time, Broecks et al. [41] did not find an effect of spatial proximity to industrial installations or of the perceived proximity to industry on CCS perceptions among survey participants from the Netherlands and the UK. The differences in the direct experiences with the oil and gas sector might, however, be relevant when comparing Germany and Norway. In 2018, 2.0% of Norwegian employees worked directly in oil and gas extraction or in supporting activities and the country built its wealth on fossil-fuel extraction, whereas this share was only about 0.01% in Germany.[1] Compared to Germany, Norway also has a longer history of public discussion about CCS, support from politicians is strong across the political spectrum and infrastructure build-up has been going on for much longer [8]. We thus expect that the overall familiarity with CCS is higher in Norway compared to Germany. This should also have an impact on the evaluation of CCS,

[1] Eurostat: Industry by employment size class (NACE Rev. 2, B-E), Persons employed in Extraction of crude petroleum and natural gas + Support activities for petroleum and natural gas extraction by employees in all sectors https://bit.ly/3sKjo6n, retrieved 2 April 2021.

as familiarity and perceived realism lower psychological distance which should lead to less abstract thinking and more differentiated evaluations [16,17,57].

H4: A higher level of familiarity with the technology and/or a higher level of perceived realism of CCS deployment will lead to more differentiated evaluations of CCS projects.

This implies that Norwegians should pay more attention to specifications of a CCS project, while Germans should evaluate the technology more generally.

In the remainder of the paper, we test the four hypotheses focusing on the influence of the nationality of the emissions and the storage site. Keeping the temporal dimension constant, we look at experimental variations offshore vs. onshore storage, the nationality of the source and the storage location in a CCS value chain. In addition, we look at differences in the attitudes toward technology, the perceived benefits, i.e., the effectiveness of CCS for mitigating emissions, worry about climate change, familiarity with oil and gas extraction and the perceived realism of the deployment of CCS.

2. Methods and Data

We fielded the survey experiment in Norway and Germany in October and November 2019. In Norway, the experiment was part of the 16th wave of the Norwegian Citizen Panel (NCP) [58]. NCP is a university-owned panel based on a randomly selected sample of the Norwegian population, drawn from the Norwegian Population Registry and recruited offline through mail.[2] In Germany, the experiment was run with participants recruited via the commercial panel provider Consumerfieldworks using quotas for age, gender, and level of education. As the online recruitment in Germany would potentially have led to the misrepresentation of older respondents, we restricted the sample in both countries to participants aged between 18 and 65 years.

By using an experimental design, we can avoid deficiencies of traditional survey questions when the purpose is to make claims about causality. Notably, regression analysis on cross-sectional data cannot rule out potential problems of endogeneity. By contrast, experiments embedded in surveys, where randomized sub-samples of the population receive divergent versions of the same question, while keeping everything else equal, significantly enhance external validity [59].

[2] The data applied in the analysis are based on Norwegian Citizen Panel wave 16, 2019. The survey was financed by the University of Bergen (UiB). The data are provided by UiB, prepared and made available by Ideas2Evidence, and distributed by Norwegian Centre for Research Data (NSD). Data are freely available at the Norwegian Centre for Research Data (NSD) http://www.nsd.uib.no/nsddata/serier/norsk_medborgerpanel_eng.html.

Box 1: Text explaining CCS to respondents in the survey and experimental variation

> *Carbon capture and storage is a process that stores CO_2 (carbon dioxide), which is captured from industrial sources and power plants that emit large amounts during production. The captured CO_2 is transported and stored deep underground to keep it out of the atmosphere, where it would contribute to climate change. This technology is already in use today. Research suggests that the technology can be expanded so that large amounts of CO_2 can be captured and stored in the future. On a large scale, carbon capture and storage can play an important role in limiting climate change.*
> *Imagine a proposal where large amounts of CO_2 from*
>
> *[source]*
> ***(1) [not specified], (2) German/Norwegian** [domestic]**, (3) German** [foreign]**, (4) European***
>
> *installations are to be stored deep*
>
> ***(I) underground, (II) under the sea-bed***
>
> *on*
>
> *[storage]*
> ***(i) [blank], (ii) German/Norwegian** [domestic]**, (iii) Norwegian** [foreign]**, (iv) European territory**.*

In our study, respondents were randomly allocated into 24 experimental groups. They all read the same explainer about CCS. This was followed by a description of a proposal for a CCS project that contained the experimental variation (see Box 1). In our 4x4x2 factorial design the nationality of the source of the CO_2 (4 levels), the nationality of the storage site (4 levels), and whether the storage site was offshore or not (2 levels) was varied. We excluded two unrealistic attributes – for German respondents Norway as a source of CO_2, for Norwegian respondents storage on German territory.

After reading the description, respondents had to indicate how they evaluated the project on a 4-point-Likert-scale from very negative to very positive; the option don't know/no opinion was also available. They were asked whether they found the project realistic or not realistic and whether they thought that CCS was an effective way to limit global warming (yes/no/don't know). We asked Norwegian respondents whether they or their relatives work(ed) in the oil and gas sector and German respondents whether they or their relatives work(ed) in the energy sector as the oil and gas sector is of negligible size in Germany.

In addition to demographic variables, we elicited views on the statement "Technological innovation will solve climate change" (strongly agree [1] – strongly disagree [7]), and how worried they are about climate change (not worried at all [1] – very worried [5]).

The full sample contained 3469 (NOR) and 2979 (GER) uninterrupted survey completions. We excluded speeders who spent less than 10 seconds as well as those who spent more than 1999 seconds reading the vignette text and answering the question about the CCS project (NOR: 125; GER: 14). In a final step we removed observations with incomplete items to have identical samples in all stepwise regressions (NOR: 115; GER: 5). The full sample for analysis including "don't know"-answers to the question evaluating CCS is 3229 in Norway and 2960 in Germany. Due to the limited panel capacity only about a third of the Norwegian sample received the control questions on worry about climate change and technological innovation (N=906). We report the results of the factorial design for the full Norwegian sample (M1 and M2 in Table 2); for the additional analyses that include these other variables we use the reduced Norwegian sample (M3 in Table 2). For the German sample, the number of observations is identical across all models.

Based on the full sample, the median age category is between 40 and 49 years in Germany and between 50 and 59 years in Norway. About half the respondents are female (GER: 49%; NOR: 52%). The share of respondents with a higher education entrance certificate is 38% in the German sample and 60% in the Norwegian sample (Table A-1). Participants were randomly allocated to the 24 treatment groups. Figures A-1 to A-4 provide an overview of the share of female respondents, the share of highly educated respondents and the mean age category in the treatment groups. Despite random allocation, there are groups that have substantially different values for these characteristics. Statistically, this is not surprising because the number of groups is large.

On average, 16.5% of respondents selected the option *"No opinion/don't know"* to the question about the CCS project. These respondents were not included in the analysis. Their share is significantly higher among Norwegian respondents (GER: 15.5%; NOR: 17.5%; one-sided binomial test: $p = 0.002$). While the shares do not vary significantly between treatment groups, they are influenced by gender, education, perceived realism of the proposed project, worry about climate change and technology perception (compare appendix Table A-2).

Therefore, we combined descriptive analysis with OLS regressions to analyse the effect of the different experimental variations on CCS acceptance. This enables us to rule out sampling and selection biases in our results: we control in all models for the demographic variables and test for interaction effects between the treatment and the demographic variables (compare Table 3). In addition, we do not use sampling weights; Instead, we include the variables used to construct the proportional weights in the NCP as controls in the analysis: age, gender, level of education and geographical region. This model-based approach can be used uniformly in the analysis of all (sub-)samples and prevents losing too much statistical power in the analysis. All variables making up the weights for NCP are available to us, allowing us to specify our model correctly.

3. Results

Neither in the Norwegian nor the German sample did it make any difference whether storage was merely defined as underground or as offshore (see Table 2), thus *rejecting Hypothesis 1*. We do not find any (positive) effect of specifying the storage location as offshore.

Table 1 shows the share of respondents who evaluate the CCS project presented to them as “somewhat positive” or “very positive”. H2 postulated that storage abroad should be evaluated more positively compared to domestic storage. We do not find support for this hypothesis. Neither the shares of “somewhat positive” and “very positive” responses (Table 1), nor the linear predictions from OLS (Figure 1) consistently show more negative evaluations. We thus *reject Hypothesis 2*.

Table 1: Share of respondents that evaluated the project as “somewhat positive” or “very positive” by the treatment combination of source location and storage location. Adds up to 100% together with the responses in the categories “somewhat negative” and “very negative”

Share of respondents that evaluated the project *somewhat positive* or *very positive*

Germany (N=2500)

source \ *storage*	not spec.	EU	NOR	domestic
not spec.	53%	54%	48%	51%
EU	45%	49%	48%	51%
NOR†				
domestic	57%	50%	51%	54%

Norway (N=2665)

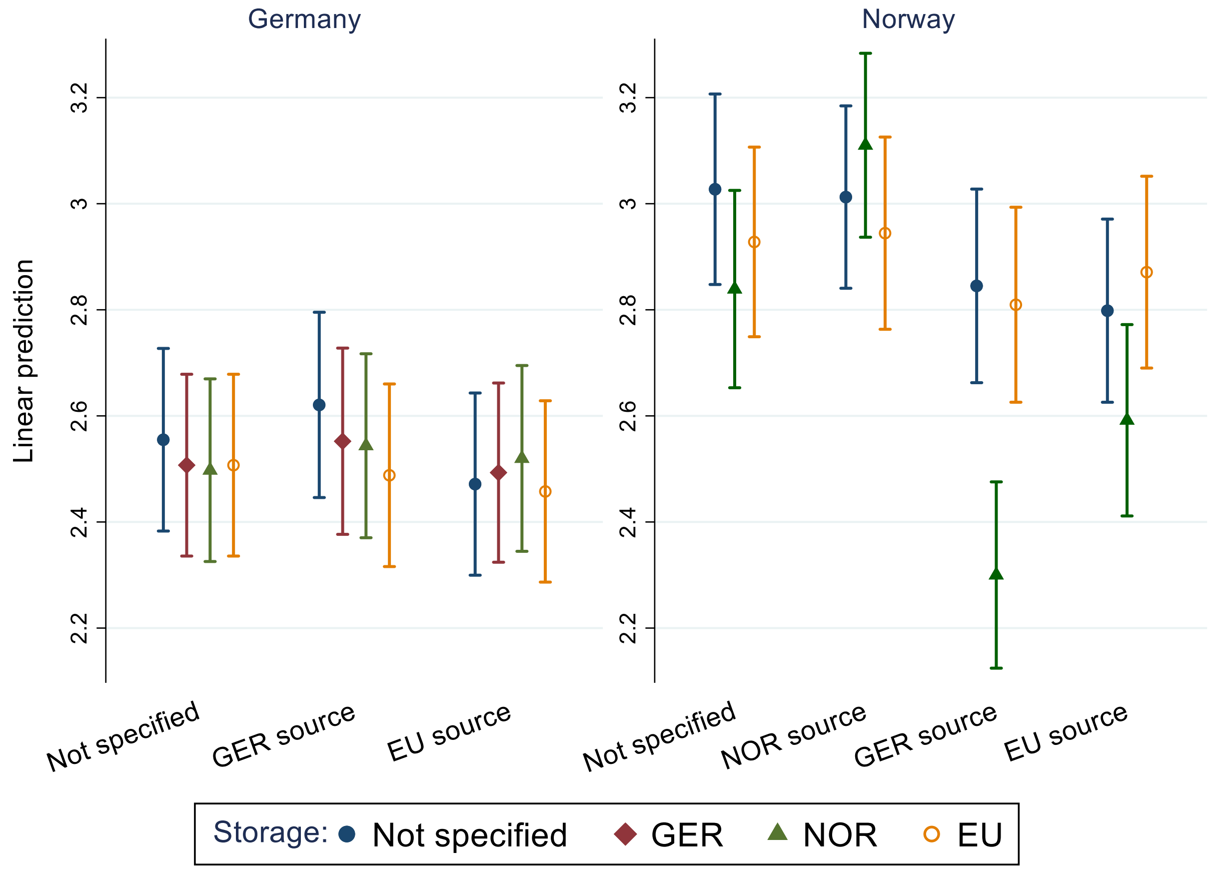
source \ *storage*	not spec.	EU	GER†	domestic
not spec.	77%	73%		64%
EU	67%	70%		56%
GER	68%	68%		42%
domestic	76%	70%		81%

†not part of the experimental design

lowest share of positive answers (red)
higest share of positive answers (blue)

Instead, we observe that 81% of Norwegians are positive towards a project where Norwegian sourced CO_2 is stored on Norwegian territory. In contrast, the support is reduced to half (42%) when Germany is explicitly mentioned as the source country and Norway is the storage country. This result is also statistically significant different from the setting where CO_2 from Europe is stored in Norway (Bonferroni adjusted p-values for multiple comparison: $p = 0.018$). This finding is robust across different specifications and controlling for alternative explanatory variables (Figure 1 and Table 2). For Germany, there are no significant differences between any of the treatment conditions.

Figure 1: Linear prediction and 95% confidence intervals for OLS regressions of attitude toward a CCS project (scale: 1 very negative – 4 very positive) for German and Norwegian samples (compare M1 Table 2)

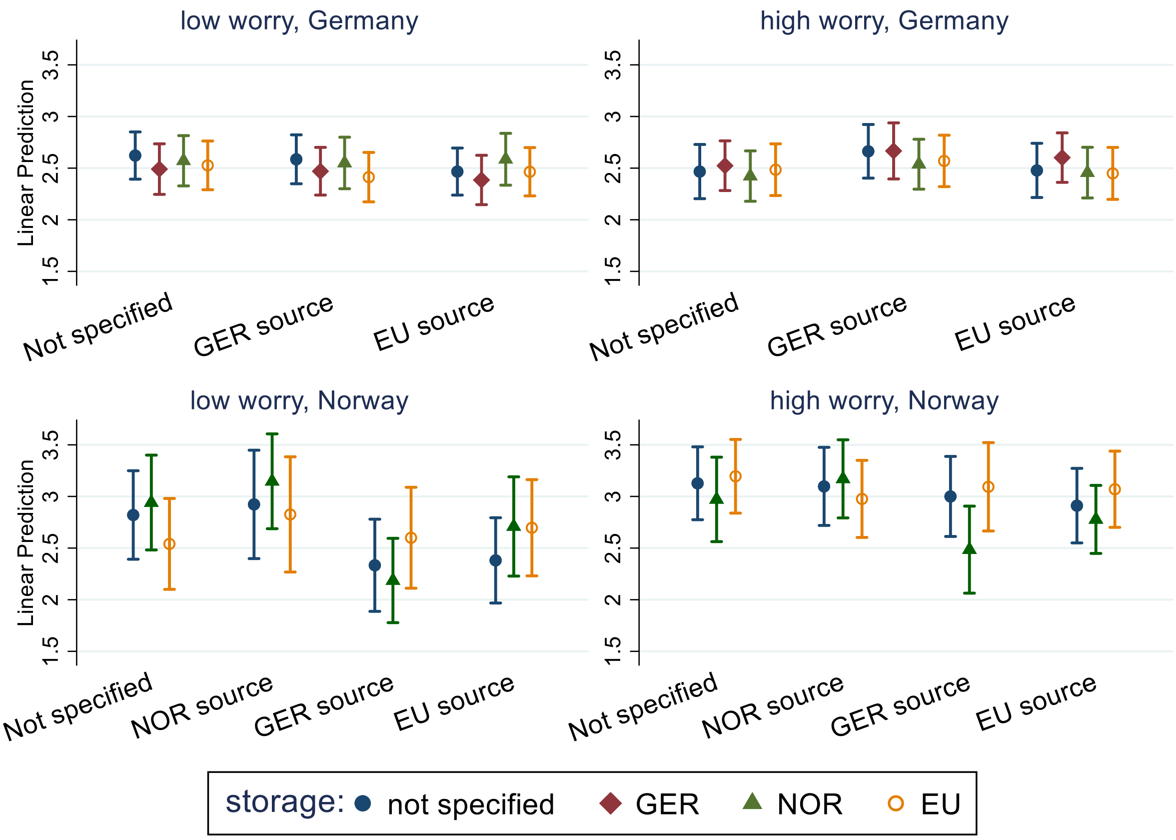


Note: The source countries on the horizontal axis are sorted by distance: not specified, domestic, foreign specific, foreign unspecific (EU)

Higher worry about climate change leads to more positive evaluations of CCS in Norway but not in Germany. In Norway, respondents that indicated higher levels of worry about climate change were significantly more likely to evaluate the proposed project positively, while we found no significant relationship for German respondents (M3 *Table 2*). On average, Norwegians are slightly more concerned about climate change than Germans (one-sided *t*-test: $\bar{x}_{GER}$=3.4, $\bar{x}_{NOR}$=3.6, p=0.000). Furthermore, those who are more worried are also more likely to think of CCS as an effective way to mitigate climate change. For example, 44% of Norwegian respondents that are very concerned about climate change think that CCS is effective. The German equivalent is 33 %. This indicates that Norwegian respondents on average perceive benefits from CCS for climate change mitigation, while German respondents do not see these benefits.

We also find that the negative effect of importing CO_2 for storage from Germany is especially pronounced among the more worried Norwegians (Figure 2). These respondents seem to believe that Germany, just like Norway and other European countries, should capture carbon, and that Norway, like other European countries, should store carbon – but they do not necessarily agree that German CO_2 should be stored on Norwegian territory. This differentiated result is driven by the respondents that are worried about climate change (Table 3). Those who are not worried about it show a broader scepticism about the scenarios with the German-source specification independently of the nationality of the storage site. Note, however, that 'worry' is not included in the experimental design and the moderating effect of this variable might therefore be confounded. Nevertheless, we *accept Hypothesis 3 for Norway and reject it for Germany*. It hypothesizes that domestic storage of domestically sourced CO_2 is evaluated more positively compared to the storage of imported CO_2.

Figure 2: Linear prediction and 95% confidence intervals for OLS regressions by subgroups with a low level or a high level of worry about climate change (scale: not worried at all (1) – very worried (5); low: worry = 1, 2, 3; high: worry = 4, 5) on attitude toward a CCS project (scale: 1 very negative – 4 very positive) for German and Norwegian sample (compare Table A-5)



Overall, we find that Norwegian respondents assess the CCS project more positively and that the variation of the assessment across treatment groups is higher compared to Germany. The share of positive evaluations across different conditions ranges between 42% and 81%, while in Germany it only ranges between 45% and 57%. The more positive evaluations and the stronger differentiation between treatment scenarios can be explained by differences in the perceived hypotheticality and uncertainty of CCS and the familiarity with the technology and the sector.

Both country samples show that higher perceived effectiveness and realism increase the evaluation of CCS (*Table 2*) but the average perceptions are different between countries. More Norwegians think of CCS as more effective and of the project as realistic in the next 5–10 years. In Norway, about 40% think that CCS is an effective technology to mitigate emissions, 25% think it is not effective and the remaining 35% respond “don’t know”. In Germany, 31% think that CCS is an effective technology to mitigate emissions, 48% think it is not effective and 21% respond “don’t know”. Thus, the perception of CCS effectiveness is significantly different in the two countries (chi^2-test: $\chi^2(2) = 318.83$; p=0.000). In addition, Norwegians are more likely to perceive the proposed project as realistic (55%) compared to Germans (47%; chi^2-test: $\chi^2(1) = 36.82$; p=0.000). We find a positive effect of working in the oil and gas sector on the evaluation of CCS in the Norwegian sample. In Germany, we find no such effect for working in the energy sector; there, we did not ask about the oil and gas sector specifically, as its size is negligible.

Table 2: Results from OLS regression for attitude towards the described CCS project (scale: 1 very negative – 4 very positive) for Germany and Norway.

	Germany			Norway		
	M1	M2	M3	M1	M2	M3
source*storage (base = not spec.*not spec.)						
*not specified *GER*	-0.051	-0.082	-0.08			
*not specified *NOR*	-0.052	-0.036	-0.039	-0.163	-0.04	0.141
*not specified * EU*	-0.048	-0.048	-0.055	-0.093	-0.026	-0.062
*GER * not specified*	0.053	0.005	-0.004	-0.191*	-0.116	-0.250*
*GER * GER*	0.005	-0.032	-0.038			
*GER * NOR*	-0.016	-0.04	-0.043	-0.726***	-0.576***	-0.541***
*GER * EU*	-0.067	-0.108	-0.107	-0.223*	-0.101	-0.056
*NOR * not specified*				0.005	0.022	-0.036
*NOR * NOR*				0.071	0.064	0.11
*NOR * EU*				-0.077	-0.01	-0.01
*EU * not specified*	-0.085	0.031	0.027	-0.208*	-0.112	-0.163
*EU * GER*	-0.078	-0.082	-0.089			
*EU * NOR*	-0.046	-0.077	-0.08	-0.405***	-0.254***	-0.166
*EU * EU*	-0.096	-0.037	-0.04	-0.169	-0.073	-0.019
offshore (base = onshore)	-0.038	-0.019	-0.026	-0.026	-0.017	0.005
realistic (base = no)		0.169***	0.151***		0.214***	0.189***
effective (base = yes)						
no		-1.073***	-1.018***		-1.200***	-1.000***
don't know		-0.394***	-0.368***		-0.576***	-0.456***
innovation will save climate			0.071***			0.052**
worry about climate change			-0.017			0.126***
working in energy (GER) / oil&gas (NOR) sector			0.083			0.282**
controls	*included*					
constant	2.676***	3.158***	2.848***	3.472***	3.692***	2.977***
N	2500	2500	2500	2665	2665	906
df	30	33	36	20	23	26
log likelihood	-3203.243	55.611	-2633.097	-3603.767	89.753	-1016.403
R^2	0.013	0.35	0.362	0.115	0.384	0.411

*Note: control variables are age, gender, education and geographical region (see Table A-3). Norwegian sample in M3 is smaller because the variables 'innovation will save climate change' and 'worry about climate change' were only elicited from a subset of respondents. Estimations for M1 and M2 with the small Norwegian sample see Table A-4. * p<.05; ** p<.01; *** p<.001*

There is a strong difference in public awareness about CCS as a technology between the two countries. While only 15% of Norwegian respondents report that they have never heard about CCS, this share is 63% in Germany, where 6% have already heard a lot about CCS compared to 26% in Norway. The share of respondents that have heard a little about it is 58% in Norway and 30% in Germany [60].[3] As these strong differences in familiarity were expected, we included a more general measure of the attitudes toward technology as a means to counteract climate change. Agreement with the statement that technological innovations will solve the problems related to climate change positively influences the evaluation of the CCS project in both country samples (M3 Table 2). At the same time, the share of respondents that at least somewhat agree with this statement is 50% in Germany and 70% in Norway (one-sided *t*-test: *p*=0.000), indicating again strong differences on the aggregate level between the two countries.

We conclude that the psychological distance from CCS in terms of uncertainty about CCS and its benefits, attitudes toward technology, and familiarity is on average lower in Norway compared to Germany. We find abstract evaluations among the German respondents who do not pay attention to the details in our project specification, whereas Norwegian respondents show differentiated evaluations. We thus *accept H4 on the between-country level.*

*Table 3: Likelihood ratio tests for respective variable added as simple term to M1 vs. respective variable added as an interaction with (source*storage) to M1*

	Germany		Norway	
	p	χ^2	p	χ^2
Realistic	0.138	16.087	0.774	7.298
Effective	0.169	28.202	0.134	29.382
Innovation	0.098	81.247	0.210	72.849
Worry	0.072	58.352	0.009	66.469
Working in energy (DE) / oil&gas (NO) sector	0.104	17.143	0.331	12.441
Female	0.611	9.117	0.453	10.882
Age	0.370	49.602	0.307	51.346
Education	0.656	8.630	0.437	11.080

However, neither perceived effectiveness, realism of CCS, technology perception nor working in the oil and gas sector can explain the differences in the reactions to the experimental variation of the nationality of the source and the storage site within the country samples. The fit of the baseline model (M1, *Table 2*) plus the simple term of perceived effectiveness or realism does not improve significantly when adding the three-way interaction term of source, storage, and effectiveness or realism, respectively (Table 3). For example, the group of respondents that perceive the project as less realistic do not show different evaluation patterns compared to those who think it is realistic. Taken together this leads to a *rejection of H4 on the within-country level* as our variables for psychological distance do not improve explanatory power.

[3] Norwegian shares are based on *N* = 3068 from wave 18 of the Norwegian Citizens' Panel in 2020, 60. German shares are based on our own sample.

We controlled for demographic variables. Women are less likely to evaluate the project positively. The effect is more pronounced in Norway compared to Germany. Unlike in Germany, a higher level of education significantly increases positive evaluations in Norway and increasing age has a downward impact on evaluations (*Table 2*). The variables do not interact significantly with the treatment as shown by the lack of significant improvement in model fit when they are included as a three-way interaction with storage and source (Table 3).

4. Discussion

We conducted a survey experiment in Germany and Norway where we were interested in the support for a hypothetical CCS project and where we varied the nationality of the source of CO_2 emissions, the nationality of the storage site for a CCS project and whether the storage site is onshore or offshore. The treatment manipulates the psychological distance in terms of spatial distance and nationality. The two study countries are very different with respect to the general population's familiarity, the level of development and the existence of a political discourse on CCS, adding further variation in the psychological distance.

In line with prior research, respondents in Norway and Germany evaluated the project on average differently [12–14]. While Norwegians perceived the project as somewhat positive or very positive, Germans evaluated it more reluctantly as somewhat positive. Specifying the storage location as offshore does not change perceptions in either of the two countries. Also, the specification of a storage location abroad does not lead to more positive evaluations of CCS. This contradicts our hypotheses that an increase in the spatial distance for storage – either by moving it offshore or abroad – would lead to more positive evaluations by reducing the risk perceptions. The lack of importance of the spatial dimension also contradicts NIMBY/NUMBY framings but points towards more nuanced drivers of CCS perceptions that extend beyond seemingly selfish motives for local opposition [50] and underlines the importance of psychological distance over spatial proximity in construal level theory.

Though the nationality of the storage site does make a difference in combination with the nationality of the CO_2-source: Norwegians are most positively inclined toward storing CO_2 from Norwegian sources on Norwegian territory. The support is significantly lower for projects where imported CO_2 is stored on Norwegian territory – especially when the source is described as German, but also when it is described more broadly as European. This is a consistent pattern; we observe the strong negative effect of Germany as a source especially among Norwegian respondents that are worried about climate change. Contrary to Norwegian respondents, German respondents do not evaluate the proposed CCS-project differently depending on the nationality of emissions or of the storage site. It seems that these differences do not matter to them. Considering the low level of familiarity with CCS, the lower beliefs about its effectiveness against climate change and the higher perceived hypotheticality of the proposed CCS project among German respondents compared to Norwegian respondents, we conclude that Germans' psychological distance from CCS is high, while it is low for Norwegians. This is consistent with the hypothesis that more distant objects are evaluated in a more abstract way.

Norwegian respondents' negative evaluation of the domestic storage of German and European sourced CO_2 could derive from various factors. They might be concerned about the safety of cross-border CO_2 transport or hold a belief that every country should take responsibility for its own emissions and should not "dump" them on Norwegian territory. CO_2 is often perceived as waste [54] and Germany's reliance on coal might be perceived as problematic by Norwegian respondents. In addition, the perceived benefits from CCS might be higher, when the technology is used to reduce Norwegian emissions thus adding to the positive perception of storing Norwegian CO_2 domestically. In the Norwegian public debate, CCS is often framed as a national project adding to the domestic focus [61].

Our experimental results can, however, only provide a limited snapshot of public perceptions that are based on our information text. That we did not find a difference between offshore and onshore storage might, therefore have occurred because we compared offshore to a scenario that did not specify onshore storage but merely underground storage. Especially for Norwegian respondents, who are mostly familiar with the CCS projects underneath the North Sea this might not have made a difference as they were thinking about offshore storage anyway. Furthermore, we can only speculate about the reasons why Norwegian respondents differentiate between Europe and Germany as a source. It could be that they question whether the CCS project should be limited to a single foreign source country, and they might question whether Germany is the optimal candidate, or they might think of Norway as a part of Europe, as we did not specify "other" European countries in the treatment. Our experiment cannot capture political mobilization processes, media campaigns, and stakeholder responses that will to a great degree influence the development of public perceptions.

Future research should explore the mechanisms that drive the effects of the nationality of emissions especially looking at perceptions of international justice and CCS as a part of international climate policy. It will be especially of practical relevance, whether such effects appear for other exporter-importer relationships such as Sweden-Norway or Poland-UK, as they are part of the planned Northern European infrastructure network.

Our findings mirror the diverging status of CCS in political discussions in Germany and Norway. German authorities had taken a cautious to disapproving position for several years, before cautiously opening up in 2019 [15], whereas the Norwegian government frames it as part of the solution to the climate change problem and promotes the development of full-scale CCS [62]. Our study also reveals potential problems for the establishment of a Northern European market for carbon storage: removing the NUMBY-aspect for Germany by storing the CO_2 under the North Sea off the coast of Norway does not improve acceptability. Adding the context of the nationality of emissions in Norway, lowers the generally positive evaluation of CCS significantly there when the CO_2 for storage is imported. Low levels of public acceptability of CO_2 exports in Germany and CO_2 import in Norway could challenge the feasibility of current plans for CCS deployment of states bordering the North Sea, as this is indeed one of the envisioned importer-exporter constellations.

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Appendix

Table A-1: Descriptive statistics for the full sample (model in Table A-2), acceptance models (M1 and M2 Table 2 and Table A-4) and the reduced sample in Norway (M3, Table 2)

	Germany			Norway			
	full	without NODK (M1 - 3)	population 18-65	full	without NODK (M1 & M2)	small sample (M3)	pop-ulation 19-65
median age category	40-49	40-49	40-49	50-59	50-59	50-59	40-49
women	48.9%	46.2%	49.4%	51.7%	48.3%	47.9%	48.8 %
higher level of education	38.1%	39.9%	36.7%	59.5%	60.8%	62.9%	40.1%
state							
Baden-Württemberg	11.4%	11.4%	13.1%				
Bayern	15.0%	15.4%	15.5%				
Berlin	6.1%	5.8%	4.1%				
Brandenburg	3.3%	3.3%	3.1%				
Bremen	0.8%	0.8%	0.8%				
Hamburg	3.1%	3.0%	2.1%				
Hessen	7.0%	7.2%	7.4%				
Mecklenburg-Vorpommern	2.5%	2.5%	2.0%				
Niedersachsen	8.5%	8.5%	9.7%				
Nordrhein-Westfalen	18.8%	18.8%	21.9%				
Rheinland-Pfalz	5.0%	5.0%	5.0%				
Saarland	1.3%	1.4%	1.2%				
Sachsen	7.1%	7.0%	5.1%				
Sachsen-Anhalt	3.1%	3.0%	2.9%				
Schleswig-Holstein	3.9%	3.8%	3.5%				
Thüringen	3.1%	3.1%	2.7%				
region							
Oslo/Akershus				27.6%	28.0%	25.4%	25.9%
Østlandet				23.2%	22.7%	25.1%	25.4%
Sørlandet				5.8%	5.6%	5.6%	5.6%
Vestlandet				26.6%	27.1%	26.4%	25.2%
Trøndelag				7.9%	7.8%	7.7%	8.7%
Nord-Norge				8.9%	8.9%	9.8%	9.2%
N	2,960	2,500	80,209,997	3,229	2,665	906	3,280,535

Sources for German population reference gender and education: VuMA Touchpoints (2019) https://bit.ly/3h2HgyW, retrieved 5 May 2021; states: Federal Statistical Office (Destatis), 2021 | as of: 05 May 2021. Data for Norwegian population (19-65) calculated based on data from Statistics Norway (2019), StatBank Norway - SSB retrieved 5 May 2021.

Figure A- 1: Number of observations in the treatment groups; all groups include No/Don't know-responses

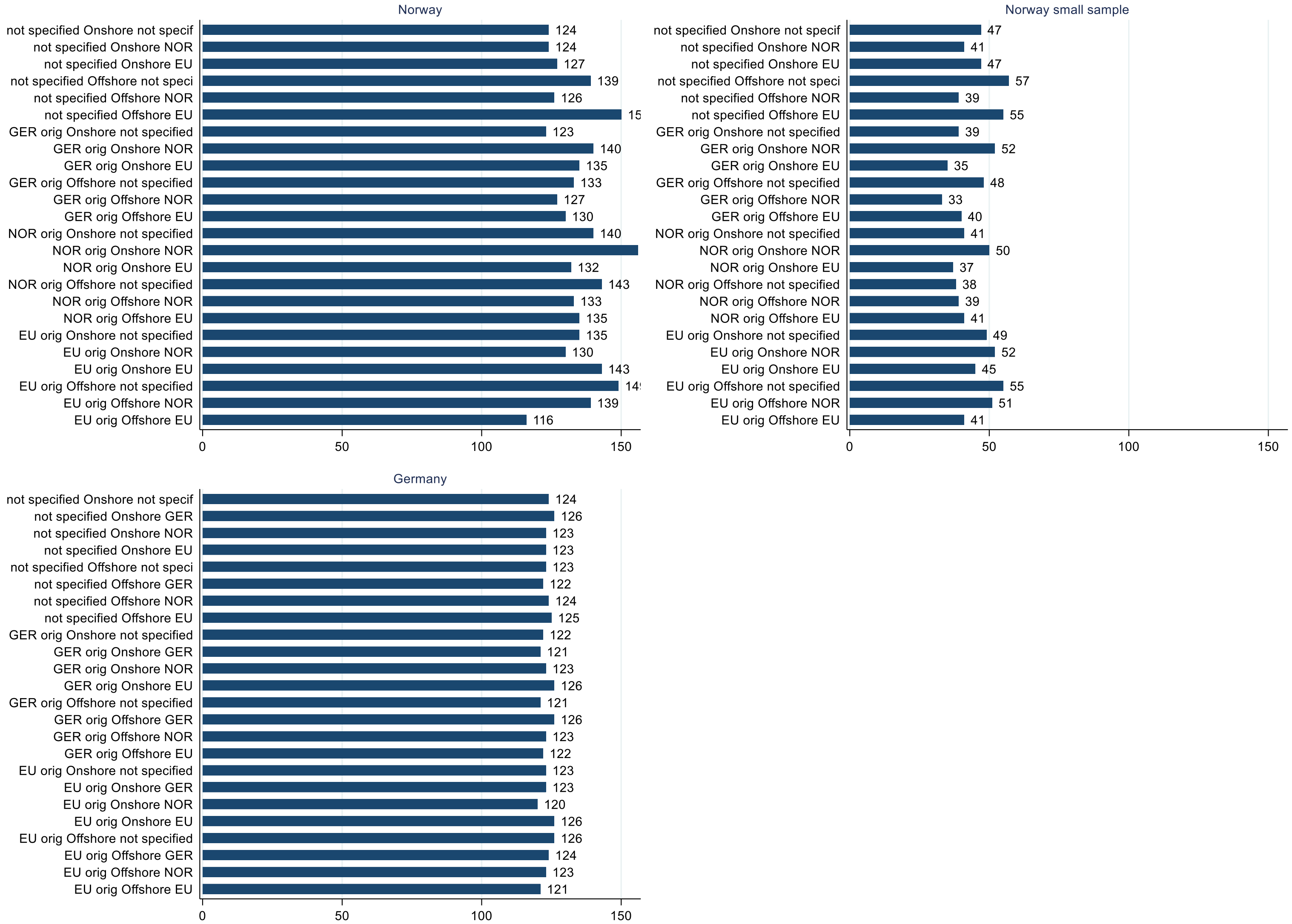

Figure A- 2: Share of female participants in the treatment groups with 95%-confidence intervals; red line indicates overall mean

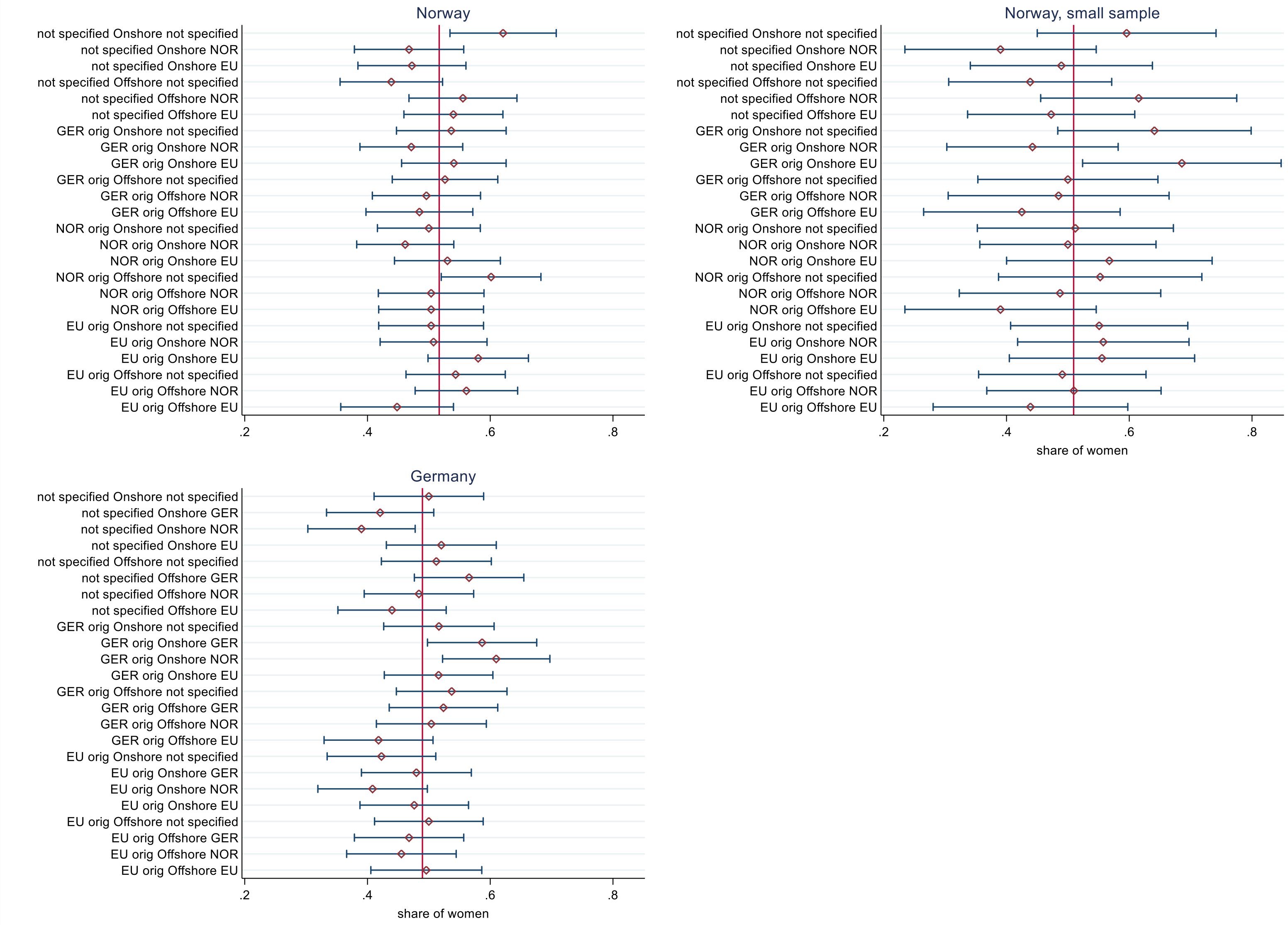

Figure A- 3: Share of highly educated participants in the treatment groups with 95%-confidence intervals; red line indicates overall mean

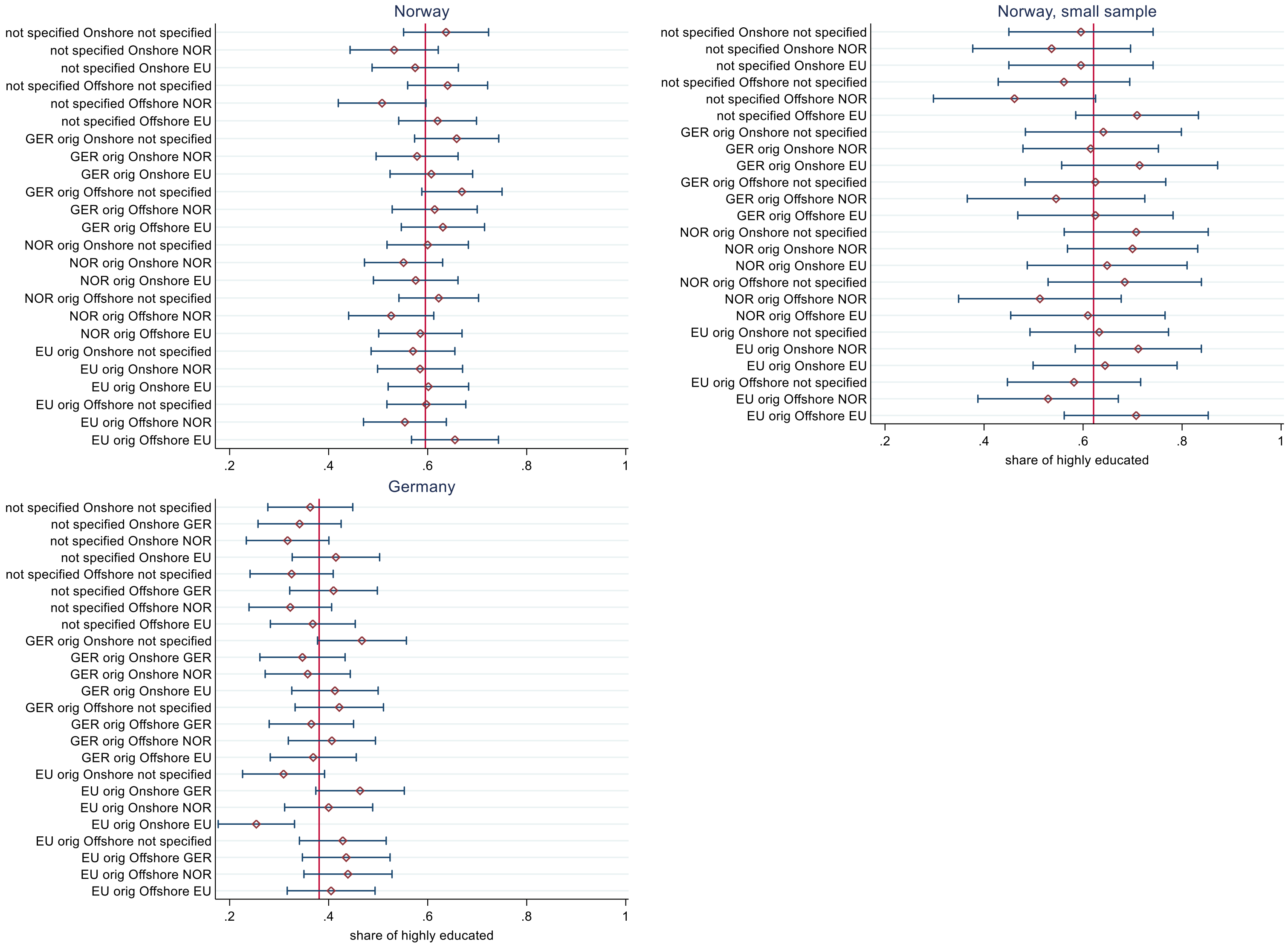

Figure A- 4: Mean age category in the treatment groups with 95%-confidence intervals; red line indicates overall mean

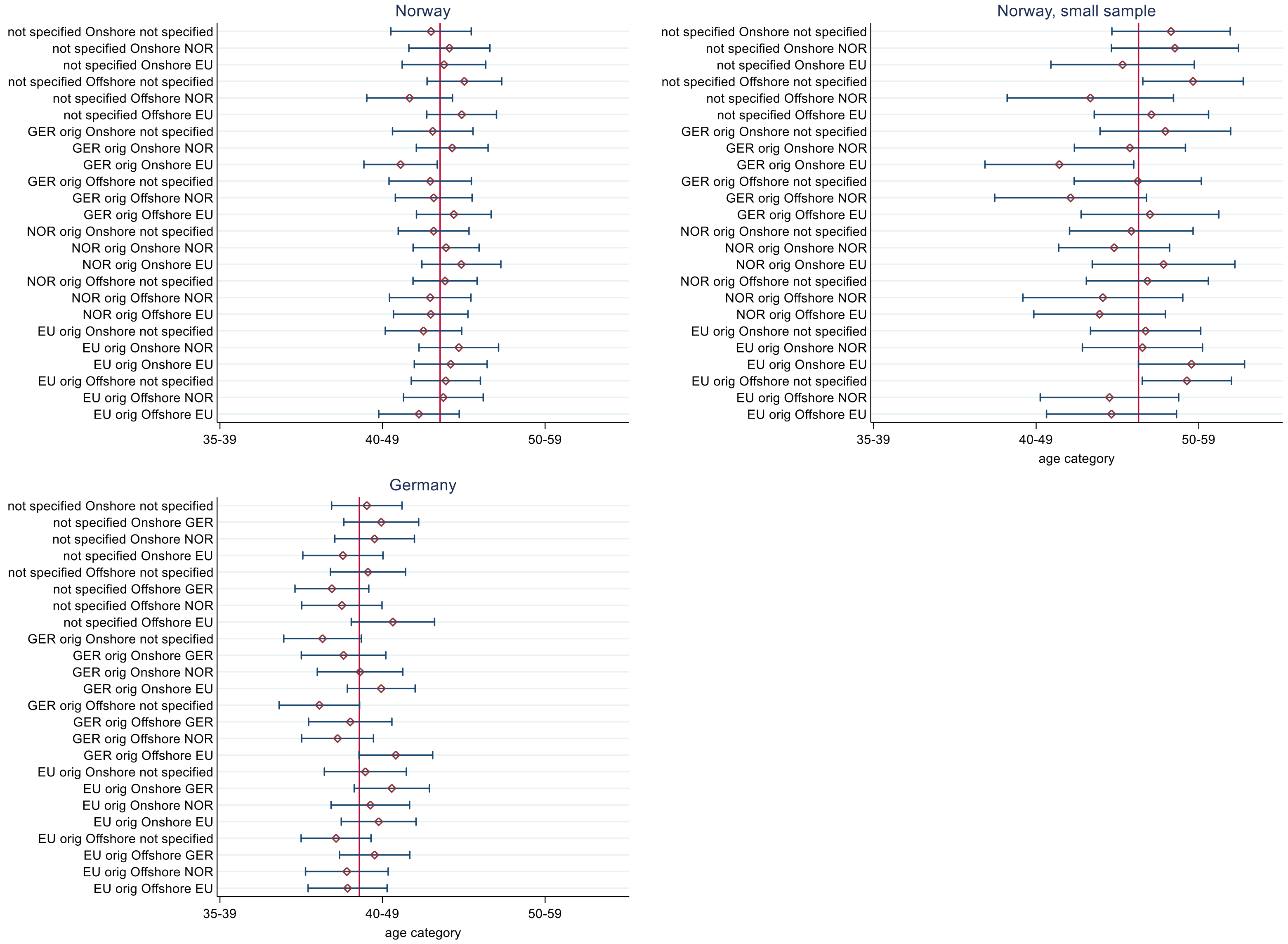

Table A-2: Results from logistic regression for the responding no response/don't know (NODK) in the question about the attitude towards the described CCS project (NODK=1) for German and Norwegian sample.

	Germany			Norway		
	M1	M2	M3	M1	M2	M3
source (base = not specified)						
Germany	0.11	0.063	0.054	-0.053	-0.071	-0.335
Norway				-0.044	-0.001	-0.008
Europe	-0.005	-0.031	-0.033	-0.074	-0.079	-0.124
storage (base = not specified)						
Germany	-0.044	-0.041	-0.036			
Norway	0.047	0.031	0.056	0.093	0.039	-0.13
Europe	-0.059	-0.127	-0.129	0.211	0.142	-0.039
offshore (base = onshore)	-0.178	-0.166	-0.155	-0.038	-0.042	0.098
realistic (base = no)		-0.419***	-0.366**		-0.101	-0.067
effective (base = yes)						
no		0.360*	0.203		0.752***	0.558
don't know		1.563***	1.511***		1.633***	1.616***
innovation will save climate			-0.135**			-0.085
worry about climate change			-0.206***			-0.200*
working in energy (GER) or oil&gas (NOR) sector			-0.727			0.069
female	0.726***	0.622***	0.653***	0.858***	0.652***	0.669***
high level of education	-0.610***	-0.650***	-0.596***	-0.364***	-0.269**	-0.14
age	-0.025	-0.054	-0.052	-0.037	-0.062	-0.044
geographic controls	*included*					
constant	-1.757***	-2.057***	-0.764	-1.845***	-2.608***	-1.579*
N	2960	2960	2960	3229	3229	1072
df	24	27	30	14	17	20
log likelihood	-1234.427	-1150.277	-1136.403	-1446.227	-1348.785	-413.287
pseudo R^2	0.035	0.1	0.111	0.033	0.098	0.106

Note: Norwegian sample in M3 is smaller because the variables innovation and worry were only elicited from a subset of respondents. * p<.05; ** p<.01; *** p<.001

Overall, 16.5% of respondents selected the option *"No opinion/don't know"* to the question about CCS acceptance (henceforth: NODK). The share of NODK is significantly higher among Norwegian respondents (GER: 15.5%; NOR: 17.5%; one-sided binomial-test: p = 0.002). Responding NODK may be explained either by the content of the CCS scenarios, by environmental and other attitudes, or by demographic factors. The shares do not vary significantly between the scenarios, though in Norway they tend to be higher when Europe is specified as the storage location ($\bar{x} = 19\%$; M1: p = 0.068).

Respondents who are female or who do not know whether CCS is an effective method for climate protection are more likely to respond NODK when asked to assess the project. While respondents with a higher level of education are less likely to choose NODK. In Germany, the likelihood to answer NODK is also lower among respondents that think the described project is realistic, that are more worried about climate change, and that think technology will help to solve climate change (Table A-2).

*Table A-3: Full models from Table 2 including coefficients of the controls, * p<.05; ** p<.01; *** p<.001*

	Germany			Norway		
	M1	M2	M3	M1	M2	M3
source*storage (base = not spec.*not spec.)						
*not specified *GER*	-0.051	-0.082	-0.08			
*not specified *NOR*	-0.052	-0.036	-0.039	-0.163	-0.04	0.141
*not specified * EU*	-0.048	-0.048	-0.055	-0.093	-0.026	-0.062
*GER * not specified*	0.053	0.005	-0.004	-0.191*	-0.116	-0.250*
*GER * GER*	0.005	-0.032	-0.038			
*GER * NOR*	-0.016	-0.04	-0.043	-0.726***	-0.576***	-0.541***
*GER * EU*	-0.067	-0.108	-0.107	-0.223*	-0.101	-0.056
*NOR * not specified*				0.005	0.022	-0.036
*NOR * NOR*				0.071	0.064	0.11
*NOR * EU*				-0.077	-0.01	-0.01
*EU * not specified*	-0.085	0.031	0.027	-0.208*	-0.112	-0.163
*EU * GER*	-0.078	-0.082	-0.089			
*EU * NOR*	-0.046	-0.077	-0.08	-0.405***	-0.254***	-0.166
*EU * EU*	-0.096	-0.037	-0.04	-0.169	-0.073	-0.019
offshore (base = onshore)	-0.038	-0.019	-0.026	-0.026	-0.017	0.005
realistic (base = no)		0.169***	0.151***		0.214***	0.189***
effective (base = yes)						
no		-1.073***	-1.018***		-1.200***	-1.000***
don't know		-0.394***	-0.368***		-0.576***	-0.456***
innovation will save climate			0.071***			0.052**
worry about climate change			-0.017			0.126***
working in energy (GER) or oil&gas (NOR) sector			0.083			0.282**
female	-0.051	-0.101***	-0.077**	-0.437***	-0.437***	-0.513***
high level of education	0.07	0.052	0.049	0.211***	0.162***	0.123*
age	-0.025	-0.012	-0.004	-0.075***	-0.058***	-0.050*
federal state (base = Baden-Württemberg)						
Bayern	-0.013	0.012	0.019			
Berlin	-0.109	-0.066	-0.063			
Brandenburg	0.135	0.009	0.011			
Bremen	-0.055	0.083	0.077			
Hamburg	-0.135	-0.112	-0.111			
Hessen	-0.128	-0.102	-0.09			
Mecklenburg-Vorpommern	0.117	0.094	0.088			
Niedersachsen	-0.037	-0.03	-0.018			
Nordrhein-Westfalen	-0.031	0.02	0.02			
Rheinland-Pfalz	-0.022	0.021	0.047			
Saarland	0.129	0.125	0.109			
Sachsen	-0.108	-0.057	-0.059			
Sachsen-Anhalt	0.111	0.092	0.102			
Schleswig-Holstein	-0.017	-0.009	-0.005			
Thüringen	-0.116	-0.052	-0.041			
region (base = Oslo/Akershus)						
Østlandet				-0.138**	-0.076	-0.115
Sørlandet				-0.240**	-0.095	-0.144
Vestlandet				-0.105*	-0.039	-0.173*
Trøndelag				-0.196**	-0.151*	-0.162
Nord-Norge				-0.142*	-0.051	-0.105
constant	2.676***	3.158***	2.848***	3.472***	3.692***	2.977***
N	2500	2500	2500	2665	2665	906
df	30	33	36	20	23	26
log likelihood	-3203.243	55.611	-2633.097	-3603.767	89.753	-1016.403
R^2	0.013	0.35	0.362	0.115	0.384	0.411

Table A-4: Comparison of estimation results for large and small Norwegian sample

	Norway				
	M1	M1 small	M2	M2 small	M3
source*storage (base = not spec.*not spec.)					
*not specified *NOR*	-0.163	-0.01	-0.04	0.133	0.141
*not specified * EU*	-0.093	-0.128	-0.026	-0.072	-0.062
*GER * not specified*	-0.191*	-0.341*	-0.116	-0.279*	-0.250*
*GER * NOR*	-0.726***	-0.701***	-0.576***	-0.593***	-0.541***
*GER * EU*	-0.223*	-0.186	-0.101	-0.065	-0.056
*NOR * not specified*	0.005	0.038	0.022	-0.041	-0.036
*NOR * NOR*	0.071	0.124	0.064	0.075	0.11
*NOR * EU*	-0.077	-0.119	-0.01	-0.007	-0.01
*EU * not specified*	-0.208*	-0.318*	-0.112	-0.172	-0.163
*EU * NOR*	-0.405***	-0.225	-0.254***	-0.162	-0.166
*EU * EU*	-0.169	-0.112	-0.073	-0.027	-0.019
offshore (base = onshore)	-0.026	0.032	-0.017	0.01	0.005
realistic (base = no)			0.214***	0.222***	0.189***
effective (base = yes)					
no			-1.200***	-1.087***	-1.000***
don't know			-0.576***	-0.497***	-0.456***
innovation will save climate					0.052**
worry about climate change					0.126***
working in energy (GER) or oil&gas (NOR) sector					0.282**
female	-0.437***	-0.552***	-0.437***	-0.505***	-0.513***
high level of education	0.211***	0.277***	0.162***	0.178**	0.123*
age	-0.075***	-0.075**	-0.058***	-0.060**	-0.050*
region (base = Oslo/Akershus)					
Østlandet	-0.138**	-0.214*	-0.076	-0.14	-0.115
Sørlandet	-0.240**	-0.292*	-0.095	-0.122	-0.144
Vestlandet	-0.105*	-0.224**	-0.039	-0.173*	-0.173*
Trøndelag	-0.196**	-0.11	-0.151*	-0.163	-0.162
Nord-Norge	-0.142*	-0.232*	-0.051	-0.125	-0.105
constant	3.472***	3.515***	3.692***	3.739***	2.977***
N	2665	906	2665	906	906
df	20	20	23	23	26
log likelihood	-3573.767	-1208.077	89.753	-1035.275	-1016.403
R^2	0.115	0.158	0.384	0.385	0.411

The estimation results for the large and the small sample are robust to the extent that they are similar in magnitude and direction. Variations are to be expected because the small sample is two thirds smaller compared to the full sample. The significant effect for European source and Norwegian storage does not appear in the small sample, while the effect of German source and Norwegian storage is present in all sample variations.

Table A-5: OLS regressions by subgroups with a low level or a high level of worry about climate change (scale: not worried at all (1) – very worried (5); low: worry = 1, 2, 3; high: worry = 4, 5) on attitude toward a CCS project (scale: 1 very negative – 4 very positive) for German and Norwegian sample

	Germany		Norway	
	low worry	high worry	low worry	high worry
source*storage (base = not spec.*not spec.)				
*not specified *GER*	-0.129	0.047		
*not specified *NOR*	-0.032	-0.064	0.119	-0.106
*not specified * EU*	-0.09	0.012	-0.366	0.068
*GER * not specified*	-0.043	0.171	-0.592**	-0.066
*GER * GER*	-0.144	0.209		
*GER * NOR*	-0.076	0.062	-0.629**	-0.646***
*GER * EU*	-0.19	0.087	-0.306	-0.002
*NOR * not specified*			0.037	0.03
*NOR * NOR*			0.223	0.076
*NOR * EU*			-0.194	-0.097
*EU * not specified*	-0.139	-0.004	-0.406	-0.188
*EU * GER*	-0.235*	0.102		
*EU * NOR*	-0.031	-0.045	-0.175	-0.247
*EU * EU*	-0.139	-0.026	-0.207	-0.019
offshore (base = onshore)	-0.025	-0.049	0.09	-0.022
female	-0.023	-0.094	-0.573***	-0.609***
high level of education	0.085	0.05	0.232*	0.195*
age	-0.023	-0.033	-0.034	-0.076**
geographic controls	*included*			
constant	2.707***	2.649***	3.365***	3.615***
N	1319	1181	408	498
df	30	30	20	20
log likelihood	-1671.763	-1491.858	-538.016	-609.576
R^2	0.023	0.024	0.199	0.167

* *p*<.05; ** *p*<.01; *** *p*<.001