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The relation between cultural structures and risk perception: How does social acceptance of carbon capture and storage emerge?

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Abstract

In this research, the highly controversial Carbon Capture and Storage technology is scrutinized from the cultural structures perspective. We argue that it is crucial to have a richer understanding of where public opinion on the technology comes from, and we develop a model that helps to understanding this.
We use survey data provided by the Eurobarometer. Also, six cross-cultural dimensions developed by Hofstede are used. Lastly, two indices, Risk Acceptance and Self-Benefit, are used to design a regression model to argue that public acceptance and risk perception of the novel technology is not a simple case of information transfer and knowledge dissemination.
We provide a framework for analysts and policy makers who wish to understand why and how societies and social actors challenge and contest the technology.

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Keywords: carbon capture and storage; cross-cultural dimmensions, risk perception, national culture, climate change, CCS

1. Introduction

In confronting the problem of global warming, the choice today is between immediate action, based on scaling up available mitigation technologies up to what is needed to avoid disastrous climate change impacts, and delay, which would provide us time to develop new, revolutionary mitigation strategies (involving fusion, solar electricity and

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artificial photosynthesis). In view of the many uncertainties about climate change, here, we follow Pacala and Socolow's precautionary "wedge approach," which argues that humanity "can solve the carbon and climate problem in the first half of this century simply by scaling up what we already know to do" [1]. Pacala and Socolow identify 15 stabilization wedges that, if deployed at a significant global scale, could conceivably reduce greenhouse gas (GHG) emissions by one gigaton each. We focus on one of these 15 wedges: Carbon Capture and Storage (CCS) technology, which could help prevent about 90% of the fossil carbon from reaching the atmosphere. The introduction of CCS at all coal plants producing 800 GW/year or at natural gas plants producing 1600 GW/year would, theoretically, reduce emissions by one gigaton [2].

Karimi et al. [3] demonstrated the role of cultural factors and cultural structures in the formation of public opinion on CCS, where cultural factors refer to the specific cultural features and traits of a nation and the cultural structure is as a base constructed on cultural factors. In their study, they developed two indices, Risk Acceptance and Self-Benefit, to indicate that paying attention to the cultural factors of a society can be an advantage in the study and planning of a CCS project. With this regard, they correlated the indices with the six cultural dimensions of Hofstede to offer supporting evidence for their hypothesis. They scrutinized the results of the study for the case studies to test if their interpretation is valid [3].

In this study, we apply a multiple regression analysis with individual level variables, such as acceptance and knowledge of CCS and climate change, age, education, and the Self- Benefit and Risk Acceptance indices. In addition, we employ the cultural dimensions of Hofstede and Minkov [4].

In the paper we will address the following two questions:

- How do cultural structures of a society affect risk perception of CCS?
- To what extent is the reaction of the public to implementation of the technology predictable?

2. CCS in society

CCS operates in a world where the general public is largely unaware of what the technology entails. The public's reactions have thus been researched as pseudo-opinions or non-attitudes, that is, very volatile reactions easily changed by contextual information. Researchers have tried to estimate the effect of providing information on these reactions as part of an experiment or a questionnaire. Results have varied both in magnitude and sign, with positive, negative and non-significant results depending on the procedure [5-8]. Although lack of knowledge might be a key factor in risk perception, many studies hypothesize "an increase in knowledge will not result in reduced aversion to risks" [9,10] because respondents always incorporate factors other than the technical properties into their reactions.

One strand of research that tries to measure this has focused on the localities with proposed CCS facilities. Here, the reactions of local publics to storage projects have been under great scrutiny [11,12]. Not-in-my-backyard (NIMBY), or more accurately, not-under-my-backyard, effects have been differentiated from general reactions by measuring the reactions of offsite and onsite publics [13]. NIMBY reactions (general support for CCS adoption but opposition to local projects) have been explained by individual values, namely the perception of the effects of CCS in society at large [14]. Trust in government has been shown to be a key factor in the inclination to protest, interacting with risk perception [13].

There are, then, estimates of some of the effects on non-CCS related values, opinions and beliefs on reactions to CCS. Our analysis looks at another factor: culture or, "the collective programming of the mind that distinguishes the members of one group or category of people from another" [15p9] also shapes how individuals will react to the technology.

3. Data

In our regression analysis, we used eleven independent variables and two dependent. The variables are discussed in

the following sub-sections.

3.1. Measures and Variables

Five of the independent variables derived from the Eurobarometer survey "Public Awareness and Acceptance of CO_2 capture and storage" [16]. These measures include education, age, Knowledge of CCS, Knowledge of CO_2, and Knowledge of Climate Change. The survey was conducted as part of the Eurobarometer survey programme in 2011 and included 13,901 respondents spread over 12 European countries where CCS projects had been started or were planned. The respondents were queried on their opinions on a variety of CCS issues.

"Education" refers to the level of education of the respondents in the Eurobarometer survey base at the age when they stopped their education. We use years in full-time education in our models. The questionnaire did not record how many years of education those still in school had completed thus far. To avoid a considerable amount of missing data due to this decision, we recoded these students as having completed high school. We believe this decision is fairly accurate in a survey where over 95% respondents are over the age of 18.

"Knowledge of CCS" is based on answers to the question QE9: "Have you ever heard of CO_2 capture and storage, also known as carbon capture and storage or carbon capture and sequestration (CCS)?" This was recoded so that higher scores would indicate that the respondent was more secure in his knowledge of CCS. The respondents were also asked to define carbon dioxide and its effects. We recoded these questions as "Knowledge of CO_2" where higher scores imply that respondent was able to define CO_2[1] and its effects on health and safety and climate change with greater accuracy. "Knowledge of Climate Change" is based on a factor analysis of question QE1 in the Eurobarometer survey, which asked, "Personally, do you think that you are well informed or not about …? The different causes of climate change/The different consequences of climate change/ Ways in which we can fight climate change." The factor score variable was transformed so that higher scores reflect more knowledge.

The other six independent variables are Hofstede's cross-cultural dimensions. The Hofstede dimensions are Power Distance (PDI), Individualism vs. Collectivism (IDV), Masculinity vs. Femininity (MAS), and Uncertainty Avoidance (UAI). In addition, Hofstede added two more dimensions from Bond's and Minkov's studies: Long-Term Orientation (LTO) and Indulgence vs. Restraint (IND) [17]. These dimensions are discussed further in section 3.2.

The dependent variables are the Risk Acceptance and Self-Benefit indices. To develop these two, we chose five CCS questions which represent reactions to the technology in general or locally, and performed a principal component analysis (PCA) on the responses (Table 1). PCA is a data reduction method that transforms correlated variables into a smaller set of components. The questions were chosen on the basis that they measure only dispositions towards CCS (and not whether the current national government is trustworthy, for example). Table 1 has the factor loadings, demonstrating the connection between each question and the resulting component, together with our interpretation of the components.

The questions were split into two components, one with questions on the benefits of CCS, the other with risk issues. We interpret these components as Risk Acceptance and Self-Benefit. Risk Acceptance (RA) is an index that refers to those people who are not concerned about the risks of CCS and rather care that the technology helps to combat climate change. Generally speaking, they care more about environment than economic benefits. Self-Benefit (SB), for its part, is an index that refers to those people who equally appreciate combating climate change and the (economic) benefits that the implementation of the technology may bring them. Here, personal benefits play an important role. The Self-Benefit variable was transformed so that higher scores would indicate that the respondents see more potential benefit. Tables 2 and 3 show some basic statistical data on the analysis.

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[1] The original survey data has coded responses "CO_2 is a greenhouse gas" and "CO_2 is a gas" wrong. We gave half a point for these and a full point for defining it as carbon dioxide

Table 1. The results of factor analysis [3].

Component and Item	Factor loading
Self-Benefit (SB)	
QE13) In my opinion, taking into account all I know about CCS or Carbon capture and storage, CCS could be effective to fight climate change	0.91
QE14) If CCS or carbon capture and storage technology was used in my region; I think I would benefit from it.	0.89
QE 21.6) I agree that CCS will ensure lower and more stable energy prices	0.88
Risk Acceptance (RA)	
QE16) If a deep underground storage site for CO_2 were to be located within 5 km of my home, I would not be worried	0.86
QE21.5) I disagree that The storage of CO_2 represents a safety risk in the future	0.94

Table 2. Statistics of Self-Benefit.

	Q13	Q14	Q21.6
Mean	0,43	0,25	0,29
Std. Deviation	0,09	0,08	0,08
Minimum	0,23	0,10	0,14
Maximum	0,56	0,33	0,37

Table 3. Statistics of Risk Acceptance.

	Q16	Q21.5
Mean	0,23	0,18
Std. Deviation	0,09	0,05
Minimum	0,10	0,12

Maximum	0,43	0,28

3.2. National Culture and Risk

"Capital formation and technological progress both appear to be influenced by human behaviour towards risk" [18p227]. Indeed, there are several studies that show the importance of cultural values and traits in risk perception and risk aversion [10,19-22]. Louberge and Outreville also discuss the "renewed interest" in the work of Hofstede regarding this field of study, i.e. risk [18]. Hofstede initiated "a new way of exploring" national cultures and cross-cultural differences through comprehensive "quantitative comparisons" [4].

In our study, we employ Hofstede's cultural dimensions. These dimensions are developed based on quantitative studies that aimed to dimensionalize cultures among nations so as to help understand cross-cultural differences. In these kinds of studies, the values of a society were measured by surveys. In other words, opinions of people were sought out through questionnaires and further translated to numbers that represent a dimension of culture for a nation or a society. So, the results of these large-scale quantitative studies are the series of scores that distinguish various cultures [23]. Table 4 represents some of the cultural features of each cross-cultural dimension.

Table 4. Some cultural features adopted from [17].

Cultural Dimensions	Features
Power Distance (PDI)	- People read relatively few newspapers (high PDI) - People rarely discuss politics (high PDI)
Individualism vs. Collectivism (IDV)	- 'Look after him or herself and his or her immediate (nuclear) family only' (individuals) - Universalism (individuals) - 'Media is the primary source of information' (individuals)
Masculinity vs. Femininity (MAS)	- More welcome to a technology that aims to increase the long-term quality of life (Femininity) - 'The dominant values in society are caring for others and quality of life' (Femininity) - 'The environment should be preserved' (Femininity) - Growing economy (Masculinity)
Uncertainty Avoidance (UAI)	- 'Uncertainty is a normal feature of life, and each day is accepted as it comes' (low UAI) - Consider difference as a 'curious' matter (low UAI) - 'What is different is dangerous' (high UAI) - 'People have more worries about health and money' (high UAI) - 'There is hesitancy toward new products and technologies' (high UAI)

	- 'Belief in experts and technical solutions' (high UAI)
Long-Term Orientation (LTO)	- Effort should produce quick results (short-term)
	- Respect for tradition (short-term)
	- Investment in mutual funds (short-term)
	- Thrift (long-term)
	- Investment in real estate (long-term)
Indulgence vs. Restraint (IND)	-'Positive attitude' (Indulgence)
	- 'High optimism' (Indulgence)

4. Data Analysis and Discussion

We did a hierarchical linear regression model on two aspects of public reactions: Risk Acceptance and Self-Benefit (Table 5).We first added variables measuring personal knowledge and then those concerning socio-demographic background; and in the third stage, we controlled for the six cultural dimensions. The goal was to see how personal knowledge is mediated by cultural dimensions.

Initially, knowledge of CCS appears to raise both Risk Acceptance and Self-Benefit, but this effect decreases when other explanatory factors**,** namely Knowledge of Climate Change, Knowledge of CO_2, education and age, were included in the model. However, none of these factors significantly affects Risk Acceptance (RA) and Self-Benefit (SB).At the same time, the role of CCS knowledge completely disappears for Self-Benefit and almost completely for Risk Acceptance when other explanatory factors, including the cultural dimensions, are controlled for.

Table 5. Hierarchical multiple regression explaining risk acceptance and self-benefit by personal knowledge on issues, socio-demographic variables and cultural dimensions.

Model		Risk acceptance	Sig.	Self-benefit	Sig.
1	Knowledge on CCS	0,43	***	0,21	***
2	Knowledge on CCS	0,37	***	0,14	***
	Knowledge on Climate Change	0,08	***	0,19	***
	Knowledge on CO2	-0,04	***	-0,03	***
	Education	0,00	***	0,00	n.s.
	Age	0,00	*	0,01	***

3	Knowledge on CCS	0,12	***	-0,09	***
	Knowledge on Climate Change	-0,05	***	0,08	***
	Knowledge on CO2	0,04	***	0,00	n.s.
	Education	0,00	***	0,00	n.s.
	Age	0,00	n.s.	0,00	***
	Power Distance	-0,03	***	-0,02	***
	Individualism vs. Collectivism	0,01	***	0,02	***
	Masculinity vs. Femininity	-0,04	***	-0,01	***
	Uncertainty Avoidance	-0,01	***	0,01	***
	Long-Term Orientation	-0,02	***	0,05	***
	Indulgence vs. Restraint	-0,01	***	0,01	***

Note. R^2=, 047 for step 1; R^2=, 56 for step 2; R^2=0,68 for step 3 (p<0,000)

Moreover, the results show that age has no effect on the RA in the final model. It is notable that the signs of "Knowledge of Climate Change" and "Knowledge of CO_2" (except for SB) are opposite in steps 2 and 3. The initial observed relationship was an artifact from the omission of relevant cultural variables.

Below is the interpretation of the results according to the cross-cultural features and the data from the survey.

4.1. Risk Acceptance (RA)

Step two of the regression model shows that regardless of cultural dimensions, knowledge of climate change and knowledge of CCS are the most important factors affecting RA and SB.

The cultural dimensions are mediating RA in the following manner. In principle, UAI and future orientation are opposite. This means that societies with lower UAI are more concerned about planning for the future [23]. The opposite signs of RA and UAI also show that societies with higher scores of uncertainty avoidance are more reluctant to take risks for combating climate change. Moreover, because the UAI score of a country is also related to interest in politics, it mediates RA in other ways as well. In societies with lower UAI, "citizens are more interested in politics" [17] while climate change is indeed highly present in political discourse. On the contrary, in cultures with high uncertainty avoidance, meaning in which there is a "fear of ambiguous situations," people are not keen enough to ponder over something that is not clearly known and might show its effect in the future**,** such as a climate change phenomena. In these societies, people also read less newspapers [17], one of the main sources for information and knowledge dissemination on climate change [16].

The opposite signs of PDI and RA are consistent with the fact that countries with higher power distance have lower RA. The results of Eurobarometer prove this as well [16]. This is explained by the fact that in hierarchical societies people "read relatively few newspapers" and "rarely discuss politics"; and as it was mentioned, climate change is highly present in social and political discourse. Therefore, people are less informed about the adverse effects of climate change and also have less knowledge of the technology.

The results show that feminine societies have higher RA. This is explained by the features of these societies, namely

people who believe that the "environment should be preserved' and who are more welcoming of a technology that aims to increase the long-term quality of life. This is contrary to masculine societies, in which the emphasis is more dominantly on economic growth.

The opposite signs of the LTO and RA show that countries demonstrating short-term orientation might tend more towards the technology since people from these countries believe that effort should produce quick results and respect traditions. So, people might be satisfied with conventional fossil fuels-based power plants. On the contrary, countries with higher scores of LTO might have less inclination for the technology due to the fact that they place more value in thrift, which implies being more careful in investing in risky or uncertain matters. In addition, investment in real estate is a notable feature of such societies; and it is closely tied with the issue of NIMBY, which, of course, is one of the most important controversies around CCS.

4.2. Self-Benefit (SB)

By comparing the scores of the regression in Table 5, it can be seen that cultural dimensions are the most important factors explaining SB. LTO has the highest impact, followed by IDV, PDI and UAI.

In our model, power distance and SB are negative controls for each other. This is exactly in keeping with our hypothesis and fits the characteristics of hierarchical societies. By increasing individualism, SB also increases. This is quite expected considering the characteristics of such societies (see Table 4) and the definition of SB.

Contrary to RA, Self-Benefit increases with increasing UAI, meaning that in societies with higher uncertainty avoidance, people care more about their individual benefits and welfare. In other words, in a society with higher UAI – a society in which "people have more worries about health and money" and "there is hesitancy toward new products and technologies" – receiving direct benefits is an important factor affecting people's risk perception.
The agreement of signs between SB and LTO consistently is in accord with the characteristic of societies with long-term orientation (see Table 4).

MAS and IVR do not have a significant control on Self-Benefit.

5. Conclusion

This study provides a clearer picture of how social acceptance of CCS emerges**,** which enables companies and policy makers to have a better understanding of how people in a given society might react to the technology. We indicated that there are some factors that play (more) important roles in risk perception of CCS than just knowledge about the technology and climate change. These factors are the cross-cultural traits and orientation of each country. The results showed that Risk Acceptance is affected by a culture's masculinity or femininity, the extent to which a society is hierarchical, and the society's short-term or long-term orientation. Self-Benefit is mainly controlled by three cultural features, including long-term orientation, individualism and power distance. Age and education have no control on risk perception of CCS according to our analysis.

This paper aimed to show the preliminary results of our analysis. These initial macro-level results cannot be directly utilized in individual projects because the social factors involved are much more nuanced than just national culture; however, for CCS practitioners, they should point out where social responses to their actions are likely to arise from. Thus, in addition to providing information about projects, one should make sure that the information provided fits the existing cultural framework of the society. The six-dimensional generalization of culture by Hofstede should be a good starting point for untangling the complex relationship between public reactions to new technologies, the individual characteristics of people and macro-level societal effects.

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