Policy design for climate change mitigation and adaptation in sheep farming: Insights from a study of the knowledge transfer chain

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Abstract

Low innovation adoption rates in agriculture have spurred intense research on farmers' attitudes and motivations. Little attention has been paid to attitudes of other important actors in the knowledge transfer chain. Evidence indeed suggests that adoption rarely happens at the farm level, but requires the right inputs from science and extension services. Divergent attitudes among actors in the knowledge transfer chain may hence contribute to low adoption rates by transferring insufficient, outdated, irrelevant and/or incorrect information. This study is an investigation on attitudes towards climate change mitigation and adaptation of three classes of actors: sheep farmers, researchers involved in fields related to sheep farming and extension officers from private companies and public agencies. The investigation is based on data collected through self-administered questionnaires submitted to 165 participants to agricultural field days in Sardinia (Italy). The sample consists of sheep farmers (37,5%), researchers (16,4%), extension officers (32,1%) and other agricultural workers or students (14%). In order to assess differences in attitude and identify the sources of attitudinal divergence, the study adopts Kolmogorov – Smirnov (KS) equality-of-distribution tests and Partial-least square structural equation modelling (PLS-SEM). Comparing and contrasting attitudes towards several topics related to GHG emission mitigation and adaptation to climate change reveal that researchers and extension officers have different attitudes towards innovation for mitigating GHG, that in turn depend on different information and beliefs on the causes and effects of climate change. This context is less than optimal to promote adoption of climate change mitigation or adaptation strategies. Climate change science and policy design need to recognise the complexity of knowledge transmission and the multiplicity of attitudes and beliefs that inform and affect the process. To mitigate the impact of diverging attitudes and beliefs among researchers and extension officers tailored communication strategies should avoid controversial issues and focus on benefits of innovation on farm efficiency. In turn, this would build trust and cooperation among all the actors in the knowledge transfer chain. Only when cooperation is assured, one could be confident that the information delivered to farmers is scientifically sound, relevant, value-neutral and useful in changing farmers' behaviour.

Keywords	attitudes; technology transfer chain; GHG mitigation and adaptation; policy design; equality-of-distribution tests; partial-least square structural equation modelling.
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Policy design for climate change mitigation and adaptation in sheep farming: insights from a study of the knowledge transfer chain

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Abstract

Low innovation adoption rates in agriculture have spurred intense research on farmers' attitudes and motivations. Little attention has been paid to attitudes of other important actors in the knowledge transfer chain. Evidence indeed suggests that adoption rarely happens at the farm level, but requires the right inputs from science and extension services. Divergent attitudes among actors in the knowledge transfer chain may hence contribute to low adoption rates by transferring insufficient, outdated, irrelevant and/or incorrect information. This study is an investigation on attitudes towards climate change mitigation and adaptation of three classes of

actors: sheep farmers, researchers involved in fields related to sheep farming and extension officers from private companies and public agencies. The investigation is based on data collected through self-administered questionnaires submitted to 165 participants to agricultural field days in Sardinia (Italy). The sample consists of sheep farmers (37,5%), researchers (16,4%), extension officers (32,1%) and other agricultural workers or students (14%). In order to assess differences in attitude and identify the sources of attitudinal divergence, the study adopts Kolmogorov – Smirnov (KS) equality-of-distribution tests and Partial-least square structural equation modelling (PLS-SEM). Comparing and contrasting attitudes towards several topics related to

GHG emission mitigation and adaptation to climate change reveal that researchers and extension officers have different attitudes towards innovation for mitigating GHG, that in turn depend on different information and beliefs on the causes and effects of climate change. This context is less than optimal to promote adoption of climate change mitigation or adaptation strategies. Climate change science and policy design need to recognise the complexity of knowledge transmission and the multiplicity of attitudes and beliefs that inform and affect the process. To mitigate the impact of diverging attitudes and beliefs among researchers and extension officers tailored communication strategies should avoid controversial issues and focus on benefits of innovation on farm efficiency. In turn, this would build trust and cooperation among all the actors in the knowledge transfer chain. Only when cooperation is assured, one could be confident that the information delivered to farmers is scientifically sound, relevant, value-neutral and useful in changing farmers' behaviour.

Keywords: attitudes; technology transfer chain; GHG emission mitigation; climate change adaptation; policy design; equality-of-distribution tests; partial-least square structural equation modelling.

1 Introduction

Agriculture is the second largest anthropogenic contributor to climate change accounting for 24% of total net greenhouse gas (GHG) emissions (Pachauri et al., 2014, p.46). The livestock sector contributes around half of agriculture emissions (Havlík et al., 2014). Agriculture is also highly vulnerable to climate change as extreme temperature, drying trends and erratic precipitation are likely to affect water availability, crop and livestock productivity, food security and income (Pachauri et al., 2014). Despite substantial public subsidies and private incentives, in Europe as in the rest of the world, climate change mitigation and adaptation in agriculture is still limited (Ampaire et al., 2017;

Findlater et al., 2019; Fleming and Vanclay, 2010; Ridier et al., 2013; Stevenson et al., 2019).

Research has identified several causes for low adoption rates in agriculture that can be organised around three major themes:

a. policy-related barriers, such as lack of political commitment, poor horizontal and/or vertical cooperation and inadequate interface between science and policy making. For instance, Ampaire et al. (2017), Matewos (2019) and Wright et al. (2014) identify governance gaps, unstructured and weak coordination among policy actors, low integration of research evidence, lack of monitoring and evaluation programs and insufficient funding in designing and implementing climate change related policies in the farming sector. Their case studies show that barriers in policy-making and implementation can arise at the political, administrative and scientific/technical stages, and often they appear at several levels at once. Clar et al. (2013) and van Buuren et al. (2018) find similar barriers to effective adaptation policies in flood risk management, but they are common in many other fields (IPCC, 2001).

b. barriers related to farmers' perceptions, attitudes and beliefs about a innovation or conservation practice (Pannell et al., 2006). This is a broad and growing research field, indicating that perceptions and beliefs are major drivers of mitigation and adaptation (see (Dang et al., 2014; de Matos Carlos et al., 2019; Mase et al., 2017; Rejesus et al., 2013; Schaak and Mußhoff, 2018). As pointed also in The World Development Report

2015 cognitive obstacles often prevent action on climate change (World Bank, 2015).

c. technical and economic barriers that restrict the rate of adoption of conservation practices. These include the effects of innovations on farms' economic performance, technology complexity, skilled labour and capital requirements, market access and structure, incentives and subsidies (see, for instance, (Biagini et al., 2014; Kuhl, 2019; Sathaye et al., 2001)

There is also a growing literature on the role that knowledge generation and technology transfer play in engaging farmers in programs to adopt better management practices (Willson and Roderick, 2018). Knowledge transfer is the sharing or disseminating of knowledge and provision of inputs to problem solving. The knowledge transfer chain is the set of agents generating, sharing and disseminating knowledge to stimulate desirable agricultural development (Anderson and Feder, 2007). It includes policy makers, scientists and extension officers, as well as farmers. Knowledge transfer in agriculture is not just a matter of provision and comprehension of sufficient information (Potter and

Oster, 2008), but farmers' engagement requires designing strategies to improve how climate change science is framed and delivered (Richards and Carruthers Den Hoed, 2018). This is crucially important in social contexts where the public and experts may be increasingly diverging in their assessment about climate change (Capstick et al., 2015). Hence, as adoption in agriculture does not take place at the farm level but within the entire technology transfer chain (Capstick et al., 2015), barriers to adoption can appear at every stage of the process: science framing and delivering, policy making and in the fields.

Scientists' values and attitudes affects the production and use of knowledge, the framing of information and the policy-science arena (Crouzat et al., 2018).

Extension officers rarely generate new knowledge but they can affect the flow of information to and from the farm as they act as intermediaries in the knowledge transfer chain between scientists and farmers. They have the power to frame, package and delivere information according to their beliefs and attitudes (Prokopy et al., 2014). (Achora et al., 2018), for instance, show that some challenges to adoption of conservation agriculture arise from the chosen knowledge transfer approach. However, the role of agricultural research and extension services is usually investigated to assess their performance in improving farm management and productivity (Anderson and Feder, 2007). While extensive scholarship has explored the role of policy actors and scientists in climate change adaptation (see, for instance, (Biesbroek et al., 2013; Garvin, 2001; Oulahen et al., 2018; Urwin and Jordan, 2008) very little is known about beliefs, perceptions and attitudes of agricultural scientists and extension officers. A few studies have recently acknowledged this gap in the literature and assessed agricultural advisors' appraisal of climate change risk (Carlton et al., 2016; Church et al., 2018; Mase et al., 2015). Other studies have focused on the interactions of scientists, policy makers, extension officers, farmers and their knowledge systems, values and cultural roles (Carr and Wilkinson, 2005; Prober et al., 2017; Richards and Carruthers Den Hoed, 2018). These studies highlight that attitudinal barriers to adoption may be found among actors other than farmers and that improving natural resource management at the farm level requires convergence of those actors' attitudes and knowledge.

In this paper we assess the support to and disposition towards climate change adaptation and mitigation of three classes of actors: sheep farmers, extension officers and researchers. We follow the approach adopted by Prokopy et al. (2014) who compared climate change beliefs by surveying scientists, agricultural advisors, extension educators, and farmers in the United States. We also explore the role of additional factors such as trust and experience in shaping attitudes. The objectives are: a) evaluate whether actors have converging or diverging attitudes; b) identify the causes of divergent or convergent dispositions; c) assess the potential impact of these attitudes on agricultural adoption and on the functioning of the knowledge transfer chain. While diversity of assessments is intrinsic to the knowledge transfer process, there may be instances when it could not be smoothed out by a mere provision of scientific information. Decreased trust in climate scientists, for example, is associated to increased scepticism about climate change (Leiserowitz et al., 2013). Climate sceptic actors in the knowledge transfer change could create conflicting messages, amplify or attenuate risk perceptions and hinder the application of scientific research and knowledge to agricultural practices. As far as we know, ours is one of the few studies to contrast and compare perceptions, beliefs and attitudes of the three major actors in the agricultural knowledge transfer chain. It is also one of the first attempts at identifying the sources of diverging attitudes and assess their likely impact on climate change science transfer. This paper is also peculiar as the attitudes and beliefs assessment will inform the design of climate change policies meant to promote innovations to abate GHG emissions in sheep farming in Sardinia (Italy). It is an exploratory investigation whose results may help to develop more effective strategies for sustainable farming.

Sardinia is one of the largest sheep milk producers in Europe: with about 3.2 million ewes, 14,000 dairy sheep farmers and 330,000t $year^{-1}$ of milk, it represents about 25% of total EU-27 production (Vagnoni and Franca, 2017).

Adoption of alternative management strategies is a crucial issue in sheep farming in Sardinia. As in most of the Mediterranean region, local sheep farming systems are predominantly extensive or low input (Ripoll-Bosch et al., 2013). This is due to agronomic and economic reasons, as well as cultural and historic factors (Nguyen et al., 2016). As GHG abatement at the farm level would require innovation and new agronomic practices, it is important to assess the potential barriers to adoption at every level of the knowledge transfer chain.

The paper is organised in four sections. Section 2 illustrates the conceptual model adopted to explore attitudes and beliefs of farmers, extension officers and researchers working on fields related to sheep farming. This section includes a description of the research method and the questionnaire developed on the basis of the model, as well as a brief summary of the sample. An outline of the instruments adopted for data analysis is in section 3. Section 4 contains a description of the results, while discussion and conclusions are in the final section 5.

2 Model and method

2.1 Conceptual Model

There is extensive evidence of the attitude-behaviour relationship in any field of human endeavour. The 2015 World Development Report, for instance, highlights the contribution of attitudes, habits, skills and abilities, along with automatic thinking, cognitive illusions, mental models and social norms, in shaping human behaviour (World Bank, 2015). On the issue of innovation adoption in agriculture, (Vanni, F. et al., 2013) and (Hou and Hou, 2019) show that farmers' decision to adopt mitigation and adaptation strategies are affected by their attitudes, among other things. Two of the most influential approaches to explain this evidence are the theory of planned behaviour (TPB) (Ajzen, 1991), and the value-beliefs-norm model (Stern, 2000). Central to these models is the idea that beliefs about the world shape attitudes towards actions and objects, and these attitudes in turn affect behavioural intentions. The value-benefit-norm model stresses the role that values and moral norms have in shaping beliefs, while the TPB suggest that self interest and rational choice drive deliberation (Kaiser et al., 2005). Fishbein and Ajzen (2010) define attitudes as function of individual beliefs on a specific object and of the individual's evaluation of that object. Under this perspective, attitudes are an

”evaluative disposition through which individuals behave positively or negatively toward an object” (Wan et al., 2015). Attitudes tend to produce a corresponding behavioural intention and both attitudes and intentions are found to be reliable predictors of subsequent actions once context and individual factors are taken into account (Ajzen, 2004).

An investigation of attitudes could help predict farmers' actual adoption of GHG mitigation and climate change adaptation strategies. One would expect that a negative disposition towards GHG mitigation, for instance, is correlated with low adoption rates. It could also help to predict the quality of the extension officers' knowledge transfer as negative attitudes towards climate change-related innovations are likely to be associated with low quality information sharing. Moreover, an investigation of attitudes would highlight instances of shared attitudes among these actors. Shared or converging dispositions may create a reference group through which information is sought to match and reinforce prior convictions (Boudet et al., 2014; Kahan et al., 2011; Leiserowitz, 2006). Shared climate scepticism among farmers and extension officers, for example, may create a reinforcing group that hinders adoption of climate change-related innovations.

(Ajzen, 2004, 1991; Ajzen and Cote, 2008; Fishbein and Ajzen, 2010) posit that beliefs (i.e. a person's subjective perception of an object), information (i.e. probabilities and outcomes) and values (i.e. desirability of outcomes) are the major determinants of attitudes. In this paper, the assessment of attitudes towards GHG emission mitigation and adaptation to climate change in sheep farming is based on the following hypothesis:

H1: for both mitigation and adaptation, attitudes are affected by the trust respondents have in the mainstream narrative on causes and effects of climate change (Arbuckle et al., 2015, 2013; Mase et al., 2015);

H2: experience, knowledge, and information on causes and effects of climate change are also assumed to affect perceptions and beliefs and hence attitudes towards mitigation and adaptation (Rejesus et al., 2013);

H3: the relevance of climate change on farmers day-to-day management is also expected to influence stakeholders disposition towards adoption (Carlton et al., 2016);

H4: attitudes towards innovation are deemed interesting to gauge farmers disposition towards management changes (Bohnet et al., 2011);

H5: stakeholders disposition towards conservation or a sense of environmental stewardship (unrelated to climate change) affects their attitude towards adoption (Vanni, F. et al., 2013).

The model is described in Figure 1. It contains 5 explanatory constructs or latent variables (*trust, knowledge, relevance, attitudes towards innovation and attitudes towards environmental conservation*) and 2 explained constructs (*attitudes towards mitigation and attitudes towards adaptation*). Both the explanatory and explained constructs are measured with a series of indicators

(D1 to D20 in Figure 1) that capture the composite nature of the variables, but

the latter are also assumed to be influenced by the former.

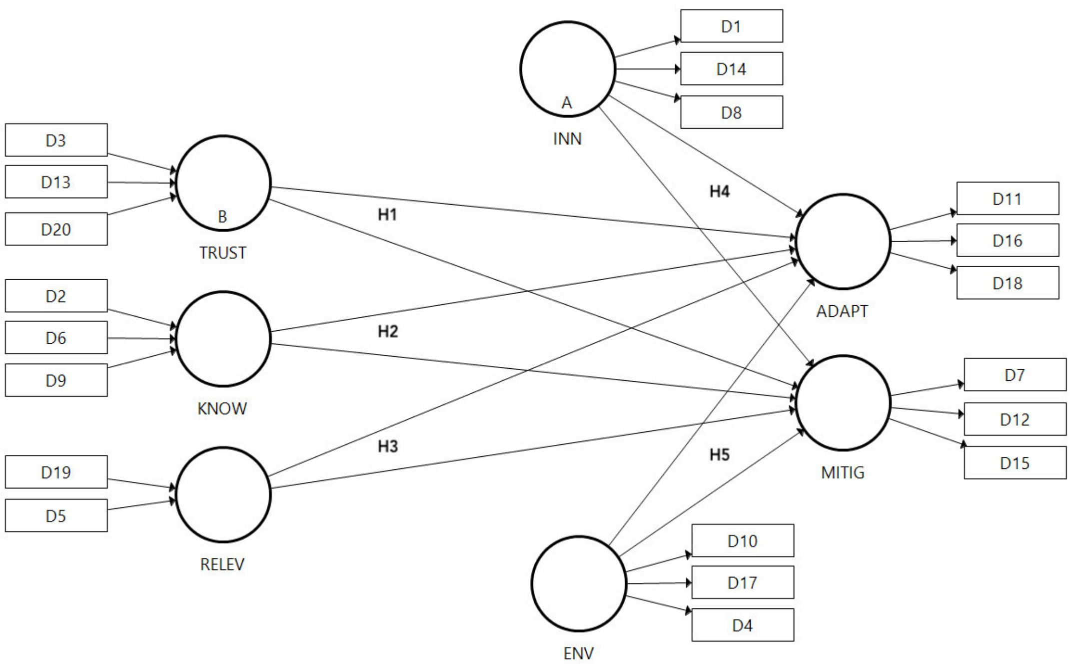

Figure 1: Explanatory and explained constructs in the model

2.2 Survey

In order to understand stakeholders attitudes towards mitigation and adaptation in sheep farming, we developed a questionnaire on the basis of the current literature, related behavioural theories, consultations with experts and two rounds of pre-testing. Having consulted with 12 scientists from universities and public research bodies, as well as agricultural advisors from the Sardinian public extension service, the first drafts of the questionnaire were administered on a non-random sample of 10 farmers to test for language, comprehension and relevance. The final version of the questionnaire contains 20 attitudinal questions, each corresponding to an indicator variable in the model (D1 to D20 in Figure 1), and they are framed as “Do you agree with the following statement?" followed by a 5-point Likert scale (*not at all*, *only a little*, *don't know*, *somewhat, absolutely*). An example of the question is shown in Figure 2 and the full questionnaire is included in Appendix A. The statements were non-neutral, as they propose a one-sided argument or a controversial declaration. The goal of attitudinal questions is indeed to force respondents to take sides. For each topic, but only if appropriate, the questionnaire contains at least a general statement, a statement related to the farmer experience or business, and a statement on the participant information or knowledge. For instance, on the topic of adaptation, the statements are[1]:

- *Investing to adapt to climate change means saving money in the future*

1 To make the questionnaire relevant for farmers, researchers and extension officers, the statements include the expression “my business/sheep farming” or similar.

- *It is not important for my business/sheep farmers to adapt to climate change*
- *I do not know solutions to adapt my business/sheep farming to climate change*

Answers are coded in such a way that higher scores indicated a favourable disposition towards the composite latent variables. For instance, consider the following two statements: *"Every year climate change causes financial losses to sheep farmers*" and "*There is very little one can do about climate change*". Agreeing with the first statement and disagreeing with the second both receive high scores, as the underlying beliefs are expected to be correlated with positive attitudes towards adaption and mitigation.

The questions broke down the issue of climate change into 7 categories:

a. Trust on the mainstream narrative on climate change;

b. Knowledge and experience of the effects of climate change;

c. Relevance of climate change for farmers;

d. Innovation;

e. Environmental protection;

f. Mitigation;

g. Adaptation.

2) Do you agree with the following statement: "Every year climate change causes financial losses to sheep farmers"?				
Not at all	Only a little	Don't Know / Indifferent	Yes, somewhat	Absolutely

Figure 2: Sample of survey question

It is desirable to research each topic in depth with as many questions as possible. However, this aspiration has to be balanced against the demands that a long and complex questionnaire poses on the respondents. An in-depth but taxing questionnaire is not a guarantee for quality of the answers. After consultations with experts and extension officers, it was agreed that the questionnaire should:

a. be self-administered; participants would fill in the questionnaire by themselves in their own time, avoiding the pressure of an interview, the warm-glow effect and "yes-saying" (Krosnick, 1991; Podsakoff et al., 2012; Revilla, 2015);

b. not take more than 10-15 minutes to complete; a longer questionnaire will have high rejection rate and poor answers, because "farmers are time-constrained and will avoid any task that is too long or cognitively taxing" (A. Atzori, pers. comm.),;

c. have a limited number of factual questions (e.g. farm size, location, etc.) as many farmers "have privacy concerns no matter how many guarantees your questionnaire provides" (A. Atzori, pers. comm.) and would avoid them and reject the whole questionnaire.

2.3 Sample

The questionnaire was administered on a sample of 62 Sardinian sheep farmers, 27 agricultural scientists, 53 public and private extension officers, and 23 respondents from heterogeneous backgrounds (students, crop farmers, farm labourers). The sample is representative neither of the farming sector nor of the research and extension services. Questionnaires were distributed and collected during a series of farm field days to promote innovation in sheep farming for efficiency and nutrition improvement. Field trials are important moments of knowledge transfer and hence they are a good setting to evaluate if there are diverging assessments of innovation. However, participants to field days are self-selected, and usually includes farmers who are more open and geared towards innovation (more educated, larger enterprises). We expect that our biased sample would highlight more converging rather than diverging evaluation. 80%

of the respondents are male and over 45 years old. As expected, many farmers did not provide answers to factual questions, but fully completed the attitudinal survey.

3 Data analysis

Kolmogorov – Smirnov (KS) equality-of-distribution tests and Partial-least square structural equation modelling (PLS-SEM) are adopted to assess model and attitudes. The Kolmogorov-Smirnov test (KS test) is a non-parametric test of the equality of continuous probability distributions that can be used to compare two samples. The KS statistic quantifies the distance between the empirical distribution functions of two samples. It is calculated under the assumptions that the samples are drawn from a population with the same distribution. The KS tests tell us if the frequencies of values computed from the Likert scale scores for each latent variable have the same distribution function between samples (Gregoire and Driver, 1987). In other words, significant differences between distributions of the samples indicate a difference in disposition or attitude towards a construct.

To understand the source of divergent or different attitudes in the sample, we assess the model in Figure 1 and test the hypotheses with the use of the PLS-SEM. PLS-SEM is an exploratory method that searches for relationships between composite (multi-items) unobserved variables that can be measured indirectly via indicators variables. Each indicator variable captures a single aspect of an abstract construct or concept. What differentiates PLS-SEM from other structural equation modelling approaches is that PLS-SEM relies on explaining the variance of the independent variables rather than estimating the covariance matrix of the dataset (Hair et al., 2014). (Venturini S. and Mehmetoglu M., 2017) suggest using PLS-SEM when the model relating explanatory and explained constructs (the structural model) is complex and the sample size is small. The application of PLS-SEM has increased of late due to its applicability to challenging models and its ability to assess data with non-normal features or with small sample sizes (Hair et al., 2014). Its use is already consolidated in several fields, among which environmental studies (Carlet, 2015), because of its capability of assessing both causal relationships between indicators and causal relationships between latent constructs (Gudergan et al., 2008). Furthermore PLS-SEM helps for exploratory and confirmatory research in the assessment of complex relationships where many indicators and constructs are present (Chin et al., 2003).

The PLS-SEM develops upon two sets of linear equations: the structural model and the measurement model. The structural model postulates the relationships between unobserved or latent constructs, whereas the measurement model specifies the relationships between a latent construct and its observed or manifest items. The data analysis follows a two-step approach: the first step assesses the measurement model to ensure reliability and validity of the constructs; the second step tests the causal paths between the constructs that comprise the theoretical model and evaluates the structural model. In the first step, item reliability, internal consistency and discriminant validity were used to test the reliability and validity of the model[2].

2 Item reliability was examined through factor loadings that indicate the degree to which each indicator is correlated with its relevant latent variable. Internal consistency was tested using Cronbach alpha and the rho. The structural model was tested based upon the significance of the path coefficients, representing the strength of causal relationships between constructs, by observing the R^2 values of the dependent variables, and observing the Average Variance Extracted (AVE) which measures the amount of variance of a latent variable that is explained by its

As shown in Figure 1, PLS-SEM assesses the relationships between the explanatory (exogenous) constructs Trust, Knowledge, Relevance, Innovation and Environmental protection with the explained (endogenous) constructs

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indicators in relation to the amount of variance due to measurement error. Among the model selection criteria, the Akaike Information Criterion (AIC), also unbiased and corrected, the Bayesian Information Criterion (BIC) and the Hannan Quinn Criterion (HQ), also corrected, are employed.

Mitigation e Adaptation, each of which captures the attitude of respondents on the topic. PLS-SEM also allows comparisons of the estimated relationships across the classes of respondents in the sample.

4 Results

Figures 3 and 4 show the probability density functions of the scores of the two latent attitudinal variables MITIG and ADAPT for each class of actors in the sample[3]. The probability functions are estimated via kernel density estimation

3 Score for MITIG is the sum of the scores obtained from responses to questions D7, D12 and D15. Score for ADAPT is the sum of scores from questions D11, D16 and D18. Scores are normalised to range from -3 to 2.

(KDE) that makes use of the Epanechnikov function[4]. A visual inspection suggests some differences in the distribution functions. For both MITIG and ADAPT, farmers show a negative disposition more frequently than the other

4 Kernel density estimation (KDE) is a technique for the non-parametric estimation of the probability density function of a random variable. It can use a range of kernel functions (uniform, triangular, biweight, triweight, Epanechnikov, normal, and others). The Epanechnikov kernel is the most efficient when compared to the optimal kernel (Wand, M.P; Jones, M.C. , 1995. Kernel Smoothing. London: Chapman & Hall/CRC).

classes. Researchers, on the contrary, show a positive attitude on both topics more frequently than the other actors. On the topic of mitigation, extension officers seem to have an attitude that is less positive than researchers' disposition, while on adaptation their attitude scores follow a similar pattern.

The results of a Kolmogorov-Smirnov (KS) equality-of-distributions test are shown in Tables 1 and 2. For the latent variable MITIG the test indicates that farmers, extension officers and the Others sub-samples have similar attitudes, and that they all differ from researchers (at 95% confidence level).

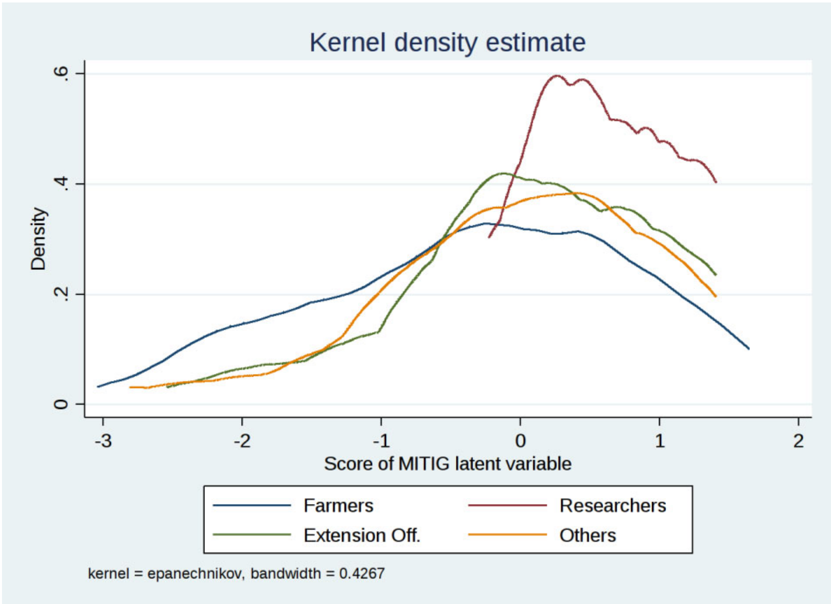

Figure 3: Kernel density of MITIG variable

For the ADAPT latent variable, the KS test indicates that researchers and extension officers have similar attitudes and that they both differ from farmers (at 95% confidence level). The Others sub-sample does not show any difference in attitude from the other classes of actors.

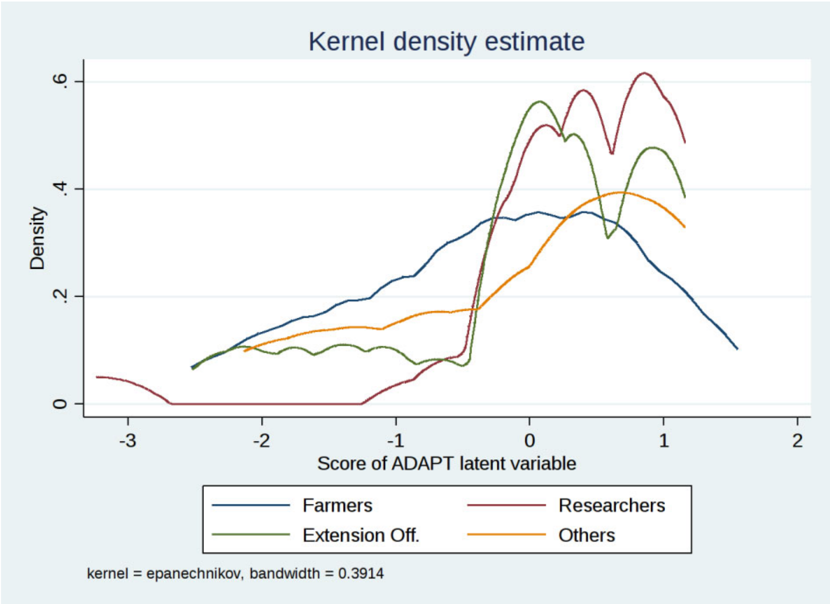

Figure 4: Kernel density of ADAPT variable

Table 1. Results of the K-S equality of distribution test for the MITIG latent variable

	RESEARCHERS				EXT OFF				OTHERS			
	Smaller group	Distance	P-value	Exact	Smaller group	Distance	P-value	Exact	Smaller group	Distance	P-value	Exact
FARMERS	1	0.470	0.000		1	0.209	0.082		1	0.218	0.203	
	2	0.000	1.000		3	-0.0027	1		4	-0.044	0.939	
	Combined K-S:	0.470	0.001	0.000**	Combined K-S:	0.2091	0.164	0.136	Combined K-S:	0.2181	0.402	0.344
RESEARCHERS					Smaller group	Distance	P-value	Exact	Smaller group	Distance	P-value	Exact
					2	0.000	1.000		2	0.000	1.000	
					3	-0.345	0.014		4	-0.367	0.035	
					Combined K-S:	0.3452	0.028	0.021**	Combined K-S:	0.367	0.070	0.051*
EXT OFF									Smaller group	Distance	P-value	Exact
									3	0.0632	0.88	
									4	-0.1025	0.714	
									Combined K-S:	0.1025	0.996	0.986

*** significant at 5%*

Significant at 10%

Table 2. Results of the K-S equality of distribution test for the ADAPT latent variable

	RESEARCHERS				EXT OFF				OTHERS			
	Smaller group	Distance	P-value	Exact	Smaller group	Distance	P-value	Exact	Smaller group	Distance	P-value	Exact
FARMERS	1	0.400	0.002		1	0.284	0.010		1	0.280	0.072	
	2	-0.037	0.950		3	-0.0271	0.959		4	-0.029	0.973	
	Combined K-S:	0.400	0.005	0.003**	Combined K-S:	0.2842	0.02	0.015**	Combined K-S:	0.2798	0.145	0.116
RESEARCHERS					Smaller group	Distance	P-value	Exact	Smaller group	Distance	P-value	Exact
					2	0.037	0.952		2	0.040	0.961	
					3	-0.178	0.324		4	-0.200	0.371	
					Combined K-S:	0.1775	0.626	0.551	Combined K-S:	0.200	0.705	0.618
EXT OFF									Smaller group	Distance	P-value	Exact
									3	0.1444	0.512	
									4	-0.0837	0.799	
									Combined K-S:	0.1444	0.892	0.835

*** significant at 5%*

Significant at 10%

Table 3. Results of the structural model estimation

	Standardised path coefficients (Bootstrap)			
Variable	MITIG	*P Values*	ADAPT	*P Values*
Trust	0.382**	*0.000*	0.184**	*0.017*
Know	0.234**	*0.018*	0.207**	*0.007*
Relev	0.098	*0.485*	0.018	*0.816*
Inn	0.002	*0.986*	0.170**	*0.014*
Env	0.128	*0.151*	0.376**	*0.000*
R-squared adjusted	0.413		0.342	

** *significant at 5%*

* *significant at 10%*

PLS-SEM gives an insight on the factors explaining divergent attitudes on mitigation and adaptation. As shown in Table 3, the latent variables TRUST and KNOW have significant impacts on both MITIG and ADAPT construct, while INN and ENV are significant only for ADAPT. The construct RELEV

has significant impact neither on MITIG nor on ADAPT.

Table 4. P-values for comparing PLS-SEM parameter estimates.

		P-values					
Model	*Variable*	Farmers vs Researchers	Farmers vs Ext Off	Farmers vs Others	Researchers vs Ext Off	Researchers vs Others	Ext Off vs Others
ADAPT	*Trust*	0.866	0.894	0.016**	0.949	0.126	0,036**
	Know	0.976	0.374	0.708	0.594	0.804	0.373
	Relev	0.590	0.435	0.497	0.294	0.387	0.930
	Inn	0.903	0.401	0.083*	0.586	0.113	0.015**
	Env	0.504	0.520	0.805	0.861	0.571	0.540
MITIG	*Trust*	0.052*	0.187	0.650	0.340	0.323	0.666
	Know	0.332	0.101	0.245	0.974	0.198	0.028*
	Relev	0.940	0.914	0.267	0.991	0.250	0.208
	Inn	0.974	0.949	0.403	0.982	0.432	0.376
	Env	0.756	0.340	0.167	0.343	0.416	0.098*

*** significant at 5%*

** significant at 10%*

In Appendix B we report the quality criteria for the PLS-SEM model estimation. The model performance is not entirely satisfactory: some indicator variables are excluded from estimation as did not have significant impact on constructs[5]. A possible explanation is that the survey focus is sheep farming and

5 To asses the relationship between latent constructs and indicator variables, PLS-SEM makes use of *outer loadings*. Outer loadings are coefficients estimated through single regressions (one for each indicator variable) of each indicator variable on its corresponding construct. Indicator variables with standardised loadings less than 0.4 are

hence farmers attitudes and opinions are related to what farmers themselves should or should not do. For researchers, extension officers and the rest of the sample, what is measured is actually their attitudes towards what sheep farmers should or should not do. Still the model provides evidence on factors affecting

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dropped from estimation while indicators with loadings between 0.4 and 0.7 are retained if they exclusion does not improve model performance (Hair et al., 2014, p.103).

mitigation and adaptation attitudes that is in line with the findings in the literature. Comparing the structural model parameter estimates indicates that the impact of latent variables on MITIG and ADAPT constructs do no differ substantially across stakeholders. Leaving aside the heterogeneous class of ”Others”, only for farmers and researchers the latent variable Trust has significantly different weights on their attitudes towards mitigation (see Table 4).

A visual inspection of the probability density functions and the KS tests identify the sources of different attitudes. Farmers trust the main narrative on causes and effects of climate change less than researchers and extension officers (see Figure 5 below and Table C1 in Appendix C). There is also a significant difference between the level of trust of researchers and extension officers while not significant differences are reported between farmers and the ”Others” sub sample. Similar pattern is found for the KNOW construct (Figure 6): farmers differ in the level of knowledge from researchers and extension officers, and those two classes differ as well. Prokopy et al. (2014) report similar results on a sample of US agricultural stakeholders.

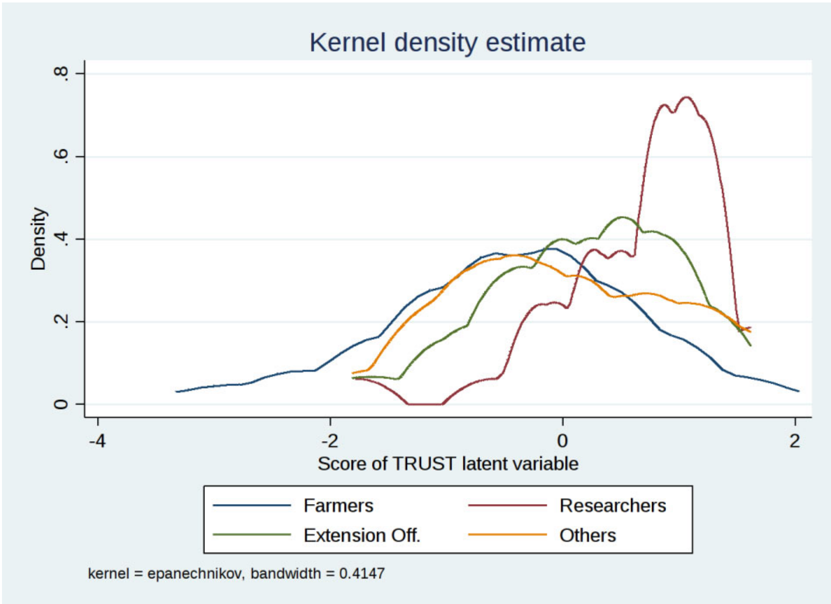

Figure 5: Kernel density of TRUST

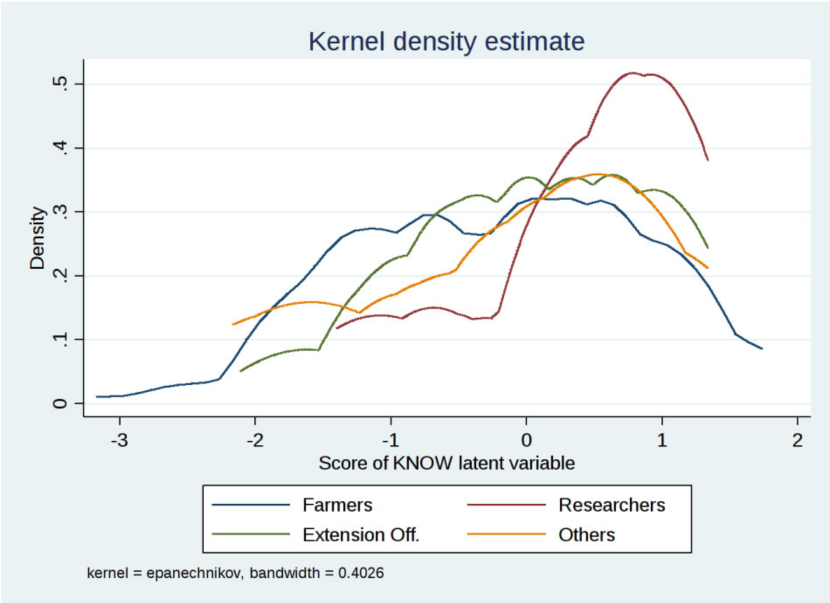

Figure 6: Kernel density of KNOW

On the topic of relevance of climate change, there are not statistically different opinions even if from a visual inspection of Figure 7, researchers appear to judge the impact of climate change in sheep farming less relevant than any other stakeholder. Innovation is a topic where the only significant difference is between farmers and researchers: farmers tend to be less favourable towards innovation (Figure 8). Furthermore, farmers have a less favourable disposition toward environmental protection than researchers and extension officers. No significant difference is found between the other classes (Figure 9).

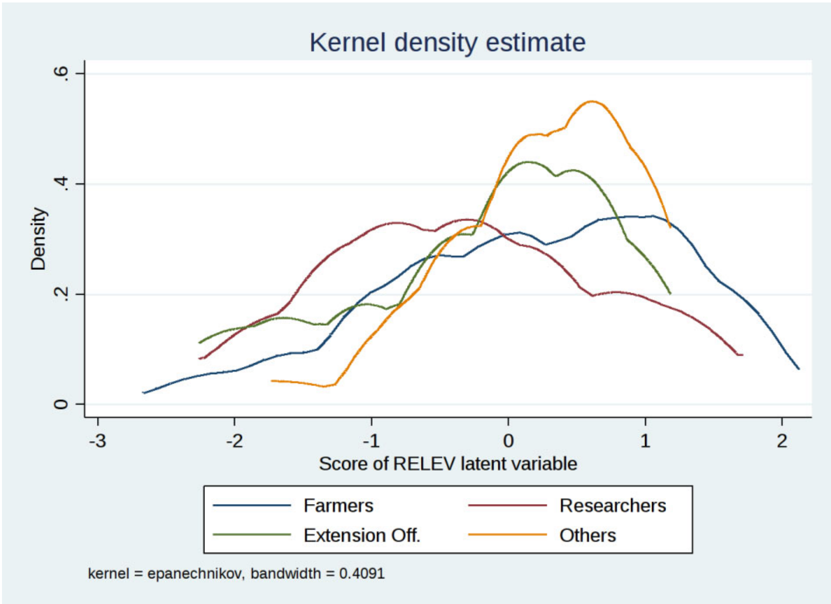

Figure 7: Kernel density of RELEV

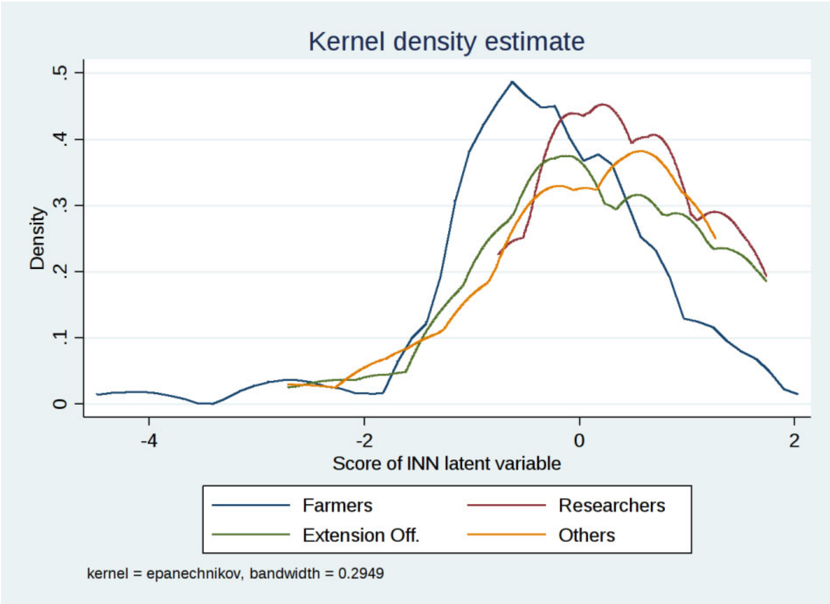

Figure 8: Kernel density of INN

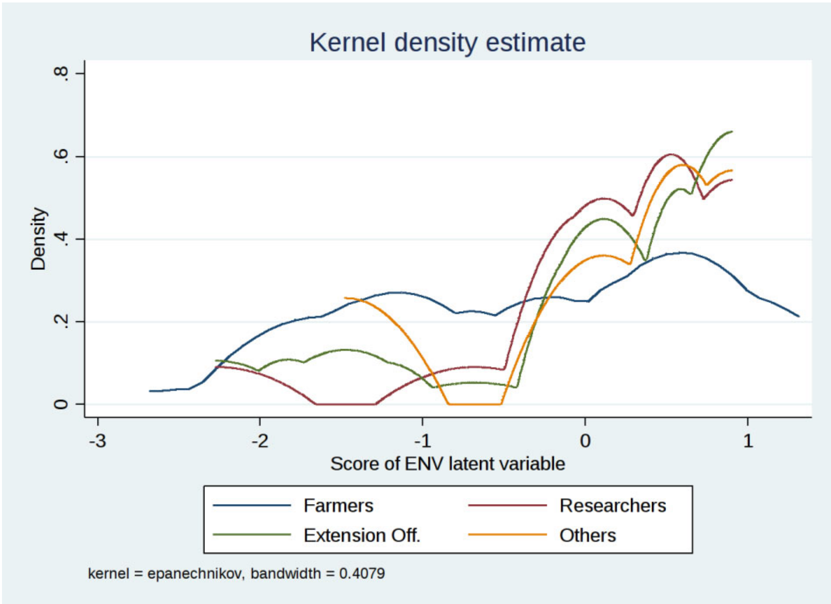

Figure 9: Kernel density of ENV

5 Discussion and conclusions

The results of our survey on sheep farming stakeholders indicate that farmers and extension officers share similar attitudes regarding GHG emission mitigation, and their attitude is less favourable to mitigation strategies compared to that expressed by scientists. Different levels of knowledge on causes and consequences of climate change and different levels of trust in the mainstream narrative regarding climate change are the sources of these diverging attitudes. For adaptation strategies, results show that researchers and extension officers have similar attitudes while farmers are less supportive of climate change adaptation than the other two groups. Again, the sources of these differences are knowledge of climate change causes and impacts and belief in climate science.

Differences in attitudes and opinions between farmers and other actors in the knowledge transfer chain are expected. As changes in the production system entail some degree of risk and uncertainty to their livelihood and lifestyle, farmers may be more cautious and conservative in embracing new ideas and information than other professionals whose livelihood is not at stake. As shown by Pannell et al. (2006), farmers need to be persuaded of the relative advantage of an innovation before abandoning the old ways. This is the very reason for establishing a knowledge transfer network.

It is however less than optimal for researchers and extension officers to have different attitudes towards innovation for mitigating GHG, that in turn depend on different levels of trust and knowledge. These gaps in information and trust in scientific explanations of climate change are evidence of a bottleneck in the process of transferring scientific information from the research laboratories to the farm. Agricultural extension officers are intermediaries in the information chain between scientists and farmers. They have the power to affect the flow of information to and from the the farm by framing, packaging and delivering information according to their beliefs and attitudes. It appears that extension officers and farmers share the same attitude towards mitigation strategies and that it is based on a decreased trust in and knowledge of climate science and facts. This shared world view may produce climate scepticism that reinforces itself in the extension officers/farmers community by disseminating information that matches prior convictions (Boudet et al., 2014; Kahan et al., 2011; Leiserowitz, 2006). This context is less than appropriate to promote adoption of climate change mitigation or adaptation strategies: scientific evidence could not be communicated or transmitted through the knowledge transfer chain in ways that can effectively change farmers' behaviour.

The implications of these findings are twofold. First, our investigation highlights the importance of recognizing the complexity of knowledge transmission and the multiplicity of attitudes and beliefs that inform and affect the process before a policy is designed and implemented. An ex ante analysis of attitudes and beliefs could shed some lights on how they cut across stakeholders' groups creating drivers or barriers to adoption of climate change mitigation strategies. Second, science and policy design for climate change mitigation and adaptation in sheep farming in Sardinia need to address the causes of different level of trust and knowledge among researchers and extension officers. On the one hand scientists could: a) start promoting innovation that both reduce GHG emission and address directly farmers needs. GHG mitigation at the farm level has comparatively smaller private benefits than adaptation, and hence is less likely to be voluntarily adopted. Science should provide solutions that increase the private benefits, such as promoting curbing emission through efficiency improvement or through strategies that shield business from adverse climate change impacts. For instance, they could promote diet and nutrition innovation in order to improve animal health and hence productivity. A better animal diet has also the side benefit of reducing emissions from enteric fermentation (Molle et al., 2008). Scientists should stress the efficiency improvement in order to avoid the controversial topic of GHG mitigation and climate change. In turn, this could also improve trust and cooperation between scientists and extension officers. More cooperation and trust means that researchers, extension officers and farmers could find solutions meaningful and coherent with their goals and needs; b) use communication expertise to promote tailored messages to avoid challenging extension officers' beliefs and world views, as well as making assumptions that could block receptiveness to learning about innovation and climate change (Prokopy et al., 2014). On the other hand, policy makers needs to provide resources for communication, training and education along with the general framework to adopt innovation. Incentives may be also necessary as appealing to farmers' sense of environmental stewardship and attitude towards innovation do not appear to be sufficient to promote adoption.

Based on prior understanding of the sources of differing attitudes, communication, training and education could help finding novel ways to overcome entrenched beliefs and communicate climate change science. This in turn would improve cooperation from all actors in the knowledge transfer chain. Only when this cooperation is assured, one could be confident that the information delivered to farmers is scientifically sound, relevant and value-neutral.

Traditionally, policies to promote innovation adoption in agriculture have targeted farmers. Given the low adoption rates, there is a clear need for more ex ante research to investigate potential bottlenecks in knowledge transfer so as to inform policy making and implementation.

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Appendix A: Questionnaire

QUESTIONNAIRE
STAKEHOLDERS' OPINION

With the following questions, we would like to know you opinion on the importance that climate change, innovation, and environmental conservation have on sheep farming in Sardinia. Please fill in the questionnaire by ticking in the square underneath the item that reflects your opinion. There are no right or wrong answer but only your point of view. We would like to remind you that participation is entirely voluntary and all the collected information is confidential and will be used only for research purposes as per Decree n.196/2003 "Code for personal data protection"

Profession	***Location***	***Business/Farm name***
☐ Farmer		
☐ Researcher		
☐ Extension officer		
☐ Other________		

1) Do you agree with the following statement: "Innovation is the key for sheep farming to take on future challenges"

Not at all	Only a little bit	Don't know/ Indifferent	Yes, somewhat	Absolutely
☐	☐	☐	☐	☐

2) Do you agree with the following statement: "In my experience, I have witnessed seasons becoming increasingly uncertain"

Not at all	Only a little bit	Don't know/ Indifferent	Yes, somewhat	Absolutely
☐	☐	☐	☐	☐

3) Do you agree with the following statement: "Climate changes are not caused by human activities"

Not at all	Only a little bit	Don't know/ Indifferent	Yes, somewhat	Absolutely
☐	☐	☐	☐	☐

4) Do you agree with the following statement: "Environmental protection is farmers' responsibility"

Not at all	Only a little bit	Don't know/ Indifferent	Yes, somewhat	Absolutely
☐	☐	☐	☐	☐

5) Do you agree with the following statement: "Every year sheep farmers incur serious economic losses because of climate change"

Not at all	Only a little bit	Don't know/ Indifferent	Yes, somewhat	Absolutely
☐	☐	☐	☐	☐

6) Do you agree with the following statement: "Climate changes are contributing to increase the earth temperature"

Not at all	Only a little bit	Don't know/ Indifferent	Yes, somewhat	Absolutely
☐	☐	☐	☐	☐

7) Do you agree with the following statement: "In order to mitigate climate change it is necessary to cut GHG emissions from sheep farming"

Not at all	Only a little bit	Don't know/ Indifferent	Yes, somewhat	Absolutely
☐	☐	☐	☐	☐

8) Do you agree with the following statement: "Only experience can help to improve the efficiency of sheep farming"

Not at all	Only a little bit	Don't know/ Indifferent	Yes, somewhat	Absolutely
☐	☐	☐	☐	☐

9) *Do you agree with the following statement:* "Extreme events such as drought, flooding and wildfires are less frequent than in the past"

Not at all	Only a little bit	Don't know/ Indifferent	Yes, somewhat	Absolutely
☐	☐	☐	☐	☐

10) *Do you agree with the following statement:* "Natural resource conservation is not a priority of sheep farming businesses "

Not at all	Only a little bit	Don't know/ Indifferent	Yes, somewhat	Absolutely
☐	☐	☐	☐	☐

11) *Do you agree with the following statement:* "Investing to adapt to climate change means saving money in the future"

Not at all	Only a little bit	Don't know/ Indifferent	Yes, somewhat	Absolutely
☐	☐	☐	☐	☐

12) *Do you agree with the following statement:* "I would like to have more information on the effects of climate change on sheep farming"

Not at all	Only a little bit	Don't know/ Indifferent	Yes, somewhat	Absolutely
☐	☐	☐	☐	☐

13) *Do you agree with the following statement:* "Recent weather conditions forecast the start of cold years"

Not at all	Only a little bit	Don't know/ Indifferent	Yes, somewhat	Absolutely
☐	☐	☐	☐	☐

14) *Do you agree with the following statement:* "Sheep farming in Sardinia is too traditional"

Not at all	Only a little bit	Don't know/ Indifferent	Yes, somewhat	Absolutely
☐	☐	☐	☐	☐

15) *Do you agree with the following statement:* "There is very little to do to avoid climate change"

Not at all	Only a little bit	Don't know/ Indifferent	Yes, somewhat	Absolutely
☐	☐	☐	☐	☐

16) *Do you agree with the following statement:* "It is not important for sheep farmering to adapt to climate change"

Not at all	Only a little bit	Don't know/ Indifferent	Yes, somewhat	Absolutely
☐	☐	☐	☐	☐

17) *Do you agree with the following statement:* "Future generations will need to adapt to a natural environment completely different from the present one"

Not at all	Only a little bit	Don't know/ Indifferent	Yes, somewhat	Absolutely
☐	☐	☐	☐	☐

18) *Do you agree with the following statement:* "I do not know of any solution to adapt my business to climate change"

Not at all	Only a little bit	Don't know/ Indifferent	Yes, somewhat	Absolutely
☐	☐	☐	☐	☐

19) *Do you agree with the following statement:* "The future of sheep farming is uncertain because of climate change"

Not at all	Only a little bit	Don't know/ Indifferent	Yes, somewhat	Absolutely
☐	☐	☐	☐	☐

20) *Do you agree with the following statement:* "In the past weather was as warm as in the last few years"

Not at all	Only a little bit	Don't know/ Indifferent	Yes, somewhat	Absolutely
☐	☐	☐	☐	☐

The Questionnaire is finished. Thanks for you cooperation.

Appendix B

Quality Criteria for PLS-SEM estimation

Table B1. R Square

	R Square	R Square Adjusted
ADAPT	0.430483	0.412574
MITIG	0.362418	0.342368

Table B2. f Square

	ADAPT	ENV	INN_ _	KNOW	MITIG	RELEV	TRUST
ADAPT							
ENV	0.208681				0.021674		
INN_ _	0.046362				0.000004		
KNOW	0.057588				0.065893		
MITIG							
RELEV	0.000573				0.014812		
TRUST	0.044810				0.172443		

Table B3. Construct reliability and validity				
	Cronbach's Alpha	rho_A	Composite Reliability	Average Variance Extracted (AVE)
ADAPT	0.491074	0.653536	0.778805	0.644559
ENV	1.000000	1.000000	1.000000	1.000000
INN	0.169279	0.172829	0.704554	0.545503
KNOW		1.000000		
MITIG	0.455895	0.644622	0.650490	0.414321
RELEV		1.000000		
TRUST		1.000000		

Discriminant validity

Table B4. Fornell-Larcker Criterion

	ADAPT	ENV	INN__	KNOW	MITIG	RELEV	TRUST
ADAPT	0.802845						
ENV	0.538425	1.000000					
INN__	0.324205	0.200185	0.738582				
KNOW	0.441278	0.332975	0.161104				
MITIG	0.565733	0.331122	0.152432	0.449930	0.643678		
RELEV	0.029437	0.030777	-0.098124	0.058879	0.124267		
TRUST	0.437689	0.317416	0.253434	0.436016	0.528141	0.022718	

Table B5. Cross loadings

	ADAPT	ENV	INN	KNOW	MITIG	RELEV	TRUST
D1	0.252511	0.089992	0.795991	0.086453	0.142320	0.103219	0.115818
D10	0.538425	1.000000	0.200185	0.332975	0.331122	0.030777	0.317416
D12	0.250194	0.025030	0.141953	0.110232	0.434525	0.231977	0.125697
D15	0.548531	0.365555	0.140655	0.454663	0.921923	0.008960	0.555125
D16	0.928235	0.535732	0.280683	0.457864	0.572459	0.024971	0.480276
D18	0.653834	0.278925	0.253176	0.190373	0.273635	0.024035	0.135663
D19	0.071859	0.103755	-0.097027	0.100876	0.096515	0.865112	0.078868
D20	0.340064	0.200902	0.161936	0.361101	0.368985	0.203604	0.730531
D3	0.335728	0.282992	0.224627	0.315136	0.440860	-0.143319	0.807178
D5	-0.026509	-0.059218	-0.068461	-0.005863	0.115715	0.833849	-0.046222
D6	0.222189	0.064121	0.105092	0.668884	0.372522	0.214835	0.254234
D7	0.154299	0.049345	-0.005903	0.143574	0.451894	0.261503	0.095039
D8	0.226023	0.219786	0.676317	0.159806	0.077556	-0.287019	0.275951
D9	0.410005	0.394075	0.130075	0.793847	0.298626	-0.096790	0.376733

Table B6. Heterotrait-Monotrait ratio (HTMT)

	ADAPT	ENV	INN	MITIG
ADAPT				
ENV	0.714011			
INN	1.132210	0.509366		
MITIG	0.916570	0.313846	0.552611	

Collinearity statistics (VIF)

Table B7. Outer VIF Values

	VIF
D1	1.008624
D10	1.000000
D12	1.179029
D15	1.027773
D16	1.118462
D18	1.118462
D19	1.246239
D20	1.036059
D3	1.036059
D5	1.246239
D6	1.006270
D7	1.184645
D8	1.008624
D9	1.006270

Table B8. Inner VIF Values

	ADAPT	ENV	INN	KNOW	MITIG	RELEV	TRUST
ADAPT							
ENV	1.191189				1.191189		
INN	1.102253				1.102253		
KNOW	1.307343				1.307343		
MITIG							
RELEV	1.016708				1.016708		
TRUST	1.331321				1.331321		

Model fit

Table B9. Fit Summary		
	Saturated Model	Estimated Model
SRMR	0.116712	0.119130
d_ ULS	1.430272	1.490158
d_ G	0.296587	0.329785
Chi-Square	292.686676	312.648260
NFI	0.425776	0.386613

Table B10. Rms Theta	
rms Theta	0.291438

Table B11. Model Selection Criteria

	AIC (Akaike's Information Criterion)	AICu (Unbiased Akaike's Information Criterion)	AICc (Corrected Akaike's Information Criterion)	BIC (Bayesian Information Criteria)	HQ (Hannan Quinn Criterion)	HQc (Corrected Hannan-Quinn Criterion)
ADAPT	-81.892557	-75.780747	85.820819	-63.256884	-74.327689	-73.330753
MITIG	-63.264870	-57.153060	104.448506	-44.629197	-55.700002	-54.703066

Appendix C

Two-sample Kolmogorov-Smirnov test for equality of distribution functions

		RESEARCHERS				EXT OFF				OTHERS			
TRUST	FARMERS	Smaller group	Distance	P-value	Exact	Smaller group	Distance	P-value	Exact	Smaller group	Distance	P-value	Exact
		1	0.522	0.000		1	0.300	0.006		1	0.208	0.236	
		2	0.000	1.000		3	-0.011	0.994		4	0.000	1.000	
		Combined K-S:	0.522	0.000	0.000	Combined K-S:	0.300	0.012	0.009	Combined K-S:	0.208	0.465	0.401
	RESEARCHERS					Smaller group	Distance	P-value	Exact	Smaller group	Distance	P-value	Exact
						2	0.000	1.000		2	0.000	1.000	
						3	-0.291	0.048		4	-0.387	0.024	
						Combined K-S:	0.291	0.096	0.072	Combined K-S:	0.387	0.049	0.035
	EXT OFF									Smaller group	Distance	P-value	Exact
										3	0.049	0.925	
										4	-0.214	0.230	
										Combined K-S:	0.214	0.454	0.390
		RESEARCHERS				EXT OFF				OTHERS			
KNOW	FARMERS	Smaller group	Distance	P-value	Exact	Smaller group	Distance	P-value	Exact	Smaller group	Distance	P-value	Exact
		1	0.383	0.004		1	0.258	0.022		1	0.180	0.339	
		2	0.000	1.000		3	-0.006	0.998		4	-0.082	0.798	
		Combined K-S:	0.383	0.008	0.005	Combined K-S:	0.258	0.045	0.035	Combined K-S:	0.180	0.652	0.581
	RESEARCHERS					Smaller group	Distance	P-value	Exact	Smaller group	Distance	P-value	Exact
						2	0.035	0.957		2	0.000	1.000	
						3	-0.328	0.021		4	-0.269	0.166	
						Combined K-S:	0.328	0.042	0.030	Combined K-S:	0.269	0.330	0.270
	EXT OFF									Smaller group	Distance	P-value	Exact
										3	0.084	0.799	
										4	-0.191	0.310	
										Combined K-S:	0.191	0.601	0.524
		RESEARCHERS				EXT OFF				OTHERS			
RELEV	FARMERS	Smaller group	Distance	P-value	Exact	Smaller group	Distance	P-value	Exact	Smaller group	Distance	P-value	Exact
		1	0.000	1.000		1	0.000	1.000		1	0.163	0.408	
		2	-0.270	0.064		3	-0.244	0.033		4	-0.133	0.555	
		Combined K-S:	0.270	0.129	0.104	Combined K-S:	0.244	0.066	0.052	Combined K-S:	0.163	0.762	0.693
	RESEARCHERS					Smaller group	Distance	P-value	Exact	Smaller group	Distance	P-value	Exact
						2	0.233	0.142		2	0.375	0.030	
						3	-0.074	0.822		4	-0.074	0.873	
						Combined K-S:	0.233	0.284	0.236	Combined K-S:	0.375	0.061	0.043
	EXT OFF									Smaller group	Distance	P-value	Exact
										3	0.299	0.056	
										4	0.000	1.000	
										Combined K-S:	0.299	0.113	0.089
		RESEARCHERS				EXT OFF				OTHERS			
INN	FARMERS	Smaller group	Distance	P-value	Exact	Smaller group	Distance	P-value	Exact	Smaller group	Distance	P-value	Exact
		1	0.365	0.007		1	0.209	0.083		1	0.270	0.087	
		2	0.000	1.000		3	0.000	1.000		4	-0.016	0.991	
		Combined K-S:	0.365	0.013	0.009	Combined K-S:	0.209	0.167	0.140	Combined K-S:	0.270	0.173	0.140
	RESEARCHERS					Smaller group	Distance	P-value	Exact	Smaller group	Distance	P-value	Exact
						2	0.038	0.949		2	0.008	0.998	
						3	-0.157	0.416		4	-0.174	0.472	
						Combined K-S:	0.157	0.773	0.704	Combined K-S:	0.174	0.847	0.770
	EXT OFF									Smaller group	Distance	P-value	Exact
										3	0.085	0.795	
										4	-0.080	0.816	
										Combined K-S:	0.085	1.000	1.000
		RESEARCHERS				EXT OFF				OTHERS			
ENV	FARMERS	Smaller group	Distance	P-value	Exact	Smaller group	Distance	P-value	Exact	Smaller group	Distance	P-value	Exact
		1	0.304	0.031		1	0.244	0.033		1	0.234	0.159	
		2	-0.026	0.975		3	-0.027	0.959		4	0.000	1.000	
		Combined K-S:	0.304	0.063	0.048	Combined K-S:	0.244	0.066	0.053	Combined K-S:	0.234	0.316	0.266
	RESEARCHERS					Smaller group	Distance	P-value	Exact	Smaller group	Distance	P-value	Exact
						2	0.027	0.974		2	0.074	0.873	
						3	-0.096	0.720		4	-0.143	0.600	
						Combined K-S:	0.096	0.997	0.989	Combined K-S:	0.143	0.961	0.915
	EXT OFF									Smaller group	Distance	P-value	Exact
										3	0.076	0.833	
										4	-0.048	0.930	
										Combined K-S:	0.076	1.000	1.000

Highlights

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- Attitudes towards GHG mitigation and climate change adaptation are assessed
- Study subjects include sheep farmers, extension officers and scientists involved in sheep farming research
- Extension officers and sheep farmers show converging negative attitudes towards mitigation
- Beliefs and information are found to cause diverging attitudes
- Consequences on the working of the knowledge transfer chain are evaluated
- Implications for Climate change science communication and and policy design are discussed

Policy design for climate change mitigation and adaptation in sheep farming: insights from a study of the knowledge transfer chain

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Abstract

Low innovation adoption rates in agriculture have spurred intense research on farmers' attitudes and motivations. Little attention has been paid to attitudes of other important actors in the knowledge transfer chain. Evidence indeed suggests that adoption rarely happens at the farm level, but requires the right inputs from science and extension services. Divergent attitudes among actors in the knowledge transfer chain may hence contribute to low adoption rates by transferring insufficient, outdated, irrelevant and/or incorrect information. This study is an investigation on attitudes towards climate change mitigation and adaptation of three classes of

actors: sheep farmers, researchers involved in fields related to sheep farming and extension officers from private companies and public agencies. The investigation is based on data collected through self-administered questionnaires submitted to 165 participants to agricultural field days in Sardinia (Italy). The sample consists of sheep farmers (37,5%), researchers (16,4%), extension officers (32,1%) and other agricultural workers or students (14%). In order to assess differences in attitude and identify the sources of attitudinal divergence, the study adopts Kolmogorov – Smirnov (KS) equality-of-distribution tests and Partial-least square structural equation modelling (PLS-SEM). Comparing and contrasting attitudes towards several topics related to

GHG emission mitigation and adaptation to climate change reveal that researchers and extension officers have different attitudes towards innovation for mitigating GHG, that in turn depend on different information and beliefs on the causes and effects of climate change. This context is less than optimal to promote adoption of climate change mitigation or adaptation strategies. Climate change science and policy design need to recognise the complexity of knowledge transmission and the multiplicity of attitudes and beliefs that inform and affect the process. To mitigate the impact of diverging attitudes and beliefs among researchers and extension officers tailored communication strategies should avoid controversial issues and focus on benefits of innovation on farm efficiency. In turn, this would build trust and cooperation among all the actors in the knowledge transfer chain. Only when cooperation is assured, one could be confident that the information delivered to farmers is scientifically sound, relevant, value-neutral and useful in changing farmers' behaviour.

Keywords: attitudes; technology transfer chain; GHG emission mitigation; climate change adaptation; policy design; equality-of-distribution tests; partial-least square structural equation modelling.

1 Introduction

Agriculture is the second largest anthropogenic contributor to climate change accounting for 24% of total net greenhouse gas (GHG) emissions (Pachauri et al., 2014, p.46). The livestock sector contributes around half of agriculture emissions (Havlík et al., 2014). Agriculture is also highly vulnerable to climate change as extreme temperature, drying trends and erratic precipitation are likely to affect water availability, crop and livestock productivity, food security and income (Pachauri et al., 2014). Despite substantial public subsidies and private incentives, in Europe as in the rest of the world, climate change mitigation and adaptation in agriculture is still limited (Ampaire et al., 2017;

Findlater et al., 2019; Fleming and Vanclay, 2010; Ridier et al., 2013; Stevenson et al., 2019).

Research has identified several causes for low adoption rates in agriculture that can be organised around three major themes:

a. policy-related barriers, such as lack of political commitment, poor horizontal and/or vertical cooperation and inadequate interface between science and policy making. For instance, Ampaire et al. (2017), Matewos (2019) and Wright et al. (2014) identify governance gaps, unstructured and weak coordination among policy actors, low integration of research evidence, lack of monitoring and evaluation programs and insufficient funding in designing and implementing climate change related policies in the farming sector. Their case studies show that barriers in policy-making and implementation can arise at the political, administrative and scientific/technical stages, and often they appear at several levels at once. Clar et al. (2013) and van Buuren et al. (2018) find similar barriers to effective adaptation policies in flood risk management, but they are common in many other fields (IPCC, 2001).

b. barriers related to farmers' perceptions, attitudes and beliefs about a innovation or conservation practice (Pannell et al., 2006). This is a broad and growing research field, indicating that perceptions and beliefs are major drivers of mitigation and adaptation (see (Dang et al., 2014; de Matos Carlos et al., 2019; Mase et al., 2017; Rejesus et al., 2013; Schaak and Mußhoff, 2018). As pointed also in The World Development Report

2015 cognitive obstacles often prevent action on climate change (World Bank, 2015).

c. technical and economic barriers that restrict the rate of adoption of conservation practices. These include the effects of innovations on farms' economic performance, technology complexity, skilled labour and capital requirements, market access and structure, incentives and subsidies (see, for instance, (Biagini et al., 2014; Kuhl, 2019; Sathaye et al., 2001)

There is also a growing literature on the role that knowledge generation and technology transfer play in engaging farmers in programs to adopt better management practices (Willson and Roderick, 2018). Knowledge transfer is the sharing or disseminating of knowledge and provision of inputs to problem solving. The knowledge transfer chain is the set of agents generating, sharing and disseminating knowledge to stimulate desirable agricultural development (Anderson and Feder, 2007). It includes policy makers, scientists and extension officers, as well as farmers. Knowledge transfer in agriculture is not just a matter of provision and comprehension of sufficient information (Potter and

Oster, 2008), but farmers' engagement requires designing strategies to improve how climate change science is framed and delivered (Richards and Carruthers Den Hoed, 2018). This is crucially important in social contexts where the public and experts may be increasingly diverging in their assessment about climate change (Capstick et al., 2015). Hence, as adoption in agriculture does not take place at the farm level but within the entire technology transfer chain (Capstick et al., 2015), barriers to adoption can appear at every stage of the process: science framing and delivering, policy making and in the fields.

Scientists' values and attitudes affects the production and use of knowledge, the framing of information and the policy-science arena (Crouzat et al., 2018). Extension officers rarely generate new knowledge but they can affect the flow of information to and from the farm as they act as intermediaries in the knowledge transfer chain between scientists and farmers. They have the power to frame, package and delivere information according to their beliefs and attitudes (Prokopy et al., 2014). (Achora et al., 2018), for instance, show that some challenges to adoption of conservation agriculture arise from the chosen knowledge transfer approach. However, the role of agricultural research and extension services is usually investigated to assess their performance in improving farm management and productivity (Anderson and Feder, 2007). While extensive scholarship has explored the role of policy actors and scientists in climate change adaptation (see, for instance, (Biesbroek et al., 2013; Garvin, 2001; Oulahen et al., 2018; Urwin and Jordan, 2008) very little is known about beliefs, perceptions and attitudes of agricultural scientists and extension officers. A few studies have recently acknowledged this gap in the literature and assessed agricultural advisors' appraisal of climate change risk (Carlton et al., 2016; Church et al., 2018; Mase et al., 2015). Other studies have focused on the interactions of scientists, policy makers, extension officers, farmers and their knowledge systems, values and cultural roles (Carr and Wilkinson, 2005; Prober et al., 2017; Richards and Carruthers Den Hoed, 2018). These studies highlight that attitudinal barriers to adoption may be found among actors other than farmers and that improving natural resource management at the farm level requires convergence of those actors' attitudes and knowledge.

In this paper we assess the support to and disposition towards climate change adaptation and mitigation of three classes of actors: sheep farmers, extension officers and researchers. We follow the approach adopted by Prokopy et al. (2014) who compared climate change beliefs by surveying scientists, agricultural advisors, extension educators, and farmers in the United States. We also explore the role of additional factors such as trust and experience in shaping attitudes. The objectives are: a) evaluate whether actors have converging or diverging attitudes; b) identify the causes of divergent or convergent dispositions; c) assess the potential impact of these attitudes on agricultural adoption and on the functioning of the knowledge transfer chain. While diversity of assessments is intrinsic to the knowledge transfer process, there may be instances when it could not be smoothed out by a mere provision of scientific information. Decreased trust in climate scientists, for example, is associated to increased scepticism about climate change (Leiserowitz et al., 2013). Climate sceptic actors in the knowledge transfer change could create conflicting messages, amplify or attenuate risk perceptions and hinder the application of scientific research and knowledge to agricultural practices. As far as we know, ours is one of the few studies to contrast and compare perceptions, beliefs and attitudes of the three major actors in the agricultural knowledge transfer chain. It is also one of the first attempts at identifying the sources of diverging attitudes and assess their likely impact on climate change science transfer. This paper is also peculiar as the attitudes and beliefs assessment will inform the design of climate change policies meant to promote innovations to abate GHG emissions in sheep farming in Sardinia (Italy). It is an exploratory investigation whose results may help to develop more effective strategies for sustainable farming.

Sardinia is one of the largest sheep milk producers in Europe: with about 3.2 million ewes, 14,000 dairy sheep farmers and 330,000t $year^{-1}$ of milk, it represents about 25% of total EU-27 production (Vagnoni and Franca, 2017).

Adoption of alternative management strategies is a crucial issue in sheep farming in Sardinia. As in most of the Mediterranean region, local sheep farming systems are predominantly extensive or low input (Ripoll-Bosch et al., 2013). This is due to agronomic and economic reasons, as well as cultural and historic factors (Nguyen et al., 2016). As GHG abatement at the farm level would require innovation and new agronomic practices, it is important to assess the potential barriers to adoption at every level of the knowledge transfer chain.

The paper is organised in four sections. Section 2 illustrates the conceptual model adopted to explore attitudes and beliefs of farmers, extension officers and researchers working on fields related to sheep farming. This section includes a description of the research method and the questionnaire developed on the basis of the model, as well as a brief summary of the sample. An outline of the instruments adopted for data analysis is in section 3. Section 4 contains a description of the results, while discussion and conclusions are in the final section 5.

2 Model and method

2.1 Conceptual Model

There is extensive evidence of the attitude-behaviour relationship in any field of human endeavour. The 2015 World Development Report, for instance, highlights the contribution of attitudes, habits, skills and abilities, along with automatic thinking, cognitive illusions, mental models and social norms, in shaping human behaviour (World Bank, 2015). On the issue of innovation adoption in agriculture, (Vanni, F. et al., 2013) and (Hou and Hou, 2019) show that farmers' decision to adopt mitigation and adaptation strategies are affected by their attitudes, among other things. Two of the most influential approaches to explain this evidence are the theory of planned behaviour (TPB) (Ajzen, 1991), and the value-beliefs-norm model (Stern, 2000). Central to these models is the idea that beliefs about the world shape attitudes towards actions and objects, and these attitudes in turn affect behavioural intentions. The value-benefit-norm model stresses the role that values and moral norms have in shaping beliefs, while the TPB suggest that self interest and rational choice drive deliberation (Kaiser et al., 2005). Fishbein and Ajzen (2010) define attitudes as function of individual beliefs on a specific object and of the individual's evaluation of that object. Under this perspective, attitudes are an

”evaluative disposition through which individuals behave positively or negatively toward an object” (Wan et al., 2015). Attitudes tend to produce a corresponding behavioural intention and both attitudes and intentions are found to be reliable predictors of subsequent actions once context and individual factors are taken into account (Ajzen, 2004).

An investigation of attitudes could help predict farmers' actual adoption of GHG mitigation and climate change adaptation strategies. One would expect that a negative disposition towards GHG mitigation, for instance, is correlated with low adoption rates. It could also help to predict the quality of the extension officers' knowledge transfer as negative attitudes towards climate change-related innovations are likely to be associated with low quality information sharing. Moreover, an investigation of attitudes would highlight instances of shared attitudes among these actors. Shared or converging dispositions may create a reference group through which information is sought to match and reinforce prior convictions (Boudet et al., 2014; Kahan et al., 2011; Leiserowitz, 2006). Shared climate scepticism among farmers and extension officers, for example, may create a reinforcing group that hinders adoption of climate change-related innovations.

(Ajzen, 2004, 1991; Ajzen and Cote, 2008; Fishbein and Ajzen, 2010) posit that beliefs (i.e. a person's subjective perception of an object), information (i.e. probabilities and outcomes) and values (i.e. desirability of outcomes) are the major determinants of attitudes. In this paper, the assessment of attitudes towards GHG emission mitigation and adaptation to climate change in sheep farming is based on the following hypothesis:

H1: for both mitigation and adaptation, attitudes are affected by the trust respondents have in the mainstream narrative on causes and effects of climate change (Arbuckle et al., 2015, 2013; Mase et al., 2015);

H2: experience, knowledge, and information on causes and effects of climate change are also assumed to affect perceptions and beliefs and hence attitudes towards mitigation and adaptation (Rejesus et al., 2013);

H3: the relevance of climate change on farmers day-to-day management is also expected to influence stakeholders disposition towards adoption (Carlton et al., 2016);

H4: attitudes towards innovation are deemed interesting to gauge farmers disposition towards management changes (Bohnet et al., 2011);

H5: stakeholders disposition towards conservation or a sense of environmental stewardship (unrelated to climate change) affects their attitude towards adoption (Vanni, F. et al., 2013).

The model is described in Figure 1. It contains 5 explanatory constructs or latent variables (*trust, knowledge, relevance, attitudes towards innovation and attitudes towards environmental conservation*) and 2 explained constructs (*attitudes towards mitigation and attitudes towards adaptation*). Both the explanatory and explained constructs are measured with a series of indicators

(D1 to D20 in Figure 1) that capture the composite nature of the variables, but

the latter are also assumed to be influenced by the former.

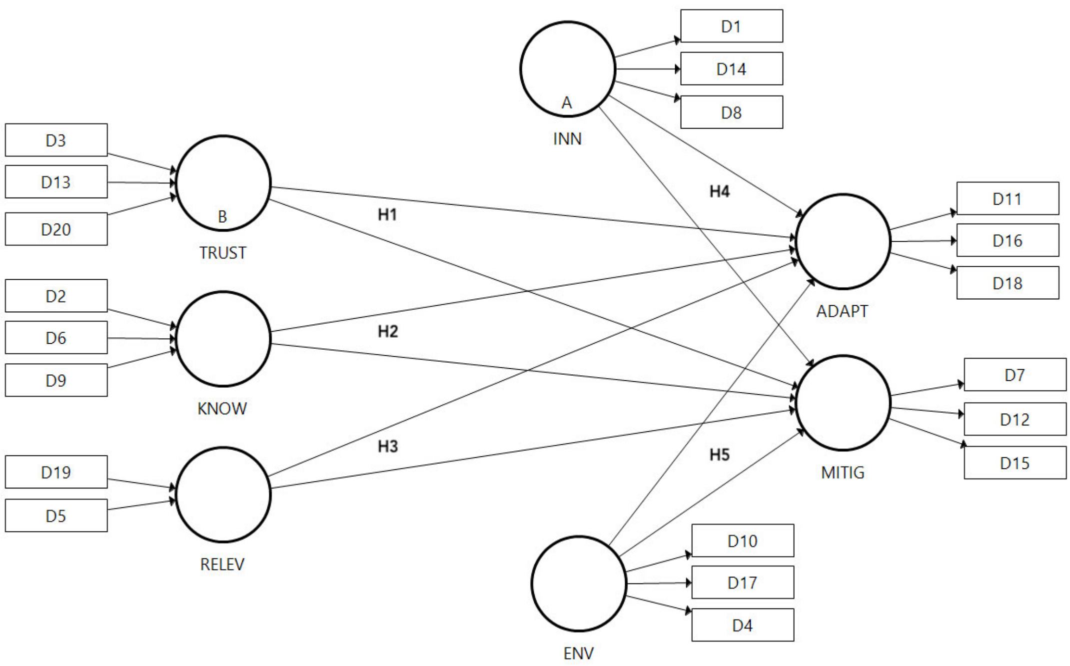

Figure 1: Explanatory and explained constructs in the model

2.2 Survey

In order to understand stakeholders attitudes towards mitigation and adaptation in sheep farming, we developed a questionnaire on the basis of the current literature, related behavioural theories, consultations with experts and two rounds of pre-testing. Having consulted with 12 scientists from universities and public research bodies, as well as agricultural advisors from the Sardinian public extension service, the first drafts of the questionnaire were administered on a non-random sample of 10 farmers to test for language, comprehension and relevance. The final version of the questionnaire contains 20 attitudinal questions, each corresponding to an indicator variable in the model (D1 to D20 in Figure 1), and they are framed as “Do you agree with the following statement?" followed by a 5-point Likert scale (*not at all*, *only a little*, *don't know*, *somewhat, absolutely*). An example of the question is shown in Figure 2 and the full questionnaire is included in Appendix A. The statements were non-neutral, as they propose a one-sided argument or a controversial declaration. The goal of attitudinal questions is indeed to force respondents to take sides. For each topic, but only if appropriate, the questionnaire contains at least a general statement, a statement related to the farmer experience or business, and a statement on the participant information or knowledge. For instance, on the topic of adaptation, the statements are[1]:

- *Investing to adapt to climate change means saving money in the future*

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1 To make the questionnaire relevant for farmers, researchers and extension officers, the statements include the expression “my business/sheep farming” or similar.

- *It is not important for my business/sheep farmers to adapt to climate change*

- *I do not know solutions to adapt my business/sheep farming to climate change*

Answers are coded in such a way that higher scores indicated a favourable disposition towards the composite latent variables. For instance, consider the following two statements: *"Every year climate change causes financial losses to sheep farmers*" and "*There is very little one can do about climate change*". Agreeing with the first statement and disagreeing with the second both receive high scores, as the underlying beliefs are expected to be correlated with positive attitudes towards adaption and mitigation.

The questions broke down the issue of climate change into 7 categories:

a. Trust on the mainstream narrative on climate change;

b. Knowledge and experience of the effects of climate change;

c. Relevance of climate change for farmers;

d. Innovation;

e. Environmental protection;

f. Mitigation;

g. Adaptation.

2) Do you agree with the following statement: "Every year climate change causes financial losses to sheep farmers"?				
Not at all	Only a little	Don't Know / Indifferent	Yes, somewhat	Absolutely

Figure 2: Sample of survey question

It is desirable to research each topic in depth with as many questions as possible. However, this aspiration has to be balanced against the demands that a long and complex questionnaire poses on the respondents. An in-depth but taxing questionnaire is not a guarantee for quality of the answers. After consultations with experts and extension officers, it was agreed that the questionnaire should:

a. be self-administered; participants would fill in the questionnaire by themselves in their own time, avoiding the pressure of an interview, the warm-glow effect and “yes-saying” (Krosnick, 1991; Podsakoff et al., 2012; Revilla, 2015);

b. not take more than 10-15 minutes to complete; a longer questionnaire will have high rejection rate and poor answers, because “farmers are time-constrained and will avoid any task that is too long or cognitively taxing” (A. Atzori, pers. comm.),;

c. have a limited number of factual questions (e.g. farm size, location, etc.) as many farmers “have privacy concerns no matter how many guarantees your questionnaire provides” (A. Atzori, pers. comm.) and would avoid them and reject the whole questionnaire.

2.3 Sample

The questionnaire was administered on a sample of 62 Sardinian sheep farmers, 27 agricultural scientists, 53 public and private extension officers, and 23 respondents from heterogeneous backgrounds (students, crop farmers, farm labourers). The sample is representative neither of the farming sector nor of the research and extension services. Questionnaires were distributed and collected during a series of farm field days to promote innovation in sheep farming for efficiency and nutrition improvement. Field trials are important moments of knowledge transfer and hence they are a good setting to evaluate if there are diverging assessments of innovation. However, participants to field days are self-selected, and usually includes farmers who are more open and geared towards innovation (more educated, larger enterprises). We expect that our biased sample would highlight more converging rather than diverging evaluation. 80%

of the respondents are male and over 45 years old. As expected, many farmers did not provide answers to factual questions, but fully completed the attitudinal survey.

3 Data analysis

Kolmogorov – Smirnov (KS) equality-of-distribution tests and Partial-least square structural equation modelling (PLS-SEM) are adopted to assess model and attitudes. The Kolmogorov-Smirnov test (KS test) is a non-parametric test of the equality of continuous probability distributions that can be used to compare two samples. The KS statistic quantifies the distance between the empirical distribution functions of two samples. It is calculated under the assumptions that the samples are drawn from a population with the same distribution. The KS tests tell us if the frequencies of values computed from the Likert scale scores for each latent variable have the same distribution function between samples (Gregoire and Driver, 1987). In other words, significant differences between distributions of the samples indicate a difference in disposition or attitude towards a construct.

To understand the source of divergent or different attitudes in the sample, we assess the model in Figure 1 and test the hypotheses with the use of the PLS-SEM. PLS-SEM is an exploratory method that searches for relationships between composite (multi-items) unobserved variables that can be measured indirectly via indicators variables. Each indicator variable captures a single aspect of an abstract construct or concept. What differentiates PLS-SEM from other structural equation modelling approaches is that PLS-SEM relies on explaining the variance of the independent variables rather than estimating the covariance matrix of the dataset (Hair et al., 2014). (Venturini S. and Mehmetoglu M., 2017) suggest using PLS-SEM when the model relating explanatory and explained constructs (the structural model) is complex and the sample size is small. The application of PLS-SEM has increased of late due to its applicability to challenging models and its ability to assess data with non-normal features or with small sample sizes (Hair et al., 2014). Its use is already consolidated in several fields, among which environmental studies (Carlet, 2015), because of its capability of assessing both causal relationships between indicators and causal relationships between latent constructs (Gudergan et al., 2008). Furthermore PLS-SEM helps for exploratory and confirmatory research in the assessment of complex relationships where many indicators and constructs are present (Chin et al., 2003).

The PLS-SEM develops upon two sets of linear equations: the structural model and the measurement model. The structural model postulates the relationships between unobserved or latent constructs, whereas the measurement model specifies the relationships between a latent construct and its observed or manifest items. The data analysis follows a two-step approach: the first step assesses the measurement model to ensure reliability and validity of the constructs; the second step tests the causal paths between the constructs that comprise the theoretical model and evaluates the structural model. In the first step, item reliability, internal consistency and discriminant validity were used to test the reliability and validity of the model[2].

2 Item reliability was examined through factor loadings that indicate the degree to which each indicator is correlated with its relevant latent variable. Internal consistency was tested using Cronbach alpha and the rho. The structural model was tested based upon the significance of the path coefficients, representing the strength of causal relationships between constructs, by observing the R^2 values of the dependent variables, and observing the Average Variance Extracted (AVE) which measures the amount of variance of a latent variable that is explained by its

As shown in Figure 1, PLS-SEM assesses the relationships between the explanatory (exogenous) constructs Trust, Knowledge, Relevance, Innovation and Environmental protection with the explained (endogenous) constructs

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indicators in relation to the amount of variance due to measurement error. Among the model selection criteria, the Akaike Information Criterion (AIC), also unbiased and corrected, the Bayesian Information Criterion (BIC) and the Hannan Quinn Criterion (HQ), also corrected, are employed.

Mitigation e Adaptation, each of which captures the attitude of respondents on the topic. PLS-SEM also allows comparisons of the estimated relationships across the classes of respondents in the sample.

4 Results

Figures 3 and 4 show the probability density functions of the scores of the two latent attitudinal variables MITIG and ADAPT for each class of actors in the sample[3]. The probability functions are estimated via kernel density estimation

3 Score for MITIG is the sum of the scores obtained from responses to questions D7, D12 and D15. Score for ADAPT is the sum of scores from questions D11, D16 and D18. Scores are normalised to range from -3 to 2.

(KDE) that makes use of the Epanechnikov function[4]. A visual inspection suggests some differences in the distribution functions. For both MITIG and ADAPT, farmers show a negative disposition more frequently than the other

4 Kernel density estimation (KDE) is a technique for the non-parametric estimation of the probability density function of a random variable. It can use a range of kernel functions (uniform, triangular, biweight, triweight, Epanechnikov, normal, and others). The Epanechnikov kernel is the most efficient when compared to the optimal kernel (Wand, M.P; Jones, M.C. , 1995. Kernel Smoothing. London: Chapman & Hall/CRC).

classes. Researchers, on the contrary, show a positive attitude on both topics more frequently than the other actors. On the topic of mitigation, extension officers seem to have an attitude that is less positive than researchers' disposition, while on adaptation their attitude scores follow a similar pattern. The results of a Kolmogorov-Smirnov (KS) equality-of-distributions test are shown in Tables 1 and 2. For the latent variable MITIG the test indicates that farmers, extension officers and the Others sub-samples have similar attitudes, and that they all differ from researchers (at 95% confidence level).

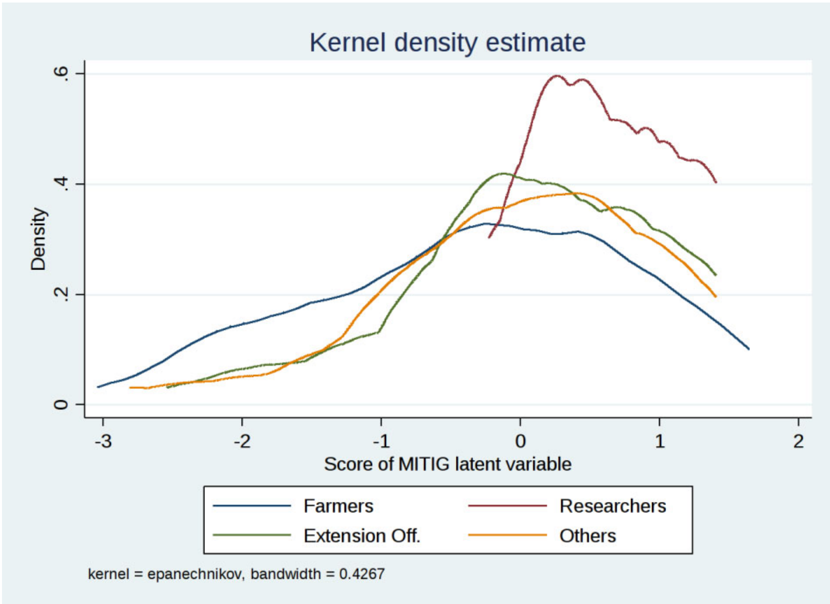

Figure 3: Kernel density of MITIG variable

For the ADAPT latent variable, the KS test indicates that researchers and extension officers have similar attitudes and that they both differ from farmers (at 95% confidence level). The Others sub-sample does not show any difference in attitude from the other classes of actors.

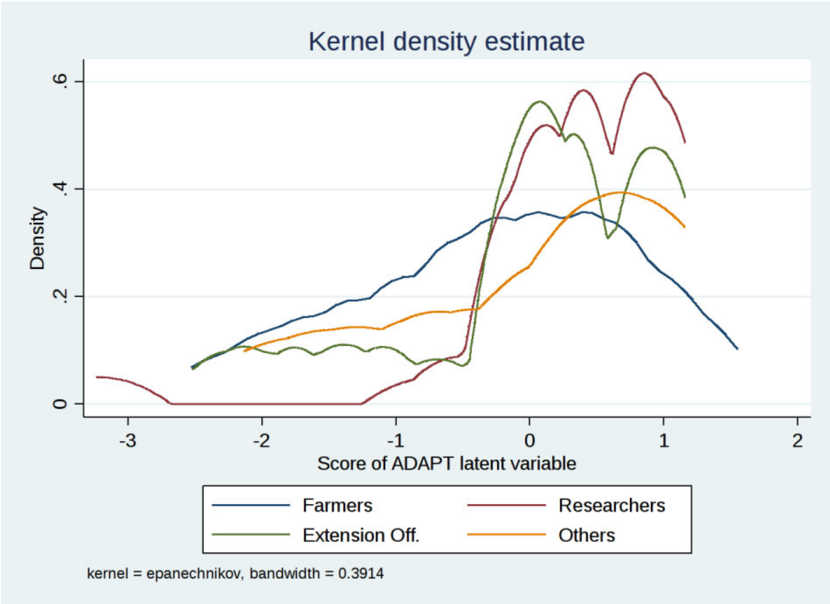

Figure 4: Kernel density of ADAPT variable

Table 1. Results of the K-S equality of distribution test for the MITIG latent variable

	RESEARCHERS				EXT OFF				OTHERS			
	Smaller group	Distance	P-value	Exact	Smaller group	Distance	P-value	Exact	Smaller group	Distance	P-value	Exact
FARMERS	1	0.470	0.000		1	0.209	0.082		1	0.218	0.203	
	2	0.000	1.000		3	-0.0027	1		4	-0.044	0.939	
	Combined K-S:	0.470	0.001	0.000**	Combined K-S:	0.2091	0.164	0.136	Combined K-S:	0.2181	0.402	0.344
RESEARCHERS					Smaller group	Distance	P-value	Exact	Smaller group	Distance	P-value	Exact
					2	0.000	1.000		2	0.000	1.000	
					3	-0.345	0.014		4	-0.367	0.035	
					Combined K-S:	0.3452	0.028	0.021**	Combined K-S:	0.367	0.070	0.051*
EXT OFF									Smaller group	Distance	P-value	Exact
									3	0.0632	0.88	
									4	-0.1025	0.714	
									Combined K-S:	0.1025	0.996	0.986

*** significant at 5%*

Significant at 10%

Table 3. Results of the structural model estimation			
	Standardised path coefficients		
Variable	MITIG	*P Values*	ADA
Trust	0.382**	*0.000*	0.18

Table 2. Results of the K-S equality of distribution test for the ADAPT latent variable

	RESEARCHERS				EXT OFF				OTHERS			
	Smaller group	Distance	P-value	Exact	Smaller group	Distance	P-value	Exact	Smaller group	Distance	P-value	Exact
FARMERS	1	0.400	0.002		1	0.284	0.010		1	0.280	0.072	
	2	-0.037	0.950		3	-0.0271	0.959		4	-0.029	0.973	
	Combined K-S:	0.400	0.005	0.003**	Combined K-S:	0.2842	0.02	0.015**	Combined K-S:	0.2798	0.145	0.116
RESEARCHERS					Smaller group	Distance	P-value	Exact	Smaller group	Distance	P-value	Exact
					2	0.037	0.952		2	0.040	0.961	
					3	-0.178	0.324		4	-0.200	0.371	
					Combined K-S:	0.1775	0.626	0.551	Combined K-S:	0.200	0.705	0.618
EXT OFF									Smaller group	Distance	P-value	Exact
									3	0.1444	0.512	
									4	-0.0837	0.799	
									Combined K-S:	0.1444	0.892	0.835

*** significant at 5%*

Significant at 10%

Table 3. Results of the structural model estimation

	Standardised path coefficients (Bootstrap)			
Variable	MITIG	*P Values*	ADAPT	*P Values*
Trust	0.382**	*0.000*	0.184**	*0.017*
Know	0.234**	*0.018*	0.207**	*0.007*
Relev	0.098	*0.485*	0.018	*0.816*
Inn	0.002	*0.986*	0.170**	*0.014*
Env	0.128	*0.151*	0.376**	*0.000*
R-squared adjusted	0.413		0.342	

** *significant at 5%*

* *significant at 10%*

Table 4. P-values for comparing PLS-SEM parameter estimates.

		P-values					
Model	*Variable*	Farmers vs Researchers	Farmers vs Ext Off	Farmers vs Others	Researchers vs Ext Off	Researchers vs Others	Ext Off vs Others
ADAPT	*Trust*	0.866	0.894	0.016**	0.949	0.126	0,036**
	Know	0.976	0.374	0.708	0.594	0.804	0.373
	Relev	0.590	0.435	0.497	0.294	0.387	0.930
	Inn	0.903	0.401	0.083*	0.586	0.113	0.015**
	Env	0.504	0.520	0.805	0.861	0.571	0.540
MITIG	*Trust*	0.052*	0.187	0.650	0.340	0.323	0.666
	Know	0.332	0.101	0.245	0.974	0.198	0.028*
	Relev	0.940	0.914	0.267	0.991	0.250	0.208
	Inn	0.974	0.949	0.403	0.982	0.432	0.376
	Env	0.756	0.340	0.167	0.343	0.416	0.098*

*** significant at 5%*

** significant at 10%*

PLS-SEM gives an insight on the factors explaining divergent attitudes on mitigation and adaptation. As shown in Table 3, the latent variables TRUST and KNOW have significant impacts on both MITIG and ADAPT construct, while INN and ENV are significant only for ADAPT. The construct RELEV has significant impact neither on MITIG nor on ADAPT.

In Appendix B we report the quality criteria for the PLS-SEM model estimation. The model performance is not entirely satisfactory: some indicator variables are excluded from estimation as did not have significant impact on constructs[5]. A possible explanation is that the survey focus is sheep farming and

5 To asses the relationship between latent constructs and indicator variables, PLS-SEM makes use of *outer loadings*. Outer loadings are coefficients estimated through single regressions (one for each indicator variable) of each

hence farmers attitudes and opinions are related to what farmers themselves should or should not do. For researchers, extension officers and the rest of the sample, what is measured is actually their attitudes towards what sheep farmers

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indicator variable on its corresponding construct. Indicator variables with standardised loadings less than 0.4 are dropped from estimation while indicators with loadings between 0.4 and 0.7 are retained if they exclusion does not improve model performance (Hair et al., 2014, p.103).

should or should not do. Still the model provides evidence on factors affecting mitigation and adaptation attitudes that is in line with the findings in the literature. Comparing the structural model parameter estimates indicates that the impact of latent variables on MITIG and ADAPT constructs do no differ substantially across stakeholders. Leaving aside the heterogeneous class of "Others", only for farmers and researchers the latent variable Trust has significantly different weights on their attitudes towards mitigation (see Table 4).

A visual inspection of the probability density functions and the KS tests identify the sources of different attitudes. Farmers trust the main narrative on causes and effects of climate change less than researchers and extension officers (see Figure 5 below and Table C1 in Appendix C). There is also a significant difference between the level of trust of researchers and extension officers while not significant differences are reported between farmers and the ”Others” sub sample. Similar pattern is found for the KNOW construct (Figure 6): farmers differ in the level of knowledge from researchers and extension officers, and those two classes differ as well. Prokopy et al. (2014) report similar results on a sample of US agricultural stakeholders.

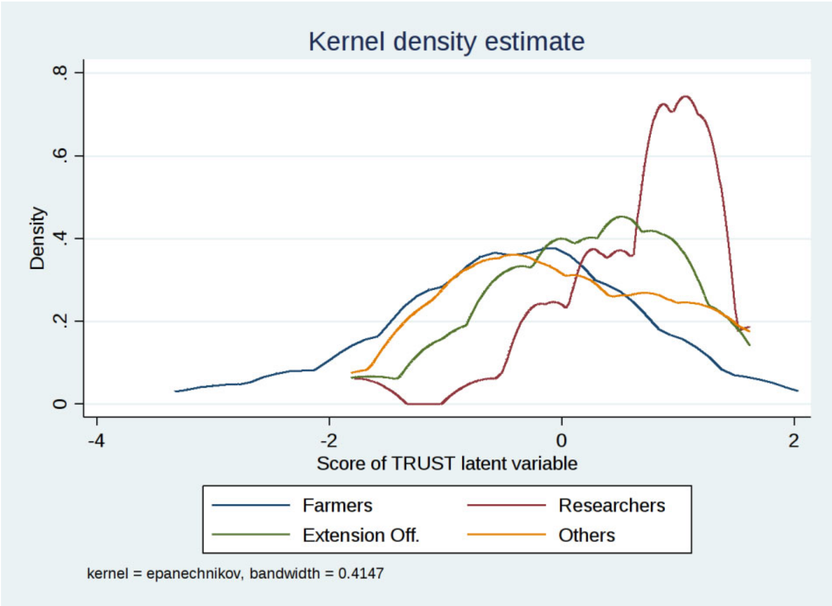

Figure 5: Kernel density of TRUST

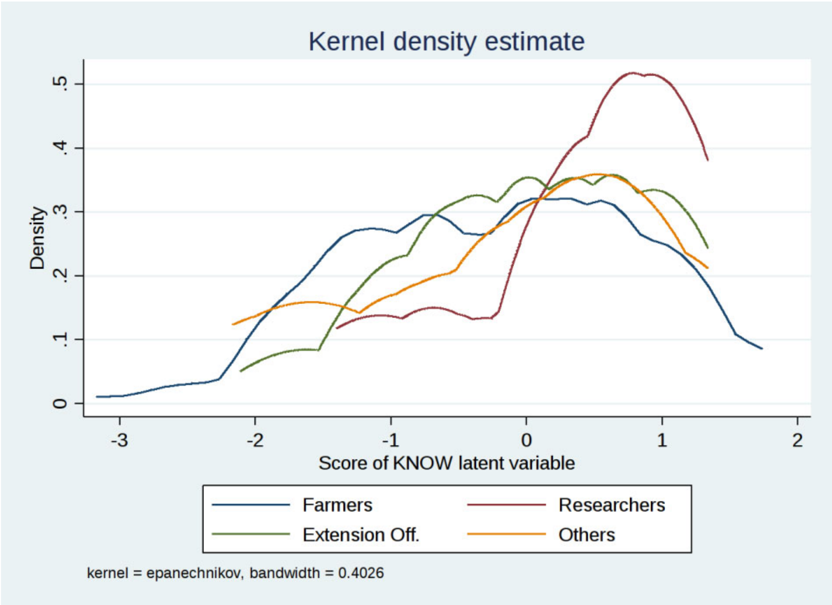

Figure 6: Kernel density of KNOW

On the topic of relevance of climate change, there are not statistically different opinions even if from a visual inspection of Figure 7, researchers appear to judge the impact of climate change in sheep farming less relevant than any other stakeholder. Innovation is a topic where the only significant difference is between farmers and researchers: farmers tend to be less favourable towards innovation (Figure 8). Furthermore, farmers have a less favourable disposition toward environmental protection than researchers and extension officers. No significant difference is found between the other classes (Figure 9).

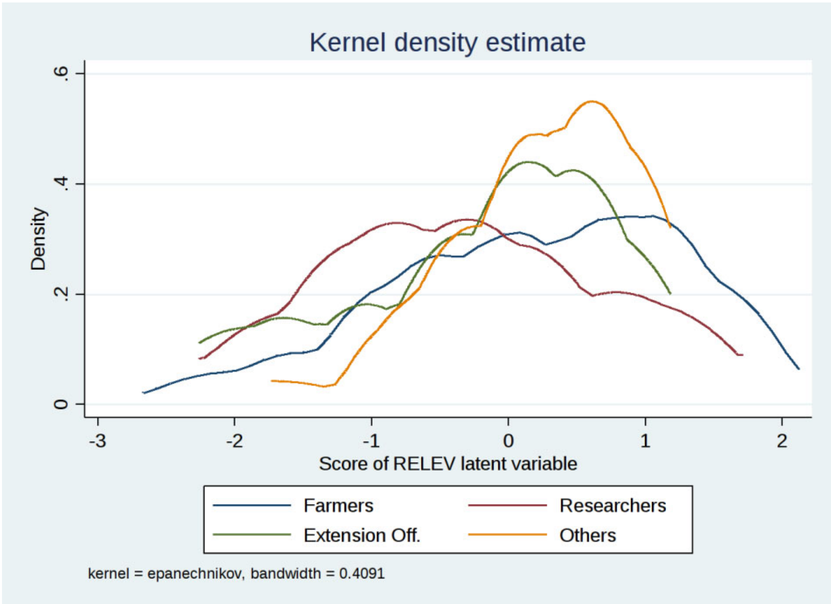

Figure 7: Kernel density of RELEV

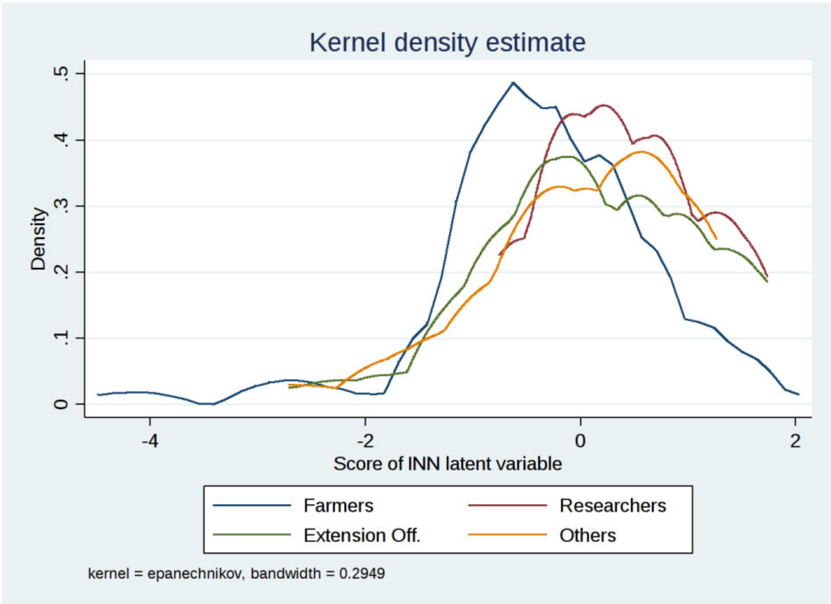

Figure 8: Kernel density of INN

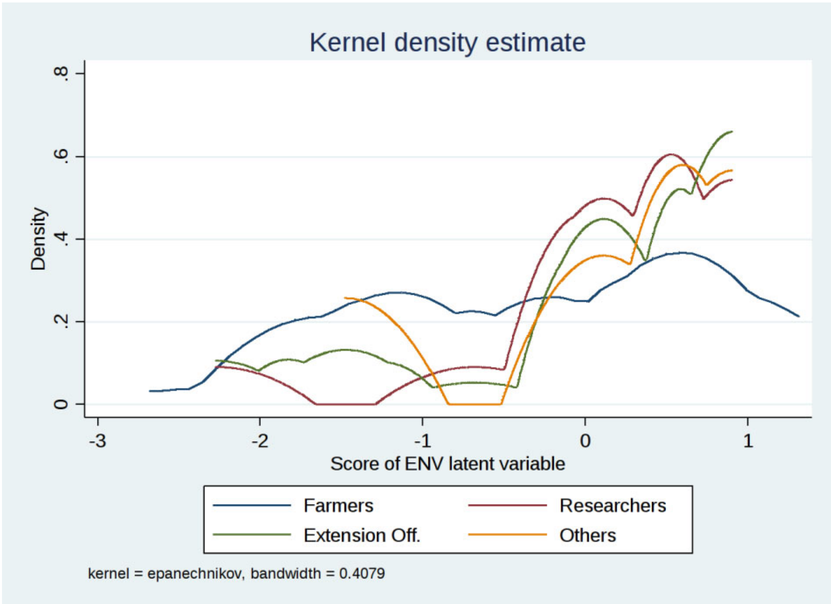

Figure 9: Kernel density of ENV

5 Discussion and conclusions

The results of our survey on sheep farming stakeholders indicate that farmers and extension officers share similar attitudes regarding GHG emission mitigation, and their attitude is less favourable to mitigation strategies compared to that expressed by scientists. Different levels of knowledge on causes and consequences of climate change and different levels of trust in the mainstream narrative regarding climate change are the sources of these diverging attitudes. For adaptation strategies, results show that researchers and extension officers have similar attitudes while farmers are less supportive of climate change adaptation than the other two groups. Again, the sources of these differences are knowledge of climate change causes and impacts and belief in climate science.

Differences in attitudes and opinions between farmers and other actors in the knowledge transfer chain are expected. As changes in the production system entail some degree of risk and uncertainty to their livelihood and lifestyle, farmers may be more cautious and conservative in embracing new ideas and information than other professionals whose livelihood is not at stake. As shown by Pannell et al. (2006), farmers need to be persuaded of the relative advantage of an innovation before abandoning the old ways. This is the very reason for establishing a knowledge transfer network.

It is however less than optimal for researchers and extension officers to have different attitudes towards innovation for mitigating GHG, that in turn depend on different levels of trust and knowledge. These gaps in information and trust in scientific explanations of climate change are evidence of a bottleneck in the process of transferring scientific information from the research laboratories to the farm. Agricultural extension officers are intermediaries in the information chain between scientists and farmers. They have the power to affect the flow of information to and from the the farm by framing, packaging and delivering information according to their beliefs and attitudes. It appears that extension officers and farmers share the same attitude towards mitigation strategies and that it is based on a decreased trust in and knowledge of climate science and facts. This shared world view may produce climate scepticism that reinforces itself in the extension officers/farmers community by disseminating information that matches prior convictions (Boudet et al., 2014; Kahan et al., 2011; Leiserowitz, 2006). This context is less than appropriate to promote adoption of climate change mitigation or adaptation strategies: scientific evidence could not be communicated or transmitted through the knowledge transfer chain in ways that can effectively change farmers' behaviour.

The implications of these findings are twofold. First, our investigation highlights the importance of recognizing the complexity of knowledge transmission and the multiplicity of attitudes and beliefs that inform and affect the process before a policy is designed and implemented. An ex ante analysis of attitudes and beliefs could shed some lights on how they cut across stakeholders' groups creating drivers or barriers to adoption of climate change mitigation strategies. Second, science and policy design for climate change mitigation and adaptation in sheep farming in Sardinia need to address the causes of different level of trust and knowledge among researchers and extension officers. On the one hand scientists could: a) start promoting innovation that both reduce GHG emission and address directly farmers needs. GHG mitigation at the farm level has comparatively smaller private benefits than adaptation, and hence is less likely to be voluntarily adopted. Science should provide solutions that increase the private benefits, such as promoting curbing emission through efficiency improvement or through strategies that shield business from adverse climate change impacts. For instance, they could promote diet and nutrition innovation in order to improve animal health and hence productivity. A better animal diet has also the side benefit of reducing emissions from enteric fermentation (Molle et al., 2008). Scientists should stress the efficiency improvement in order to avoid the controversial topic of GHG mitigation and climate change. In turn, this could also improve trust and cooperation between scientists and extension officers. More cooperation and trust means that researchers, extension officers and farmers could find solutions meaningful and coherent with their goals and needs; b) use communication expertise to promote tailored messages to avoid challenging extension officers' beliefs and world views, as well as making assumptions that could block receptiveness to learning about innovation and climate change (Prokopy et al., 2014). On the other hand, policy makers needs to provide resources for communication, training and education along with the general framework to adopt innovation. Incentives may be also necessary as appealing to farmers' sense of environmental stewardship and attitude towards innovation do not appear to be sufficient to promote adoption.

Based on prior understanding of the sources of differing attitudes, communication, training and education could help finding novel ways to overcome entrenched beliefs and communicate climate change science. This in turn would improve cooperation from all actors in the knowledge transfer chain. Only when this cooperation is assured, one could be confident that the information delivered to farmers is scientifically sound, relevant and value-neutral.

Traditionally, policies to promote innovation adoption in agriculture have targeted farmers. Given the low adoption rates, there is a clear need for more ex ante research to investigate potential bottlenecks in knowledge transfer so as to inform policy making and implementation.

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Appendix A: Questionnaire

QUESTIONNAIRE
STAKEHOLDERS' OPINION

With the following questions, we would like to know you opinion on the importance that climate change, innovation, and environmental conservation have on sheep farming in Sardinia. Please fill in the questionnaire by ticking in the square underneath the item that reflects your opinion. There are no right or wrong answer but only your point of view. We would like to remind you that participation is entirely voluntary and all the collected information is confidential and will be used only for research purposes as per Decree n.196/2003 "Code for personal data protection"

Profession	*Location*	*Business/Farm name*
☐ Farmer		
☐ Researcher		
☐ Extension officer		
☐ Other________		

1) *Do you agree with the following statement:* "Innovation is the key for sheep farming to take on future challenges"

Not at all	Only a little bit	Don't know/ Indifferent	Yes, somewhat	Absolutely
☐	☐	☐	☐	☐

2) *Do you agree with the following statement:* "In my experience, I have witnessed seasons becoming increasingly uncertain"

Not at all	Only a little bit	Don't know/ Indifferent	Yes, somewhat	Absolutely
☐	☐	☐	☐	☐

3) *Do you agree with the following statement:* "Climate changes are not caused by human activities"

Not at all	Only a little bit	Don't know/ Indifferent	Yes, somewhat	Absolutely
☐	☐	☐	☐	☐

4) *Do you agree with the following statement:* "Environmental protection is farmers' responsibility"

Not at all	Only a little bit	Don't know/ Indifferent	Yes, somewhat	Absolutely
☐	☐	☐	☐	☐

5) *Do you agree with the following statement:* "Every year sheep farmers incur serious economic losses because of climate change"

Not at all	Only a little bit	Don't know/ Indifferent	Yes, somewhat	Absolutely
☐	☐	☐	☐	☐

6) *Do you agree with the following statement:* "Climate changes are contributing to increase the earth temperature"

Not at all	Only a little bit	Don't know/ Indifferent	Yes, somewhat	Absolutely
☐	☐	☐	☐	☐

7) *Do you agree with the following statement:* "In order to mitigate climate change it is necessary to cut GHG emissions from sheep farming"

Not at all	Only a little bit	Don't know/ Indifferent	Yes, somewhat	Absolutely
☐	☐	☐	☐	☐

8) *Do you agree with the following statement:* "Only experience can help to improve the efficiency of sheep farming"

Not at all	Only a little bit	Don't know/ Indifferent	Yes, somewhat	Absolutely
☐	☐	☐	☐	☐

9) *Do you agree with the following statement:* "Extreme events such as drought, flooding and wildfires are less frequent than in the past"

Not at all	Only a little bit	Don't know/ Indifferent	Yes, somewhat	Absolutely
☐	☐	☐	☐	☐

10) *Do you agree with the following statement:* "Natural resource conservation is not a priority of sheep farming businesses "

Not at all	Only a little bit	Don't know/ Indifferent	Yes, somewhat	Absolutely
☐	☐	☐	☐	☐

11) *Do you agree with the following statement:* "Investing to adapt to climate change means saving money in the future"

Not at all	Only a little bit	Don't know/ Indifferent	Yes, somewhat	Absolutely
☐	☐	☐	☐	☐

12) *Do you agree with the following statement:* "I would like to have more information on the effects of climate change on sheep farming"

Not at all	Only a little bit	Don't know/ Indifferent	Yes, somewhat	Absolutely
☐	☐	☐	☐	☐

13) *Do you agree with the following statement:* "Recent weather conditions forecast the start of cold years"

Not at all	Only a little bit	Don't know/ Indifferent	Yes, somewhat	Absolutely
☐	☐	☐	☐	☐

14) *Do you agree with the following statement:* "Sheep farming in Sardinia is too traditional"

Not at all	Only a little bit	Don't know/ Indifferent	Yes, somewhat	Absolutely
☐	☐	☐	☐	☐

15) *Do you agree with the following statement:* "There is very little to do to avoid climate change"

Not at all	Only a little bit	Don't know/ Indifferent	Yes, somewhat	Absolutely
☐	☐	☐	☐	☐

16) *Do you agree with the following statement:* "It is not important for sheep farmering to adapt to climate change"

Not at all	Only a little bit	Don't know/ Indifferent	Yes, somewhat	Absolutely
☐	☐	☐	☐	☐

17) *Do you agree with the following statement:* "Future generations will need to adapt to a natural environment completely different from the present one"

Not at all	Only a little bit	Don't know/ Indifferent	Yes, somewhat	Absolutely
☐	☐	☐	☐	☐

18) *Do you agree with the following statement:* "I do not know of any solution to adapt my business to climate change"

Not at all	Only a little bit	Don't know/ Indifferent	Yes, somewhat	Absolutely
☐	☐	☐	☐	☐

19) *Do you agree with the following statement:* "The future of sheep farming is uncertain because of climate change"

Not at all	Only a little bit	Don't know/ Indifferent	Yes, somewhat	Absolutely
☐	☐	☐	☐	☐

20) *Do you agree with the following statement:* "In the past weather was as warm as in the last few years"

Not at all	Only a little bit	Don't know/ Indifferent	Yes, somewhat	Absolutely
☐	☐	☐	☐	☐

The Questionnaire is finished. Thanks for you cooperation.

Appendix B

Quality Criteria for PLS-SEM estimation

Table B1. R Square

	R Square	R Square Adjusted
ADAPT	0.430483	0.412574
MITIG	0.362418	0.342368

Table B2. f Square

	ADAPT	ENV	INN_ _	KNOW	MITIG	RELEV	TRUST
ADAPT							
ENV	0.208681				0.021674		
INN_ _	0.046362				0.000004		
KNOW	0.057588				0.065893		
MITIG							
RELEV	0.000573				0.014812		
TRUST	0.044810				0.172443		

Table B3. Construct reliability and validity

	Cronbach's Alpha	rho_A	Composite Reliability	Average Variance Extracted (AVE)
ADAPT	0.491074	0.653536	0.778805	0.644559
ENV	1.000000	1.000000	1.000000	1.000000
INN	0.169279	0.172829	0.704554	0.545503
KNOW		1.000000		
MITIG	0.455895	0.644622	0.650490	0.414321
RELEV		1.000000		
TRUST		1.000000		

Discriminant validity

Table B4. Fornell-Larcker Criterion

	ADAPT	ENV	INN__	KNOW	MITIG	RELEV	TRUST
ADAPT	0.802845						
ENV	0.538425	1.000000					
INN__	0.324205	0.200185	0.738582				
KNOW	0.441278	0.332975	0.161104				
MITIG	0.565733	0.331122	0.152432	0.449930	0.643678		
RELEV	0.029437	0.030777	-0.098124	0.058879	0.124267		
TRUST	0.437689	0.317416	0.253434	0.436016	0.528141	0.022718	

Table B5. Cross loadings

	ADAPT	ENV	INN	KNOW	MITIG	RELEV	TRUST
D1	0.252511	0.089992	0.795991	0.086453	0.142320	0.103219	0.115818
D10	0.538425	1.000000	0.200185	0.332975	0.331122	0.030777	0.317416
D12	0.250194	0.025030	0.141953	0.110232	0.434525	0.231977	0.125697
D15	0.548531	0.365555	0.140655	0.454663	0.921923	0.008960	0.555125
D16	0.928235	0.535732	0.280683	0.457864	0.572459	0.024971	0.480276
D18	0.653834	0.278925	0.253176	0.190373	0.273635	0.024035	0.135663
D19	0.071859	0.103755	-0.097027	0.100876	0.096515	0.865112	0.078868
D20	0.340064	0.200902	0.161936	0.361101	0.368985	0.203604	0.730531
D3	0.335728	0.282992	0.224627	0.315136	0.440860	-0.143319	0.807178
D5	-0.026509	-0.059218	-0.068461	-0.005863	0.115715	0.833849	-0.046222
D6	0.222189	0.064121	0.105092	0.668884	0.372522	0.214835	0.254234
D7	0.154299	0.049345	-0.005903	0.143574	0.451894	0.261503	0.095039
D8	0.226023	0.219786	0.676317	0.159806	0.077556	-0.287019	0.275951
D9	0.410005	0.394075	0.130075	0.793847	0.298626	-0.096790	0.376733

Table B6. Heterotrait-Monotrait ratio (HTMT)

	ADAPT	ENV	INN	MITIG
ADAPT				
ENV	0.714011			
INN	1.132210	0.509366		
MITIG	0.916570	0.313846	0.552611	

Collinearity statistics (VIF)

Table B7. Outer VIF Values

	VIF
D1	1.008624
D10	1.000000
D12	1.179029
D15	1.027773
D16	1.118462
D18	1.118462
D19	1.246239
D20	1.036059
D3	1.036059
D5	1.246239
D6	1.006270
D7	1.184645
D8	1.008624
D9	1.006270

Table B8. Inner VIF Values

	ADAPT	ENV	INN	KNOW	MITIG	RELEV	TRUST
ADAPT							
ENV	1.191189				1.191189		
INN	1.102253				1.102253		
KNOW	1.307343				1.307343		
MITIG							
RELEV	1.016708				1.016708		
TRUST	1.331321				1.331321		

Model fit

Table B9. Fit Summary

	Saturated Model	Estimated Model
SRMR	0.116712	0.119130
d_ULS	1.430272	1.490158
d_G	0.296587	0.329785
Chi-Square	292.686676	312.648260
NFI	0.425776	0.386613

Table B10. Rms Theta	
rms Theta	0.291438

Table B11. Model Selection Criteria

	AIC (Akaike's Information Criterion)	AICu (Unbiased Akaike's Information Criterion)	AICc (Corrected Akaike's Information Criterion)	BIC (Bayesian Information Criteria)	HQ (Hannan Quinn Criterion)	HQc (Corrected Hannan-Quinn Criterion)
ADAPT	-81.892557	-75.780747	85.820819	-63.256884	-74.327689	-73.330753
MITIG	-63.264870	-57.153060	104.448506	-44.629197	-55.700002	-54.703066

Appendix C

Two-sample Kolmogorov-Smirnov test for equality of distribution functions

		RESEARCHERS				EXT OFF				OTHERS			
TRUST	FARMERS	Smaller group	Distance	P-value	Exact	Smaller group	Distance	P-value	Exact	Smaller group	Distance	P-value	Exact
		1	0.522	0.000		1	0.300	0.006		1	0.208	0.236	
		2	0.000	1.000		3	-0.011	0.994		4	0.000	1.000	
		Combined K-S:	0.522	0.000	0.000	Combined K-S:	0.300	0.012	0.009	Combined K-S:	0.208	0.465	0.401
	RESEARCHERS					Smaller group	Distance	P-value	Exact	Smaller group	Distance	P-value	Exact
						2	0.000	1.000		2	0.000	1.000	
						3	-0.291	0.048		4	-0.387	0.024	
						Combined K-S:	0.291	0.096	0.072	Combined K-S:	0.387	0.049	0.035
	EXT OFF									Smaller group	Distance	P-value	Exact
										3	0.049	0.925	
										4	-0.214	0.230	
										Combined K-S:	0.214	0.454	0.390
		RESEARCHERS				EXT OFF				OTHERS			
KNOW	FARMERS	Smaller group	Distance	P-value	Exact	Smaller group	Distance	P-value	Exact	Smaller group	Distance	P-value	Exact
		1	0.383	0.004		1	0.258	0.022		1	0.180	0.339	
		2	0.000	1.000		3	-0.006	0.998		4	-0.082	0.798	
		Combined K-S:	0.383	0.008	0.005	Combined K-S:	0.258	0.045	0.035	Combined K-S:	0.180	0.652	0.581
	RESEARCHERS					Smaller group	Distance	P-value	Exact	Smaller group	Distance	P-value	Exact
						2	0.035	0.957		2	0.000	1.000	
						3	-0.328	0.021		4	-0.269	0.166	
						Combined K-S:	0.328	0.042	0.030	Combined K-S:	0.269	0.330	0.270
	EXT OFF									Smaller group	Distance	P-value	Exact
										3	0.084	0.799	
										4	-0.191	0.310	
										Combined K-S:	0.191	0.601	0.524
		RESEARCHERS				EXT OFF				OTHERS			
RELEV	FARMERS	Smaller group	Distance	P-value	Exact	Smaller group	Distance	P-value	Exact	Smaller group	Distance	P-value	Exact
		1	0.000	1.000		1	0.000	1.000		1	0.163	0.408	
		2	-0.270	0.064		3	-0.244	0.033		4	-0.133	0.555	
		Combined K-S:	0.270	0.129	0.104	Combined K-S:	0.244	0.066	0.052	Combined K-S:	0.163	0.762	0.693
	RESEARCHERS					Smaller group	Distance	P-value	Exact	Smaller group	Distance	P-value	Exact
						2	0.233	0.142		2	0.375	0.030	
						3	-0.074	0.822		4	-0.074	0.873	
						Combined K-S:	0.233	0.284	0.236	Combined K-S:	0.375	0.061	0.043
	EXT OFF									Smaller group	Distance	P-value	Exact
										3	0.299	0.056	
										4	0.000	1.000	
										Combined K-S:	0.299	0.113	0.089
		RESEARCHERS				EXT OFF				OTHERS			
INN	FARMERS	Smaller group	Distance	P-value	Exact	Smaller group	Distance	P-value	Exact	Smaller group	Distance	P-value	Exact
		1	0.365	0.007		1	0.209	0.083		1	0.270	0.087	
		2	0.000	1.000		3	0.000	1.000		4	-0.016	0.991	
		Combined K-S:	0.365	0.013	0.009	Combined K-S:	0.209	0.167	0.140	Combined K-S:	0.270	0.173	0.140
	RESEARCHERS					Smaller group	Distance	P-value	Exact	Smaller group	Distance	P-value	Exact
						2	0.038	0.949		2	0.008	0.998	
						3	-0.157	0.416		4	-0.174	0.472	
						Combined K-S:	0.157	0.773	0.704	Combined K-S:	0.174	0.847	0.770
	EXT OFF									Smaller group	Distance	P-value	Exact
										3	0.085	0.795	
										4	-0.080	0.816	
										Combined K-S:	0.085	1.000	1.000
		RESEARCHERS				EXT OFF				OTHERS			
ENV	FARMERS	Smaller group	Distance	P-value	Exact	Smaller group	Distance	P-value	Exact	Smaller group	Distance	P-value	Exact
		1	0.304	0.031		1	0.244	0.033		1	0.234	0.159	
		2	-0.026	0.975		3	-0.027	0.959		4	0.000	1.000	
		Combined K-S:	0.304	0.063	0.048	Combined K-S:	0.244	0.066	0.053	Combined K-S:	0.234	0.316	0.266
	RESEARCHERS					Smaller group	Distance	P-value	Exact	Smaller group	Distance	P-value	Exact
						2	0.027	0.974		2	0.074	0.873	
						3	-0.096	0.720		4	-0.143	0.600	
						Combined K-S:	0.096	0.997	0.989	Combined K-S:	0.143	0.961	0.915
	EXT OFF									Smaller group	Distance	P-value	Exact
										3	0.076	0.833	
										4	-0.048	0.930	
										Combined K-S:	0.076	1.000	1.000

Declaration of interests

☐ The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

☐The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: