Examining Irish farmers' awareness of climate change and the factors affecting the adoption of an advisory tool for the reduction of GHG emissions

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Abstract

Livestock is a very significant sector in Irish agriculture and it could possibly mitigate a large amount of greenhouse gas emissions. However, farmers' awareness and acceptance towards climate change might be a significant barrier to voluntary adoption of best practice techniques. This paper presents results from a supplementary survey of 747 Irish farmers conducted as part of the National Farm Survey (NFS) in 2014, with a view to understanding farmers' awareness of and attitudes to climate change and greenhouse gas (GHG) emissions. Survey results showed that there was a general uncertainty towards a number of agricultural GHG emissions related questions and that farmers' attitude towards GHG emissions reduction was not very positive. In order to explore further farmers' attitudes towards climate change, a multinomial logit model was used to examine the socio-economic factors that affect farmers' willingness to adopt an advisory tool that would show the potential reduction in GHG emissions from the adoption of new technologies. Results showed that investment in machinery, awareness, region, environmental subsidies, use of social networking, agri-training encouraged adoption while off-farm income was negatively related to adoption.

Keywords climate change, adoption, awareness, multinomial logit

JEL code Agricultural and Natural Resource Economics; Environmental and Ecological Economics; P32

1 Introduction

The issues of climate change, global warming and curtailing man-made greenhouse gas emissions are indisputably some of the most significant challenges that society is currently facing, as evidenced by the efforts to secure an international agreement at the COP21 Climate that took place in Paris in December 2015.

Agriculture upon which society depends for sustaining livelihoods, is one of the sectors that is most vulnerable to shifts in climate, but also one of the main sources of GHG emissions accounting for 24 percent of global GHG emissions (IPCC, 2014). Over the past 10 years we have seen global food prices and food security significantly impacted by the extreme rain and floods in the US Midwest in 2008, the heat and drought in Russia in 2010 and the floods in Pakistan in 2010 (Nelson et al., 2010). Agriculture in Ireland is predominantly focussed on grass-based livestock production and this combined with the relatively low human population and lack of traditional "heavy industry" leads to agriculture accounting for 33 percent of Irelands GHG emissions (EPA, 2015). There is scope to reduce emissions from the sector as identified by Schulte and Donnellan (2012) through the adoption of abatement technologies. However, the extent to which farmers perceive and accept climate change as a risk is often a barrier to voluntary adoption of best practice techniques (Barnes and Toma, 2012).

While it is widely accepted that the investigation of farmers' awareness of and attitude towards climate change and agriculture's contribution to GHG emissions is very important to understand, very few studies have focused on this area (Barnes and Toma, 2012). Understanding producers' perceptions of climate change and how they would respond to initiatives which contribute to GHG emission reduction is essential for policy makers. This study presents the outcome of a 2014 survey examining Irish farmers' awareness and attitudes to climate change and agricultures contribution.

2 Background

The agri-food sector in Ireland plays a significant role in the economy accounting for 7.1% of Gross Value Added (DAFM, 2014). Furthermore, the sector is expected to grow significantly based on the government's ambitious "Food Harvest 2020" policy vision (DAFM, 2010). Indicative targets include an increase of primary output in the agriculture, fisheries and forestry sector by 33% over the 2007-2009 average. Despite the optimistic vision for agricultural intensification in terms of increasing levels of economic output and employment levels, recent attention has been placed on livestock production and its contribution to environmental pollution. Livestock activities produce significant amounts of CO_2, CH_4 and Nitrous oxide (N_2O).

Agriculture is one of the most climate-sensitive sectors in Ireland, as outdoor production relies on particular levels of temperature and rainfall. According to Sweeney et al. (2008), climate change will have an impact on Irish agriculture by the 2050s with wetter winter and drier summer soils, as well as increased temperatures. Climate change challenges will be different for different regions in Ireland. For instance, in regions where water stress is expected, production of grass, barley, potato and to a lesser extent maize will be affected. Dairying will be affected by summer soil moisture deficits in some areas while in the extreme north-west with cool temperatures dairying will not be heavily impacted.

As part of a the EU Climate and Energy Package in 2008, Ireland has agreed for the post-Kyoto period 2013-2020 to reduce its national GHG emissions by 20% compared with 2005 emission levels by 2020 (DAFM, 2013). Under this package Ireland is challenged to reduce its GHG emissions in the sectors of the economy not covered by the EU Emissions Trading Scheme (ETS). The ETS was launched in 2005 and deals with emissions from the EU's larger installations, such as power stations, factories etc. Sectors not covered by the ETS, such as agriculture, transport, residential and waste were covered by the Effort Sharing Decision (ESD 409/2009) (DAFM, 2015).

A number of studies have focused on developing technologies and strategies with a view to reducing the emissions of greenhouse gases. For instance, higher daily weight gains in beef cattle, extended grazing season, manure management, use of nitrification inhibitors, use of cover crops, bio-fuel/bioenergy crops etc. are some mitigation measures that may potentially reduce GHG emissions from Irish agriculture (Schulte and Donnellan, 2012).

2.1 Literature review on farmers' awareness of and attitude to climate change

Very few studies focus on farmer attitudes towards climate change and how these attitudes are affected by individual or socio economic factors. There has been some research on farmer attitudes to and awareness of climate change in developed countries using statistical methods such as, factor analysis or structural equation model (Harrington and Lu, 2002; Barnes and Toma, 2012; Arbuckle et al., 2013). The majority of applied work is focused on farmers in developing countries (Deressa et al., 2011; Maponya et al., 2013; Mukteshawar and Shehrawat, 2015; Kibue et al., 2015) and this can be explained by the more fragile economies and natural resources in these countries.

With respect to studies conducted in developed countries, Harrington and Lu (2002) surveyed cattle farmers in southwestern Kansas to investigate their perceptions and attitudes regarding climatic change issues and industrial change. They found that 58% of the 24 feedlot respondents did not believe that global warming associated with fossil fuel burning is a proven theory and around half of them felt that climate changes caused by global warming will not be a problem at all in the next 50-100 years. However, despite the strong doubts existing about climate change, there were some positive attitudes to reduce the threat of global warming. For example, 25% of the respondents were willing to pay additional $85 to reduce global warming, around 21% were willing to pay $250, 21% would pay $500 and 25% would be willing to pay $1000. However, at least on third of the respondents refused to undergo any additional cost.

Rejesus (2012), examined perceptions and beliefs about climate change amongst North Carolina farmers. In this survey 36% of the farmers agreed or strongly agreed that climate change has been scientifically proven, with older farmers being less sceptical than younger farmers. Almost half of the farmers (47.4%) accepted the statement that human activities are causing changes in the earth's climate and 60.4% believed that normal weather cycles explain most or all recent changes in climate. However when farmers were asked about a possible impact of climate change on crop yields, only 18.3% believed that climate change would decrease average yields by 5% or more over the next 25 years. Arbuckle et al., (2013) found that 68% of farmers surveyed in Iowa believed that climate change is occurring. However, only 10% considered human activities to be a cause of climate change and around 23% considered the natural variation as the main cause of climate change.

Barnes and Toma (2012), conducted a survey in 2008 with a view to gathering information on farmer characteristics, as well as attitudes, values and intentions towards the economic and environmental aspects of climate change within dairy farming. In a survey of 550 Scottish dairy farmers they found that a large percentage of farmers were uncertain about statements related to climate change. Nearly one third of the respondents were unsure if it is likely that the average annual temperatures will increase in the future, while 47.7% of them either agreed or strongly agreed with the statement. With the statement that "climate change will only impact negatively in the long term" around 35% of the farmers agreed or strongly agreed, while the majority (41.5%) were uncertain.

2.2 Literature review on technology adoption in agriculture

There is a large literature on the adoption and diffusion of new technology, with the theory of Rogers (1995) being popularized in his book *Diffusion of Innovations* and widely applied. In general, the literature on the adoption of new agricultural and more environmentally friendly technologies suggests that farmers' decision making depends on a variety of factors, such as economic, structural characteristics of the farm, as well as demographic and personal characteristics (Austin et al., 1998; Rehman et al., 2007; OECD, 2012; Tornatzky and Klein, 1982).

A basic hypothesis regarding the adoption of an innovation is that larger farms would be more receptive to new technology than smaller farms mostly due to issues related to cost. For instance, requirements in fixed costs by new technologies may constrain technology adoption by smaller farms. These costs are related to new machinery, time for learning, training hired labour and locating and developing markets (Just and Zilberman, 1983).

Land ownership is widely hypothesised to encourage adoption of technologies mostly linked to land such as irrigation equipment or drainage systems, while tenant farmers are less likely to adopt these types of innovations primarily due to concerns over whether or not they directly benefit from the land improvements associated with the adoption (Daberkow and McBride, 2003). Although several studies support this hypothesis, results vary and the subject has been widely debated (Feder et al., 1985).

Profitability of the farm is another factor that influences farmers' decision making on technology adoption. It is regularly hypothesised that more profitable farms are more likely to adopt new technologies (Gould et al., 1989; Saltiel et al., 1994; Somba et al., 2002). It is often concluded that higher income farmers are more likely to adopt new technology due to their capacity to afford investments (Prokopy et al., 2008; Gould et al. 1989). The existence of an off-farm income is also usually positively related to the innovation adoption (Genius et al., 2006; Davey and Furtan, 2008; Fernandez-Cornejo et al., 2005). However, Keelan et al. (2009), inferred a negative relationship between off-farm income and the adoption of GM technology.

When a considerable investment is required more profitable farms are more likely to adopt new technologies than less profitable as investments in innovations often require fixed costs that are more risky than technologies that are already used (Keelan et al., 2009). In support of this view, Hoff et al. (1995) and El-Osta and Morehart (1999), found that credit constraints may impede technology adoption. However, in a Dutch study Diederen et al., (2003) found that solvency level, measured as the ratio of equity capital over total capital, had a negative impact on technology adoption. That could be explained as the result of solvency capturing farmers' attitude towards risk rather than farm's financial condition. That is, farmers who tend to be risk averse have higher solvency levels than farmers who tend to invest in innovations.

In addition to farm characteristics, the relationships between farmers and others, such as other family members, peer farmers, advisors etc. play a significant role in the decisions on technology adoption. It has been shown that farmers who were members of environmental groups were positively influenced towards adopting new technology (Kington and Pannell, 2003; Sobels et al., 2001). A willingness to participate in public good or 'commons' activities generates trusting behaviour and many times encourages innovation solutions (Brehm and Rahn, 1997; Sobels et al., 2001).

Following the adoption literature the relationship between farmers who have contact with agricultural consultants with regard to climate change issues and adoption has been found positive in studies conducted in Europe and the USA (Islam et al., 2013). However, the physical distance of the farm from sources of information is negatively related to adoption as it seems that farmers are less exposed to the information (Lindner et al. 1982).

Ryan and Gross (1943) have shown that the adoption of agricultural innovations is not even for all farmers, therefore further research has focused on the investigation of certain farmer characteristics in order to explain this difference. Demographic factors are prominent in the literature on technology adoption. Pannell et al. (2006), argued that demographic factors are important because they influence the goals of the farmer and that goals will in turn influence the level of adoption. In their study Pannell et al. (2006) tried to explain the influence of some of the commonly identified demographic factors such as age, experience and education on farmers' willingness to adopt conservation practices such as reduced tillage, improving soil structure, claying etc.

Prokopy et al. (2008), conducted a meta-analysis of 55 studies on the adoption of agricultural best management practices in the United States. Age was considered in 26 studies and appeared to have a negative relationship with adoption more often than a positive relationship, indicating that as farmers got older they were less likely to adopt new technologies. According to Gasson and Errington (1993), older farmers were less willing to adopt conservation practices especially if the farm was not to be passed on to the landholder's children, or the changes in their farms would not be fully reflected in the sale price of the farm. Empirical studies have often concluded that farmers with higher education tend to adopt beneficial innovations quicker than less educated farmers since education is likely to promote awareness and understanding of environmental issues, which are often complex (e.g. Feder et al., 1985; Islam et al. 2013; Prokopy et al., 2008).

3 Data

3.1 Survey Data

This study uses data from the 2014 Teagasc Irish National Farm Survey (NFS). The NFS collects data on a random nationally representative sample of between 800 and 1,000 Irish farms on behalf of the Farm Accountancy data Network of the European Union. Each farm has its own unique farm code and is assigned a weighting factor which makes the results representative of a national population of approximately 80,000 to 90,000 farms.

A supplementary survey was conducted of a subset of the NFS farms (747 farms) between July and December 2014. Fourteen questions relevant to climate change were incorporated in the supplementary survey with a view to understanding farmers' awareness and attitudes towards climate change.

3.2 Descriptive statistics

Definitions and descriptive statistics of the variables used in the multinomial logit model are presented in Table 1. The dependent variable was derived from an answer to the question "would you be interested in using an advisory tool that would show the potential reduction in GHG emissions from the adoption of new technologies on your farm?"[1] The response categories were "yes", "no", or "I don't know" for y=1, y=2 and y=3 respectively.

The explanatory variables included farmers' attitudinal characteristics such as the extent to which farmers use social networking to support their farm management decisions and it was captured by the ordinal variable *social_networking.* Farmers' attitude to climate change and their willingness to receive agri-environmental advice was also captured through the inclusion of their response to two questions within the supplementary survey. In order to capture farmers' awareness about climate change the response to whether they agree or disagree with the statement that man-made GHG emissions contribute to global climate change was included as a categorical independent variable (*awareness*). Whether farmers have received agri-environmental advice or training, or not and if they would be willing to receive some was used as a categorical variable (*agri_env_advice*) in the multinomial logit model.

[1] The advisory tool refers to the carbon navigator developed by Teagasc. The reference to the carbon navigator in the question was omitted to avoid any confusion. It is possible that farmers were unfamiliar with the term or they already used a similar tool called differently.

With regard to economic characteristics, the off-farm income dummy variable (*off_farm_income*) represents the existence of a wage from an off-farm employment or self-employment, or none income coming from off-farm activities. The average investment in machinery per hectare (*investment_machinery_ha*) is included. The environmental subsidies continuous variable (*ENVIRON_SUBS_HA*) represents the subsidies per ha paid as part of the REPS (Rural Environment Protection Scheme), AEOS (Agri-Environment Options Scheme) or ESA (Environmentally Sensitive Area)[2]. The location impact of regions is captured by the dummy variable *BMW* which represents the Border Midlands West region of Ireland, farms are generally more intensive in the East and South West of the country than in the Border, Midlands and Western regions. A variable representing the share of land owned (*LAND_OWNED_HA*) is also incorporated into the model. *LAND_OWNED_HA* is a continuous variable and expresses the amount of land owned by the farmers as a percentage of the farmer's UAA.

4 Multinomial Logit Model

In this study, we use a multinomial logit model to examine the socioeconomic factors that affect a farmers' decision to adopt an advisory tool that would show farmers the potential reduction in GHG emissions from the adoption of new technologies on their farm are estimated. The multinomial logit model is widely used in the technology adoption literature as a standard method for understanding the association between explanatory variables and a categorical dependent variable (Lapple and Van Rensburg, 2011; Lapple and Hennessy, 2015). The multinomial logit was preferred for this study to its counterpart, the multinomial probit model, because it is simpler to compute (Hassan and Nhemachena, 2008).

The multinomial logit model is an extension of the binary logit model and is used in cases where the unordered response variable has more than two responses. The outcome variable Y takes on the values for J a positive integer and x_i is the explanatory variables for an i farm. Specifically, the model used in this study explains the probability of the farmers who responded "Yes" when j=1, those who responded "No" when j=2, and those who answered

[2] REPS, AEOS, or ESA are schemes designed to reward farmers for farming in an environmentally friendly manner.

Table 1. Summary statistics of the variables used in the analysis (n=746)

Variable definition and codes	*Variable name*	*N*	*Mean*	*Standard deviation*	*Minimum*	*Maximum*
Independent variables						
Age (continuous variable)	FARM_MD_AGE	746	56.22	11.04	23	91
Social Networking (categorical) 0 = No; 1 = Yes, but infrequently; 2 = Yes, frequently	Social_networking	746	0.40	0.66	0	2
Agri-environmental advice & training (categorical) 0 = No I have not and I do not want to receive any; 1 = No I have not, but I would like to receive one; 2 = Yes, I have	agri_env_advice	746	0.98	0.83	0	2
Awareness (categorical) 0 = Disagree with this statement; 1 = Don’t know ; 2 = Agree with this statement	awareness	746	1.36	0.76	0	2
Off=farm Income (dummy) 0 = none; 1 = wage/salary or self-employed	off_farm_income	746	0.21	0.41	0	1
Investment in machinery per ha (continuous)	investment_machinery_ha	746	769.27	674.83	0	4864.06

Environmental Subsidies per ha (continuous)	ENVIRON_SUBS_HA	746	43.21	88.31	0	1059.08
BMW (Border, Midlands & West region) (dummy variable) 0 = SE region; 1 = BMW region	BMW	746	0.43	0.49	0	1
Land Owned per hectare (continuous)	LAND_OWNED_HA	746	52.44	41.41	0	528.2
Dependent variable						
Advisory tool; 1 = Yes; 2 = No; 3 = Don't know	adv_tool_adoption	746	0.48	0.50	1	3

“Don’t know” when j=3. The explanatory variables of each category can be contrasted with the base category, which is the farmers who replied “No” in this case.

This model shows how ceteris paribus changes in the elements of *x* affect the response probabilities, $P(y_i = j|x)$ (the probability that individual *i* chooses alternative *j*), *j*=1, 2,…*J* (Wooldridge, 2001). The response probabilities of the multinomial logit model are determined by the following equation:

$$P\,(y_i = k|x_i) = \frac{\exp(\beta_k x_i)}{\sum_{j=1}^{J}\exp(\beta_j x_i)}\ , \qquad j= 1, 2,\dots, J$$

where *k* is one of the *j* subgroups and $P(y_i=k)$ is the probability that the i_{th} farmer belongs to the k subgroup and x_i describes farm and farmer characteristics.

Because the response probabilities must sum to unity,

$$P(y_i = 0|\ x_i) = 1\ /\left[1 + \sum\nolimits_{j=1}^{J}\exp(\beta_j x_i)\right]$$

When $J = 1$, β_1 is the K x 1 vector of unknown parameters, and the binary logit model is derived (Wooldridge, 2001).

The estimation of the multinomial logit model is based on maximum likelihood defined by the following equation:

$$L(\beta_{2,\dots,}\beta_{j,}|\ y,\ X) = \prod_{k=1}^{j}\prod_{y_i}\frac{\exp(\beta_k x_i)}{\sum_{j=1}^{J}\exp(\beta_j x_i)}$$

where $\Pi y_i=k$ is the product over all cases for which $y_i=k$ (Long, 1997).

The outcome in the multinomial model is measured by Relative Risk Ratios (RRR), which can be obtained by exponentiating the multinomial logit coefficients. These ratios indicate that for a unit change in an explanatory variable, the odds of the outcome falling in the comparison groups relative to the outcome falling in the base group changes by the relative risk ratio ceteris paribus. A relative risk ratio below 1.00 indicates a negative relationship. This means that the variable’s effect on the probability that farmers reply “Yes” to adoption of an advisory tool (compared with the probability that farmers reply “No” is negative, while a relative risk ratio greater than 1.00 means that the effect is positive.

5 Results and discussion

5.1 Multinomial logit model results

The multinomial logit model separates individual farmers into three distinct groups ("Yes", "No", "Don't know") in order to explore the factors that distinguish these groups. Based on the previous results of the survey in 2014, while 52% of the farmers agreed that man-made GHG emissions contribute to global climate change only 35% of them would be willing to adopt an advisory tool that would help them in reducing the GHG emissions on their farm. Therefore, particular interest lies in whether or not farmers who were negative to adopt an advisory tool significantly differ from farmers who were positive and those who were unsure differ from those who were negative. This means that the estimation of the multinomial logit model for this study was undertaken by using as the "base category" the group of farmers who replied "No". The results of the multinomial logit model are reported as relative risk ratios and are shown in table 2. The model computed using Stata is statistically significant at the 1% significance level.

5.1.1 Attitudinal characteristics

Examining first the results for farmer characteristics, famers' age was found to not be significantly related to either of the categories although based on previous studies (Prokopy et al., 2008; Gasson and Errington, 1993) age was found to be negatively associated with technology adoption. In accordance with the meta level analysis conducted by Prokopy et al. (2008) utilisation of social networking was found to be positively associated with the adoption of an advisory tool. Farmers who use information from social networking tools more frequently than others who do not use social networking at all are more likely to adopt an advisory tool than reject it.

Examining the influence that agri-environmental advice and training would have on technology adoption, multinomial logit results showed a positive relationship for both categories. The more willing farmers are to receive agri-environmetnal advice or training the more likely they are to adopt an advisory tool. The results also suggest that farmers who are more open to accepting agri-environmental advice and training were also more likely to give the response "Don't Know" than to answer "No". This result was consistent with previous research which has found that participation in advisory programmes is positively associated with adoption of artificial insemination in Ireland (Howley et al., 2012).

The relationship between farmers' awareness of climate change and the adoption of an advisory tool that would help them in reducing their GHG emissions was investigated. In order to capture farmers' awareness, the relative response was taken from the supplementary survey and it was used as an awareness variable. Results showed that farmers who were more aware of climate change were more likely to say "Yes" to the adoption of an advisory tool than saying "No".

5.1.2 Economic characteristics

One further background variable found to affect the probability of farmers adopting an advisory tool was the existence of an off-farm income. The negative relationship between being employed off-farm and the probability of adopting an advisory tool could be attributable to time constraints and additional production expenses. According to Ervin and Ervin (1982) off-farm income could reflect the need for supplemental income for family living expenses or even farm production expenses, resulting in farmers' unwillingness to undergo additional expenses and resulting in less time available for on-farm work. However, investment in machinery was positively related to technology adoption, indicating that the relative risk ratio confirms that farmers who invested more in machinery were more likely to adopt an advisory tool than reject it. It could be suggested that farmers who invest in machinery tend to be more risk takers, therefore more likely to adopt new technology.

5.1.3 Farm level characteristics

With respect to farm level characteristics environmental subsidies were found to be positively associated with the adoption of an advisory tool. This result is in line with the hypothesis that introducing a subsidy generates a positive effect, which reduces ambiguity and contributes positively to decision making (Allbers et al., 2009). *BMW* variable is included in the model as a measure of location impact on technology adoption. Results showed that farms located in the Border, Midland and Western region are more likely to reject the adoption of an advisory tool compared with the farms located in the South-East region. This could be attributable to the fact that BWM region suffers from low levels of innovative activity compared with the rest of the country.

Farmers who are uncertain are likely to own more land than farmers who are negative to adoption of an advisory tool, while there is no significant difference in relation to owning land per hectare between those who would accept and those who would reject the adoption of an advisory tool.

Table 2. Results of the Multinomial Logit Model

Variables	*Yes*	*Don't Know*
Attitudinal characteristics		
FARM_MD_AGE	0.98(0.008)	1.004(0.01)
social_networking	1.83(0.25)***	0.80(0.19)
agri_env_advice	1.73(0.19)***	1.66(0.24)***
awareness	1.29(0.15)**	0.90(0.14)
Economic factors		
off_farm_income	0.64(0.14)*	0.61(0.20)
investment_machinery_ha	1.000257 (0.001)*	0.99(0.00)
ENVIRON_SUBS_HA	1.002(0.001)**	0.99(0.001)
Farm level characteristics		
BMW	0.28(0.05)***	0.71(0.17)
LAND_OWNED_HA	1.00(0.002)	1.004(0.002)*
Loglikelihood	-635.74	
LR $chi^2(15)$	186.09	
Pseudo R2	0.12	

**** significant at the 1% level, **significant at the 5% level, *significant at the 10% level, farmers who answered "No" as comparison group, relative risk ratios (RRR) are reported, standard errors (se) of RRRs are reported in parentheses and are calculated as*

5.2 Views on climate change

5.2.1 Farmers' awareness of climate change

Over half of farmers (53.3%) agreed that man-made GHG emissions are contributing to global climate change and changing weather patterns while only 18% disagreed. The outcome of this question indicates a high level of awareness of climate change as a global issue. However, as farmers are questioned further on what contribution agriculture makes and how climate change might impact on their farm, the level of uncertainty as well as disagreement are much greater.

Further results showed that there was a general uncertainty towards a number of climate change related questions. Farmers were asked if they expect that climate change will have a negative effect on their production decision, 27.7% of the whole farmer population felt that climate change will be a problem only in the long term (more than 20 years), 28.9%

of the farmers considered no impact at all and 19.7% were unsure. Only 8% of the respondents expected a negative effect in the medium term (i.e. within next 5 years), however 14% of farmers believed that they were already being negatively impacted by climate change. These results might suggest that farmers would not be willing to adopt new technologies to reduce farm-level GHG emissions.

Farmers were also asked to rate their level of agreement or disagreement with the contribution made by different activities to agricultural greenhouse gas emissions in Ireland. This question suggested that there is a high degree of uncertainty and disagreement amongst farmers as to whether or not particular activities were important sources of GHG emissions. The results again point to either a lack of awareness or in some cases a high degree of misinformation amongst farmers about the sources of GHG emissions. The emissions of methane (CH_4) and Nitrous Oxide (N_2O) from the production of livestock accounts for the bulk of GHG emissions from Irish agriculture and yet when asked if livestock production was an important source of GHG emissions 27.9% of farmers said that they don't know and 30.2% of farmers either disagreed or strongly disagreed with the statement. In contrast 69.4% of farmers either agreed or strongly agreed that clearing of forests is an important source of GHG emissions.

The contribution of deforestation to climate change and global warming in a global context has been well documented and so it is possible that this information is shaping farmers' understanding of what are the main contributors to GHG emissions in a national context. Furthermore, 41.2% of the farmers were not sure if tilling of land causes GHG emissions, 32.7% disagreed and 9.2% strongly disagreed while, only 2.2% strongly agreed and 14.8% agreed. In relation to the application of artificial fertilizers 34.7% were unsure, 41.8% agreed or strongly agreed and a minority disagreed or strongly disagreed to this statement. Clearing of forests and electricity and fuel use on the farm were both deemed by the majority of respondents as activities that made an important contribution to agricultural GHG emissions.

5.2.2 Farmers' attitudes towards climate change

As regards attitudes, farmers were asked whether or not they had received agri-environmental advice or training. 32.2% of the farmers stated that they have received agri-environmental advice or training, 28.5% stated that they have not received but they would like to receive one and 39.3% indicated that not only have they not received any agri-environmental advice and training and they are not willing to receive any in the future. The low number of farmers indicating that they have received agri-environmental advice is surprising given the high uptake of agri-environmental schemes such as REPS in the past.

Farmers were asked how much additional cost they would be willing to incur in order to reduce their greenhouse gas emissions by 5%. The most popular answer (77.6%) to this question was farmers' unwillingness to incur any increase in their production costs, whereas only 18% would be willing to incur an increase between 0 and 5%. Only a negligible proportion would be willing to increase their costs of production by more than that. Over half (52.9%) of the farmers were reluctant to use an advisory tool that would show the potential reduction in GHG emissions from the adoption of new technologies on their farm, 35.2% would be willing and the remainder of farmers were unsure.

6 Conclusions

Climate change, global warming and reduction in GHG emissions are some of the most significant challenges that modern society is facing. The agricultural sector is the most vulnerable sector to changes in weather patterns and at the same time is a significant source of GHG emissions globally and particularly in Ireland. Therefore, there is a need to reduce emissions from the sector as identified by Schulte and Donnellan (2012) through the adoption of abatement technologies. However, the extent to which farmers perceive and accept climate change as a risk is often a barrier to voluntary adoption of best practice techniques (Barnes and Toma, 2012). Therefore, this study examined the extent to which Irish farmers are aware of climate change and agriculture's contribution to it, as well as the factors that affect farmers' willingness to adopt a tool that will quantify the GHG emissions on their farm.

Previous research (Arbuckle et al., 2013), has shown that high proportions of farmers believed that climate change is occurring and at the same time very few of them believed that climate change is a cause of human activities. Very similar to this study, Rejesus et al. (2012), showed that approximately half of the farmers agreed that human activities are causing changes in earth's climate. As opposed to this study, Harrington and Lu (2002) indicated farmers' positive attitude in the context of undergoing additional costs to reduce global GHG emissions. Barnes and Toma (2012) showed high levels of uncertainty associated with questions related to climate change such as whether high temperatures will occur in the future caused by climate change.

This study showed that over half of the farmer population is aware that man-made GHG emissions are contributing to global climate change and changing weather conditions. However, when asked more specific questions about Irish agricultures contribution to GHG emissions, farmers' responses varied more. Likewise farmers expectations of climate change might impact on their business varied substantially which might in turn hamper their willingness to adopt new low emission technologies or strategies. In support of this view the *awareness* variable in the multinomial logit model was found to be positively associated with technology adoption, indicating that farmers who are more aware of climate change issues are more likely to adopt the proposed advisory tool. Therefore, there may be a requirement to increase farmers' awareness of GHG emissions from agriculture through greater media coverage and advisory attention in relation to climate change and global warming both in global and national level.

Many Irish farmers do not seem to prioritise the need to contribute to GHG emissions reduction, possibly as a result of their low level of awareness in association with the contribution that their farm makes to GHG emissions. For example, almost 40% of the farmer population has not received and does not want to receive any agri-environmental advice or training. Based on the multinomial logit results, agri-environmental advice and training seemed to affect significantly technology adoption. For instance, farmers who tended to receive some training or advice would be more willing to adopt an advisory tool than the farmers who did not receive any. That might recommend an increase in farmers' motivation towards agri-environmental training and advice.

Farmers' lack of familiarity with and use of social networking tools reflects the older age of Irish farmers and the limited source of information they are exposed to. Based on the multinomial logit model results, the positive impact social networking had on technology adoption might suggest that ways to acquaint farmers with social networking, such as organising free or low cost workshops, seminars, or encouraging the advisory contact could increase technology adoption.

In accordance with previous studies (Keelan et al., 2009), this research showed that the existence of off-farm income is negatively correlated with adoption of an advisory tool while investment in machinery was positively correlated. Subsidies are a primary instrument of innovation policy and they have been an important part of environmental policies. This study fortified subsidies' important role in innovation policy as multinomial logit results showed that the more farmers received environmental subsidies the more likely they were to adopt an advisory tool. Finally, farms located in the BMW region were less likely to adopt an advisory tool compared with those located in SE region. This could suggest that farmers from the BMW region might need more advice and training in matters pertaining the adoption of innovative technologies and strategies.

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APPENDIX A

Table xx. The activities listed below are important causes of agricultural GHG emissions

	Strongly Disagree	Disagree	Don't know	Agree	Strongly Agree
Livestock Production					
Dairying	10	20.1	23.7	37.6	8.7
Cattle rearing	13.6	23.1	23.6	31.7	8.1
Cattle other	7.9	21	28.3	34.2	8.5
Sheep	10.7	18.2	36.4	24.8	9.9
Tillage	4.3	15.9	33.1	40.8	6
Other	10.1	24.6	23.4	34.4	7.4
Artificial fertiliser application					
Dairying	4.8	24.6	32.9	33.1	4.6
Cattle rearing	6.3	15.1	32.3	36	10.3
Cattle other	4	21.4	28.9	35.7	10.1
Sheep	7.1	13	40.5	27.8	11.6
Tillage	3.2	11.2	54	27.4	4.2
Other	3.6	20.3	41.9	25.7	8.6
Tilling of land					
Dairying	12.1	33.8	34.8	18.1	1.3
Cattle rearing	9.7	32.9	43.7	9.2	4.6
Cattle other	8.1	37.2	35.5	18.6	0.7
Sheep	7.1	22.5	59.8	8.2	2.5
Tillage	7.1	32.5	36.6	20.5	3.2
Other	13.3	30	45.4	8.2	3.1
Clearing of forests					
Dairying	2.4	5.1	21.1	40	31.3
Cattle rearing	1.9	8.8	19.3	31.1	38.9

Cattle other	4.6	6.7	13	37.6	38.1
Sheep	6.4	5.3	31.6	17.6	39.1
Tillage	1.1	7	28.9	44.7	18.4
Other	-	7	26.5	41.8	24.7
Electricity and fuel use on the farm					
Dairying	6.5	16.2	27	39.3	11
Cattle rearing	5.9	17.4	31.3	30.6	14.8
Cattle other	3.1	14.6	28.3	38.5	15.6
Sheep	6.4	6.9	36.6	30.9	19.1
Tillage	2.2	15.1	40.7	39.9	2.2
Other	5.5	25.8	30.7	34.4	3.5