Understanding farmers: From adoption to attitudes

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Abstract

Agriculture contributes significantly to global Greenhouse Gas (GHG) emissions, but there are many technologies and practices that have the potential to significantly mitigate these GHG emissions. Technology adoption research, through a better understanding of the individual adoption decision can help policymakers realise this potential via better policy design and targeting. The attitude of potential adopters is one important aspect influencing this decision. Identifying groups or typologies of farmers with similar attitudes and their associated farm/farmer characteristics can inform policy to encourage adoption of GHG mitigation practices. Using new data from a face-to-face nationally representative survey, this paper identifies five farmer typologies based on attitudes towards a range of farming/non-farming issues. It considers their impact on the adoption decision, before identifying underlying farm/farmer characteristics to such farmer typologies to allow for a number of recommendations to help policy design.

Introduction

Agriculture, forestry and other land use (AFOLU), was estimated in 2010 to account for just under one quarter of total anthropogenic global emissions, comprising agriculture (10-12%), forestry and other land use emissions (FOLU) (9-11%) (Smith et al, 2014). While there is a range of agricultural practices that have the potential to mitigate GHG agricultural GHG emissions, (see Beach, et al., 2015), they are only effective if adopted widely. Uncertainty around the adoption of GHG mitigation practices contributes not only to uncertainty around agricultural emissions, but also to the appropriateness of policy responses.

The most recent Irish GHG emission estimates forecast that by 2020 agriculture will account for 47% of total Irish non-ETS emissions[1], remaining the single largest sector source of non-ETS emissions (EPA, 2017). A number of GHG mitigation practices have been identified for Irish agriculture (see Schulte and Donnellan, 2012; Lanigan et al., 2018). Even where profitable to the farmer the adoption of GHG mitigation practices is "difficult to project" (Schulte and Donnellan 2012, p. 28), with a strong linkage between research and policy-making "required in order to maximise adoption" (Lanigan et al., 2018, p. 31).

The theoretical literature can provide an insight into the factors affecting this adoption decision and so inform policy. When included in adoption studies as explanatory variables, attitudes[2] have a significant influence on farmers' adoption decisions (for example see Prokopy et al., 2008; Kallas et al., 2010). For policymakers it can be useful to identify different attitudinal typologies of farmers to effectively simplify and represent the heterogeneity of such attitudes (Valbuena et al., 2008; Daloğlu et al., 2014). Subsequently analyzing the relationships between these attitudinal typologies and the characteristics of the farm/farmer provides a more practical focus for policy interventions to support adoption of new technologies and practices (Boon and Meilby, 2007). This approach to segmenting the farming population has become an increasingly popular tool for developing and targeting extension programs to particular farmer groups or segments (Schwarz et al., 2009). More generally, change is more likely to occur amongst those where it fits with attitudes (Pike, 2008).

While existing research on technology adoption and farmer attitudinal typologies is useful it remains largely research-context specific (Karali et al., 2013; Sulemana and James, 2014). Therefore, the objective of this paper is to understand Irish farmer attitudes in more detail, specifically, to identify farmer attitudinal typologies and their underlying farm/farmer characteristics. Doing so provides policymakers with a more informed view of how farmers' attitudes can be utilized to improve the targeting of policy incentives. Using a bespoke survey and taking Ireland as a case study, this paper adds to existing agriculture technology adoption research by identifying Irish farmer attitudinal typologies and variables associated with such typologies.

[1] ETS sectors include energy and heavy industry; non-ETS sectors include agriculture, waste and transport.
[2] While recognising different literatures provide different definitions for different key concepts such as attitude, values, beliefs and opinions this paper borrows from that widely used in environmental management to consider attitudes as evaluations of various environmental, financial, and moral dimensions (Floress et al. (2017).

Background

Technology adoption research uses a number of theoretical frameworks, paradigms and methodologies to better understand the adoption decision, although such research is not confined to a single framework or paradigm (Prager and Posthumus, 2010; Tambo and Abdoulaye, 2012).

One of the most widely used frameworks in technology adoption research is the Diffusion of Innovation (DOI) theory (Rogers, 1983). By combining existing diffusion research Rogers developed a meta-theory of diffusion, providing the most widely accepted theory on the adoption of innovations based on a common understanding of the innovation decision process (Talke and Heidenreich, 2014; Miller, 2015). Within the adoption-decision process, the adoption decision is the third step in a process that begins with the individual gaining knowledge about the new technology, before forming an attitude towards the technology (Sahin, 2006). Two other widely used frameworks in agriculture technology adoption research are the Theory of Reasoned Action (TRA) (Fishbein and Ajzen, 1975) and the Theory of Planned Behaviour, (TPB) (Ajzen and Madden, 1986; Borges, et al., 2015). These models provide a framework for understanding the relationship between a person's attitudes and their underlying beliefs (Meijer et al., 2015).

Drawing on these multiple frameworks, technology adoption research has identified a wide range of factors that influence the individual's decision to adopt a new technology or farming practice (Boz and Akbay, 2005). Such research suggests the characteristics of both the specific technology and the characteristics of the farm/farmer determine the adoption decision (Keelan et al., 2009; Baumgart-Getz et al., 2012). Attitudes is one such farm/farmer characteristic often included in agriculture technology adoption research (Prager and Posthumus, 2010; Baumgart-Getz et al., 2012). While important, attitudes have received less attention, possible due to the fact they are more difficult to measure than variables such as farmer age and farm size (Meijer et al., 2015). A practical use of knowledge about farmer attitudes is the identification of different typologies or styles of farming based on common attitudes, followed by the identification of underlying farm/farmer characteristics. This can then support more focused policy interventions to support adoption of new technologies and practices (Boon and Meilby, 2007; Valbuena et al., 2008; Schwarz et al., 2009; Daloğlu et al., 2014).

Technology adoption research

Challenges when using existing technology adoption literature to inform this paper include the absence of a single universal methodological approach, no single list of relevant farm/farmer characteristics and/or no single set of farmer attitudinal typologies. For example, Irish agriculture technology adoption studies have included the use of not just DOI theory (Keelan, et al., 2009) and TPB (Lapple and Kelley, 2010), but other theoretical frameworks such as the Technology Acceptance Model (TAM) (Kelly et al., 2015). In their study of adoption of Artificial Insemination (AI) amongst Irish dairy farmers Howley et al. (2012) found that age was negatively associated with AI use. However, in their study amongst US farmers Gedikoglu et al. (2011) found a positive relationship between age and adoption of the practice of injecting manure. Finally, in their study of Scottish dairy farmers Barnes and Toma (2012) identified six distinct farmer typologies based on a common outlook towards climate change impacts, while in their study amongst New Zealand farmers Niles and Mueller (2016) identified four typologies relating to climate change beliefs and future concerns.

Despite some limitations, the existing research does allow some useful generalizations to inform new research. For example, research shows that older farmers tend to have a more conservative mind-set and less innovative attitude relative to younger famers. This conservative attitude is often associated with greater risk-aversion and resistance to change (Defrancesco et al., 2006; Anastasova-Chopeva et al., 2015; Ulu and Smith, 2016). Off-farm employment can also affect attitudes via risk, where off-farm employment provides an alternative income source to reduce financial risk and support a more positive financial outlook (Fernandez-Cornejo et al., 2007; Gillespie and Mishra, 2011). Off-farm employment may also allow a farmer develop new skills and social networks, suggesting a more innovative and less conservative orientation (McElwee and Bosworth, 2010). Larger farm size may also have a positive impact on a farmer's financial outlook via their larger capacity to bear risk (Pyykkonen et al., 2008). More intensive farming practices can require a more innovative attitude, with a willingness not just to try new ideas but also an ability to cope with uncertainty around trying such technologies (Sahin, 2006).

Generally, agricultural education provides the farmer with specific knowledge about farming practices and an increased ability or capacity to receive order and understand information (Weir and Knight, 2004). In addition, there is general agreement that education has a positive effect on agricultural productivity (Padhy and Jena, 2015), while specific agricultural education may place a greater emphasis on production (Drake et al (1999) cited in Mathijs, (2003). Thus, agricultural education would suggest both a more innovative and production-focused attitude.

Agricultural advice provides farmers with practical information to allow them to use and manage new farming technologies and practices (Dethier and Effenberger, 2012), suggesting a more innovative attitude. Membership of farmer discussion groups, where groups of farmers meet regularly to discuss technical issues, share information and solve problems, could also support a more innovative attitude (Adesina et al., 2000; Hennessy and Heanue, 2012). Finally, general lack of awareness of new farming practices may be associated with a more conservative attitude, reflecting a risk-aversion and resistance to change (Ulu and Smith, 2016).

Next steps

In addition to the context-specific nature of existing technology adoption research the complex nonlinear nature of the adoption decision process means farm/farmer characteristics commonly used to explain adoption have a different impact across multiple stages in this process (Lambrecht et al., 2014). For example, older farmer are considered more risk-adverse and therefore less likely to adopt due to uncertainty about new technologies. However, Byron et al. (2005) cited in Stanley et al. (2006) suggests that it is younger farmers (under 30) that are more likely to face constraints to adoption due to emerging family commitments, savings and debt. In addition, knowledge and information can reduce uncertainty about new technologies, with the age of the farmer influencing the choice of information source (Opara, 2010). Typically, a conservative attitude is associated with older farmers. However, age is also a reflection of experience and so what is perceived as a new practice may be something an older farmer has already tried but decided is not practicable or profitable for their particular farm. This highlights a much deeper issue with technology adoption research and a particular challenge for agriculture. A focus on the adoption of a new technology implies a pro-innovation bias, i.e. the technology or innovation should be adopted by all. However, due to the heterogeneous nature of farms, individual farms operate under varying agronomic constraints resulting in differing production systems with unique production and cost functions, and particular efficiencies within their production system. Thus, a new technology may not be practicable or profitable for some farmers and non-adoption the logical choice.

To better understand the adoption decision this paper considers a similar set of farm/farmer characteristics across two aspects or stages in the adoption decision process: adoption and attitudes. Famer attitudes, considered via attitudinal typologies, are first identified as relevant to the adoption decision. The paper then identifies underlying farm/farmer characteristics associated with these farmer attitudinal typologies. This allows for suggested policy interventions to encourage the adoption of GHG mitigation practices.

Data and Methods

The data in this paper come from a bespoke farm-level survey of 1,000 Irish farmers during October to December 2012, based on the methodology of the Teagasc[3] National Farm Survey (NFS). The Teagasc NFS has been conducted on an annual basis since 1972 and fulfills Ireland's statutory obligation to supply harmonized, annual data on farm output, costs and income to the EU Farm Accountancy Data Network (FADN). In conjunction with the Irish Central Statistics Office[4] (CSO), Teagasc selects a random nationally representative sample of between 1,000 and 1,200 farms depending on the year. A weighting factor is assigned so the results of the survey are representative of the national population of farms. For example, the 2016 NFS results are based on a sample of 861 farms, which represents 84,736 farms nationally (Dillon et al., 2016). Thus, the sample used for this paper is a random nationally representative sample of farms (1,000), with a Teagasc NFS weighting factor applied to be representative of the national population of Irish farms.

The survey questions were informed by past and present Teagasc NFS's, with many of those involved in the design, delivery and analysis of the Teagasc NFS actively involved in the design of the survey questionnaire. A number of agriculture extension agents and agriculture researchers also inputted into the questionnaire design, including representatives from the Department of Agriculture, Food and Marine (DAFM) and private agricultural extension agents. Each individual brought not only an extensive understanding of Irish agriculture, but specific expertise. This included those researching GHG emissions and mitigation, and agriculture extension agents with direct experience of working with farmers implementing GHG mitigation practices.

As a result, while previous surveys have considered adoption of specific GHG mitigation practices this was the first such survey of Irish farmers to include a section on multiple GHG

[3] Teagasc, the Agriculture and Food Development Authority, is an Irish state body under the responsibility of the Department of Agriculture, Food and the Marine (DAFM). Teagasc was established by the Agriculture (Research, Training and Advice) Act 1988 to provide integrated research, advisory and training services to the agriculture and food industry and rural community. Its mission is to support science-based innovation in the agri-food sector and wider bio-economy so as to underpin profitability, competitiveness and sustainability.

4 The Irish Central Statistics Office (CSO) was established in 1949 as Ireland's national statistical office and provides high quality impartial and relevant statistical information.

mitigation technologies. This was in direct response to the growing challenge facing Irish agriculture to contribute to national GHG mitigation efforts while meeting national policy objectives to expand agricultural output. Researchers also wished to capture a broader range of farm/farmer characteristics than previously available. This recognised that adoption of GHG mitigation practices required behavioural change and a more detailed understanding of Irish famers' behaviours was necessary. Therefore, information on farm/famer characteristics, such as farm size and age, is complemented by information on farmer awareness, knowledge and attitudes. This resulted in forty-six survey questions providing new, novel and innovative data to understand the adoption decision.

The analysis begins with the adoption decision, where farmer attitudes (attitudinal typologies) and other farm/famer characteristics are included as explanatory variables. The same set of attitudinal typologies are then used as dependent variables, with a similar set of farm/farmer characteristics used as explanatory variables.

Attitudes

Farmer attitudinal typologies are constructed using a Principle Component Factor Analysis (PCA). The PCA used survey responses recorded on a 5-point Likert scale (strongly agree to strongly disagree) to fifteen statements relating to a number of farm/non-farming issues. For example, '*To be successful in farming it is important for me to adapt and use new technologies'*, '*Farmers should be allowed to maximise their income irrespective of the environmental consequences'*. A full list of statements is included in the Appendix.

Table 1 describes the attitudinal variables resulting from the PCA process described in more detail below. Those farmers identified as being innovative orientated are associated with statements such as '*To be successful in farming it is important for me to adapt and use new technologies'* while those with a focus on profit or production (Productivity orientated) were associated with statements or attitudes such as '*Farmers should be allowed to maximise their income irrespective of the environmental consequences'*

Table 1: Attitudinal Variables

Variable	Description
Innovative Orientation	More open to new technology, using new information to help farm continue to run in the future
Productivity Orientation	Focused on output and profit regardless of environmental consequences
Positive Caretakers	Positive attitude to farming and believe farmers are having a positive impact on the environment
Conservative Orientation	Cautious about new ideas, do not like risk and believe it is important to be respected by other farmers
Agricultural Optimism	Optimistic about economic potential for farming, feeling that agricultural land is underutilised

PCA process

The PCA simplifies data analysis, i.e. reducing an excessive number of observed variables to allow for a more parsimonious and conceptually meaningful summary of the data for use in regression analysis (Byrne, 2005; Kellow, 2006; O'Rourke et al., 2013). The PCA offers a practical, standardised and straightforward method for extracting relevant information from confusing data sets, reducing the dimensionality of the data set and identifies new meaningful underlying variables (Joliffe and Morgan, 1992; Paul et al., 2013).

The PCA approach provides a linear combination of optimally weighted observed variables. Optimal coefficients or weights within each equation is determined such that for a given set of data, no alternative set of weights could produce a set of components that are more effective in accounting for variance among observed variables. Weights are created to satisfy the principle of least squares O'Rourke et al., 2013). The first component extracted from this process accounts for the maximum amount of total variance among the observed variables, i.e. the first component is correlated with at least some (usually many) of the observed variables. The second component extracted from this process accounts for the maximum amount of variance in the dataset not accounted for by the first component, i.e. the second component is correlated with some of the observed variables that were not strongly correlated with component 1. Importantly, the second component is uncorrelated with the first component. This process continues, where each additional component accounts for a progressively smaller amount of variance.

The PCA process provides a list of factor loadings or eigenvalues of the correlation matrix, where a factor loading represents the amount of variance captured by a given component. These factor loadings give some idea about how much the variable has contributed to the factor, where a larger factor loading indicates the variable has contributed more to that component. As the analysis continues until all variance in the dataset has been accounted for the next step is to determine how many meaningful components should be retained to interpret (Yong and Pearce, 2013; O'Rourke et al., 2013). In general, later components capturing only trivial amounts of variance will not be retained. In addition to the eigenvalues, the PCA output will also show the 'proportion' of variance explained by each of the components. One of the most commonly used criterion used to determine the number of factors to retain is Kaiser's criterion (Kaiser 1960). This provides a rule of thumb that all components with eigenvalues greater than 1.00 should be retained. An eigenvalue greater than 1.00 suggests a variable that accounts for a greater amount of variance than had been contributed by that one variable, i.e. it accounts for a meaningful amount of variance and is worthy of retention (O'Rourke et al., 2013). In order to provide a simpler interpretation of the factor loadings and simpler structure the factor loadings are rotated. A simpler structure provides variables with relatively high factor loadings on only one component/ near zero loadings on the other components. After rotation, the factors must be interpreted, i.e. determine what each of the retained components is measuring. Doing so allows each factor to be given a descriptive name (Yong and Pearce, 2013; O'Rourke et al., 2013; Mooi et al., 2017). Rotated factor loadings for general attitudes towards faming/non-farming issues are reproduced in the Appendix. (Kaiser's criterion applied).

Attitudes Regression Analysis

A stepwise regression was used to identify statistically significant variables across each of the five attitudinal typologies. In a stepwise regression variables are added (forward selection) or removed (backward selection) based on a specified significance level. The model used in this paper is a backward stepwise regression, with the significance level of .3.

A backward elimination stepwise regression begins with all explanatory variables and eliminates one variable at each model iteration. The first explanatory variable removed is that which explains the least amount of variation in the dependent variable, the second explanatory variable removed is that which explains the next greatest amount of the remaining variation in the dependent variable, etc. The removal of variables is based on a specified significance level, commonly 0.05 or 0.01. The process stops when the addition/removal of the last variable does not meet the significance criteria. The model results therefore only include those variables that met this criterion. In summary, the basic idea of a stepwise regression is to explain the greatest variation in the dependent variable using the fewest possible explanatory variables. This involves multiple iteration of models, adding/removing explanatory variables that explain the greatest/least variation in the dependent variable (Weiers, 2010).

Adoption

In order to identify the relevance, or otherwise, of attitudes in the adoption decision this paper begins by analysing the adoption decision in relation to a longer grazing season length.

The grazing season is the number of days an animal spends on grass outdoors. As grass growth is highly seasonal with little or no net growth between November and February, the typical grazing season (number of days animals spent on grass outdoors) runs from early spring to late autumn. Grazing season length varies across Ireland due mainly to differences in soil quality and climate. In 2016, the average grazing season length amongst Irish dairy farmers was 235 days (Teagasc, 2016).

Methane (CH_4) emissions arise directly as part of the natural digestive process (enteric fermentation) of ruminant animals, while the storage and use of their excreta results in both CH_4 and Nitrous oxide (N_2O) emissions. The levels of direct emissions depend on a number of factors including the type of animal, age and feed type. As grazed grass is more digestible than other feedstuff it is processed and passes through the animal quicker, resulting in reduced methane emissions. Indirect emissions of CH_4 and N_2O from stored slurry (organic manure) are also reduced as animals are inside for a shorter period and slurry volumes are lower (Hook, et al., 2010; Murphy et al., 2013). Extending the grazing season length therefore results in lower GHG emissions via reduced quantities of stored manure, lower direct enteric methane (CH_4) emissions (improved feed digestibility and quality) and energy use (feeding, manure management and harvesting of silage). The estimated mitigation potential of extended grazing (0.264 Mt CO2eq) presented in Irelands Marginal Abatement Cost Curve (MACC) (Schulte and Donnellan 2012) is based on an extension of the average dairy grazing season by 21 days, rising from 227 days in 2010 to 248 days in 2020.

The dependent variable for grazing season length was created based on the reported let-in and let-out dates, i.e. the day and month respondents normally let stock out/took stock in. An

Ordinary Least Square (OLS) approach is used to examine the adoption of a longer grazing season.

Farm/farmer characteristics

Table 2 provides a brief description of explanatory variables used in the analysis.

Table 2: Explanatory Variables

Variable Description		**Obs**	**Mean***	**Std. Dev.**	**Min.**	**Max.**
Farm/Farmer characteristics						
Younger (<30 years) 1=Yes; 0=No		979	0.080695	0.272505	0	1
Older (65+ years) 1=Yes; 0=No		979	0.201226	0.401121	0	1
Off-farm job/income 1=Yes; 0=No		979	0.259448	0.438556	0	1
Soil: No limits[1] 1=Yes; 0=No		979	0.538304	0.498785	0	1
Soil: Some limits[1] 1=Yes; 0=No		979	0.402452	0.490643	0	1
Dairy 1=Yes; 0=No		979	0.199183	0.39959	0	1
Cattle Rearing 1=Yes; 0=No		979	0.439224	0.496546	0	1
Cattle Other 1=Yes; 0=No		979	0.11236	0.31597	0	1
Sheep 1=Yes; 0=No		979	0.136874	0.34389	0	1
Stocking Rate		979	1.335482	1.152066	0	10.33
Farm size: >100 ha[2] 1=Yes; 0=No		979	0.074566	0.262824	0	1
Farm size: 10-20 ha[2] 1=Yes; 0=No		979	0.263534	0.440775	0	1
Awareness, Advice and Knowledge					0	1
Aware:	Spring slurry spreading has lower GHG emissions 1=Yes; 0=No	979	0.741573	0.437994	0	1
	Clover in grass sward results in less nitrogen spread 1=Yes; 0=No	979	0.493361	0.500212	0	1
Don't Know:	Feasible to extend grazing season 1=Yes; 0=No	979	0.07763	0.267726	0	1
	Feasible to finish beef earlier 1=Yes; 0=No	979	0.670072	0.470427	0	1
	Feasible to spread slurry	979	0.066394	0.249097	0	1

	in the spring rather than summer 1=Yes; 0=No					
	GHG emissions are lower from trailing shoe slurry spreading method 1=Yes; 0=No	979	0.102145	0.302994	0	1
	Presence of clover means less nitrogen can be spread 1=Yes; 0=No	979	0.325843	0.468928	0	1
Member of farmer discussion group 1=Yes; 0=No		979	0.299285	0.458179	0	1
Agricultural advice[3] 1=Yes; 0=No		979	0.713994	0.452123	0	1
Some agricultural education[4] 1=Yes; 0=No		979	0.624106	0.4846	0	1
Participated in Agri-environment scheme (AES)[5] 1=Yes; 0=No		979	0.552605	0.497479	0	1

* This is the mean of the variable. As all variables except for stocking rate ranges from 0 to 1 (the min and max values) the mean is the proportion of observations coded as 1.
1. No limits to agricultural activity/some limits to agriculture activity. Agriculture activities were not defined in the survey. While not a perfect measure of soil type it is included to capture this potentially important physical farm characteristic
2. Farms less than 10 ha (25 acres) not included in the survey
3. Extension agent and/or agriculture consultant.
4. Short course, certificate and/or third level.
5. Participation in any Irish agriculture-environment scheme (AES), 1994 to 2010 (Commencement of Irish AES to date of survey).

The older age profile of respondents, 20% over 65 years with only 8% under 30 years, is comparable to the most recent Irish agricultural census data. This showed that a quarter (26%) of all Irish farm holders are aged over 65 years and just 6% under 35 years (CSO, 2010). Just over one-quarter of respondents (26%) farmed between 10 and 20 hectares, compared to just over one-third (34.2%) in the most recent Irish farm structure survey (CSO, 2013). The 2015 Teagasc NFS identified almost one-third (30%) of farm holders with an off-farm job, only slightly above that in this analysis (26%).

Over half (55%) of respondents participated in an AES and almost three-quarters (71%) accessed agricultural advice. The construction of the variable capturing participation in AES makes comparison to existing research problematic. The variable used in this analysis refers to participation in any AES scheme(s), with a number of different AES schemes introduced in Ireland. For example, the Rural Environment Protection Scheme (REPS) was available to all Irish farmers between 1994 and 2009, with participation decreasing from 32% to 27% between 1999 and 2003. This increased to 48% and 45% in 2006 and 2010 respectively (Murphy et al., 2014). The agriculture advice variable include advice from public/private agents and did not distinguish between the type and frequency of advice/contact. Thus, comparisons with existing estimates of access to advisory services is also difficult as Irish farmers have a range of service providers who deliver different level of service, e.g. public and private providers offer advice from basic administration to farm-specific technical advice (Prager and Thomson, 2014).

Previous research suggested 44% of Irish farmers had some agricultural education (Heanue and O'Donoghue, 2014). The higher percentage identified in this analysis (62%) may reflect the variable construction, where agricultural education included a wide range of different types of education, including agricultural college, University degree in agriculture and/or a short agricultural course run by Teagasc.

Awareness, or lack of awareness, is a particularly important aspect of the adoption decision process, where awareness is the first step or a pre-condition to adoption (Lambrecht et al., 2014). The variables capturing awareness/lack of awareness correspond to GHG mitigation practices available to Irish farmers (See Schulte and Donnellan 2012 and Lanigan et al., 2018), i.e. spring spreading of slurry, finishing beef earlier, using low GHG emissions slurry spreading methods, use of clover. Table 3 briefly outlines the environmental impact of these practices. Comparisons with existing research is not possible due to the specific nature of these variables, although it is worth noting that a significant proportion of respondents (67%) were not aware if it was feasible to finish beef earlier.

Table 3: Dependent variables: Description and GHG emissions impacts

GHG mitigation practice	Environmental Impact
Finishing Beef earlier	Higher growth rates for beef livestock lead to a lower finishing age, i.e. age at which animal achieves required weight for slaughter. Reduced beef finishing times increase absolute GHG emissions on a per animal basis due to increased quantities of feed consumed and manure produced. However, GHG emissions per unit of beef produced are reduced as the increased quantities of beef produced more than offset the increase in GHG emissions (Schulte and Donnellan, 2012).
Slurry spreading methods	Relative to the splash plate slurry spreading method other methods such as the trailing shoe/injection/band spreader result in lower ammonia (NH_3) emissions via lower nitrous oxide (N_20) emission (re-deposition) and lower N_2O and carbon dioxide (CO_2) emissions (reduced fertiliser use/manufacturing) (Schulte and Donnellan, 2012).
Slurry spreading timing	If slurry is spread in spring rather than in summer, the weather is cooler and less gases are released into the atmosphere.
Use of clover in grass swards	The inclusion of clover in grassland can convert atmospheric N gas into a form that is available to plant roots in the soil via a process known as biological N fixation. Including clover in grass swards therefore reduces nitrogen requirements, reducing direct N_2O emissions, but also reducing energy use in the chemical fertilizer production, transportation and application (Humphreys and Lawless, 2006. Murphy et al., 2013).

Results

Table 4 presents results from the analysis of the adoption decision. Table 5 present results from the analysis of farmer attitudinal typologies. As the focus of this paper is farmer attitudes the adoption results are only briefly noted.

Table 4: Adoption Model Results

Variable Description		**Longer Grazing Season**
Farm/Farmer characteristics		
Younger (<30 years)		3.407
Older (65+ years)		-4.243
Off-farm job/income		3.486
Soil: No limits		17.92***
Soil: Some limits		3.796
Dairy		16.71***
Cattle Rearing		-1.769
Cattle Other		-3.892
Sheep		6.936
Stocking Rate		-4.670*
Farm size: >100 ha		1.895
Farm size: 10-20 ha		-0.176
Awareness, Advice and Knowledge		
Aware:	Spring slurry spreading has lower GHG emissions	-2.174
	Clover in grass sward results in less nitrogen spread	1.535
Don't Know:	Feasible to extend grazing season	1.778
	Feasible to finish beef earlier	-4.198*
	Feasible to spread slurry in the spring rather than summer	4.154
	GHG emissions are lower from trailing shoe slurry spreading method	14.48***
	Presence of clover means less nitrogen can be spread	4.949
Member of farmer discussion group		5.898**
Agricultural advice		1.816
Some agricultural education		5.689**
Participated in Agri-environment scheme (AES)		-5.405**
Attitudes		
Innovative Orientation		1.751
Productivity Orientation		2.682**
Positive Caretakers		-2.505**
Conservative Orientation		-2.093*
Agricultural Optimism		4.454***

R-squared 0.22 2; *** p<0.01, ** p<0.05, * p<0.1

Results: Adoption

A focus on dairy enterprise and soil type that did not limit agricultural activity had a positive impact on adoption of a longer grazing season. The result also identify a positive relationship between membership of farmer discussion group and the length of the grazing season. This may reflect the ability of such groups to help farmers better understand the practical implications of what is a complex farming practice (Hennessy and Heanue, 2012). Similarly, agricultural education had a positive impact on the length of the grazing season. Such education can provide the farmer an increased ability or capacity to receive order, analyze and understand information (Jenkins et al., 2011). Interestingly, participation in an AES had a negative impact on the length of the grazing season, possibly due to restrictions imposed by such schemes.

Of particular interest for this paper are those results relating to attitudes, where four of the famer attitudinal typologies considered had a statistically significant impact on the length of the grazing season.

A focus on production (Productivity orientation) and an optimistic outlook for the future of farming (Agricultural optimism) both had a positive impact on the length of the grazing season. This may reflect the positive impact a longer grazing season will have on farm production or profitability, where an increase in grazed grass reduces average production costs (O'Donovan et al., 2011; Hennessey et al., 2006). A conservative orientation and the view that farmers have a positive impact on the environment (Positive Caretaker) had a negative impact on the length of the grazing season. The impact of holding a conservative attitude is as expected as such an attitude is associated with a resistance to change and inability to cope with uncertainty around a new practice (Sahin, 2006). Those that view their environmental impact as positive may be aware of the potential negative impacts of an extended grazing season, e.g. extended/overgrazing can reduce biodiversity and negatively affect water quality through erosion and nutrient leaching/run-off (Hubbard et al., 2004; Lanigan et al., 2018).

Results: Attitudes

Table 5 presents results of the analysis of farming/non-farming attitudes, i.e. farmer typologies and their underlying farmer characteristics.

Table 5: Attitudes Model Results

<table>
<tr><th colspan="2"></th><th>Positive Caretakers</th><th>Innovative Orientation</th><th>Productivity Orientation</th><th>Conservative Orientation</th><th>Agricultural Optimism</th></tr>
<tr><td colspan="2">Farm/Farmer characteristics</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="2">Younger (<30 years)</td><td></td><td></td><td></td><td>-0.390***</td><td></td></tr>
<tr><td colspan="2">Older (65+ years)</td><td></td><td>-0.317***</td><td></td><td>0.208***</td><td></td></tr>
<tr><td colspan="2">Off-farm job/income</td><td></td><td>0.274**</td><td></td><td>-0.213***</td><td>0.498***</td></tr>
<tr><td colspan="2">Soil: No limits</td><td></td><td>0.406***</td><td></td><td></td><td>0.308**</td></tr>
<tr><td colspan="2">Soil: Some limits</td><td>-0.237***</td><td></td><td></td><td>-0.197***</td><td></td></tr>
<tr><td colspan="2">Dairy</td><td>0.483***</td><td></td><td>-0.139*</td><td>-0.287***</td><td></td></tr>
<tr><td colspan="2">Cattle Rearing</td><td>0.340***</td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="2">Cattle Other</td><td>0.578***</td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="2">Sheep</td><td>0.262**</td><td></td><td></td><td>-0.155*</td><td></td></tr>
<tr><td colspan="2">Stocking Rate</td><td></td><td>0.0856***</td><td></td><td></td><td></td></tr>
<tr><td colspan="2">Farm size: >100 ha</td><td></td><td>0.264**</td><td></td><td>-0.199*</td><td>0.282**</td></tr>
<tr><td colspan="2">Farm size: 10-20 ha</td><td></td><td>-0.179**</td><td></td><td></td><td></td></tr>
<tr><td colspan="2">Awareness, Advice and Knowledge</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td rowspan="2">Aware</td><td>Spring slurry spreading has lower GHG emissions</td><td></td><td>0.286***</td><td></td><td>0.129*</td><td></td></tr>
<tr><td>Clover in grass results in less N spread</td><td></td><td></td><td>-0.230*</td><td>-0.348***</td><td></td></tr>
<tr><td rowspan="5">Don’t Know</td><td>Feasible to extend grazing season</td><td></td><td></td><td>-0.230*</td><td>-0.348***</td><td></td></tr>
<tr><td>Feasible to finish beef earlier</td><td></td><td>0.109*</td><td></td><td>0.182**</td><td></td></tr>
<tr><td>Feasible to spread slurry in the spring rather than summer</td><td></td><td></td><td></td><td></td><td>0.351**</td></tr>
<tr><td>GHG emissions are lower from trailing shoe slurry spreading method</td><td></td><td></td><td></td><td></td><td>-0.231**</td></tr>
<tr><td>Presence of clover means less nitrogen can be spread</td><td></td><td></td><td>0.219***</td><td>0.211***</td><td></td></tr>
<tr><td colspan="2">Member of farmer discussion group</td><td></td><td></td><td>-0.163**</td><td></td><td></td></tr>
<tr><td colspan="2">Agricultural advice</td><td>0.129*</td><td>0.352***</td><td></td><td></td><td></td></tr>
<tr><td colspan="2">Some agricultural education</td><td></td><td>0.182***</td><td></td><td></td><td>0.152**</td></tr>
<tr><td colspan="2">Participated in Agri-environment scheme (AES)</td><td></td><td>0.116*</td><td></td><td></td><td></td></tr>
<tr><td colspan="2">R-squared</td><td>0.048</td><td>0.188</td><td>0.036</td><td>0.105</td><td>0.049</td></tr>
</table>

*** $p<0.01$, ** $p<0.05$, * $p<0.1$

The results show that an older age profile have a positive impact on holding a conservative attitude and negative impact on holding an innovative attitude. In addition, a younger age profile has a negative impact on holding a conservative attitude. This was expected, reflecting a resistance to change/adoption and risk-aversion amongst older famers relative to younger farmers (Ulu and Smith, 2016; Defrancesco et al., 2006; Anastasova-Chopeva et al., 2015).

Holding an **off-farm** job has a negative impact on having conservative attitude and a positive impact on a more innovative attitude. Such off-farm employment may help farmers develop new skills and social networks that would support a less conservative and more innovative outlook (McElwee and Bosworth, 2010).

A higher **stocking rate** has a positive impact on farmers holding a more innovative attitude. This may reflect the complexity and uncertainty of managing a higher stocking rate, where an innovative attitude is associated with a willingness to try new ideas and ability to cope with uncertainty (Sahin, 2006). A larger **farm size** also had a positive impact on farmers holding a more innovative attitude. Similar to stocking rate managing a larger farm may be associated with greater uncertainty and thus require a more innovative attitude.

The results show that lack of knowledge of the impacts of clover on nitrogen use had a positive impact on holding more conservative attitudes. If farmers are not aware of the impacts of different farming practices it adds to uncertainty and risk, supporting a more conservative attitudes and greater resistance to change (Ulu and Smith, 2016). Lack of awareness of the feasibility to extend the grazing season had a statistically significant but negative impact on holding a conservative attitude. Relative to clover use in grass swards, grazing season is a more widely established farming practice. Therefore, this result may instead reflect the older age profile of farmers with a more conservative view, i.e. younger farmers by nature of their fewer years of farming experience may be less likely to be aware if extending the grazing season is feasible on their farm. As noted previously, older farmers tend to have a more conservative attitude relative to younger famers.

Accessing agricultural advice and participating in an AES both had a positive impact on farmers holding a more innovative attitude. This is as expected, where agricultural advice provides farmers with information to allow them to use and manage new technologies and practices (Dethier and Effenberger, 2012). In addition, an agricultural education had a positive impact on holding an innovative attitude. This supports the general view that farmers that are more educated are more receptive to new ideas (Keelan et al. 2009). Another agriculture advice channel, farmer discussion groups, had a negative impact on farmers holding a more productive outlook. Such groups were expected to support a focus on farm productivity via exposure to new ideas, helping famers discuss technical issues, share information and solve problems. In addition, discussion group members tend to have larger farming operations than those not participating in such groups, suggesting a greater focus on productivity (Adesina et al., 2000; Hennessy and Heanue, 2012). An alternative interpretation is that strong opinion leaders within farmer discussion groups may emerge that are less willing to take risks (Lamm et al., 2014; Lamm et al., 2016). This attitude may restrict adoption of new technologies that can enhance productivity as such technologies involve some element of risk (Miller et al., 2004).

Discussion

This paper confirms that attitudes, along with a number of other farm/farmer characteristics is relevant to the adoption decision. In itself, this is of interest to policymakers. For example, farmer discussion groups and agricultural advice as policy interventions support adoption of a longer grazing season. The results also show that, for example, a conservative attitude has a negative impact on adoption. While interesting, in itself this is of little practical relevance to policymakers. However, viewing adoption as a process rather than a single decision allows underlying farm/farmer characteristics to be identified.

The results of this paper highlight the importance of viewing adoption is a process rather than a single decision. For example, age had no statistically significant impact on the adoption of a longer grazing season. However, attitudes did have a statistically significant impact on adoption and age had a statistically significant impact on these attitudes. For policymakers tasked with reducing GHG emissions, the question should not only be are older farmers more/less likely to adopt GHG mitigation practices, but how does age impact across the adoption decision process. This paper shows that an older age profile had a positive impact on holding a more conservative attitude, an attitude likely to restrict uptake of new farming practices. If such an attitude is a reflection of uncertainty the question for policymakers then becomes how can policy help reduce this uncertainty. Alternatively, is it a case that the return on investment for new practices is not compatible with older farmers' shorter planning horizon? Now the question may be one of alternative farming structures such as farming partnerships.

The result that agricultural education had a positive impact on farmers holding a more innovative outlook may offer an opportunity for policymakers to engender a less conservative and more open-minded attitude. Specifically, the agriculture education can address the greater risk-aversion and resistance to change amongst older farmers (Defrancesco et al., 2006; Anastasova-Chopeva et al., 2015; Ulu and Smith, 2016). However, if considering the shorter planning horizon of older farmers nearing retirement the practical relevance of this approach may be limited. Again, policymakers may need to look at alternative supporting measures, such as enhanced taxation enticements for retirement following farm transfers. One final observation is that a conservative orientation reflects a concern about being respected by other farmers. For policymakers this may suggest a peer-led approach to agricultural advice would be more effective.

Farm size had no statistically significant impact on the adoption of a longer grazing season, but was significant in relation to attitudes. Specifically, a larger farm size had a statistically significant impact on holding an innovative attitude, while a smaller farm size had a negative impact. A more cautious or less innovative attitude is the logical response amongst small farms where the capacity to bear the risk associated with new farming practices is lower (Pyykkonen et al., 2008). The non-financial policy responses may simply include providing good information to a farmer allowing them better manage risk (Tangermann, 2011). A more difficult policy question may be to ask if the overall farming system structure needs a more radical change, e.g. address the longer-term sustainability of a farming system with fewer but more financially viable farms.

Agriculture advice and education will remain one of the principal interventions available to policymakers, but the specific type of interventions requires careful consideration. For example, returning to the older farmer, if agricultural advice has a positive impact on adoption it is worth asking what type of agricultural advice might older farmers favour. Do older farmers prefer individual visits by extension agents, or discussion groups? Also as noted, the role of the facilitator in discussion groups is important to supporting a more innovative attitude. A more general point when considering adoption as a process, and one more difficult to address, is that of causation. For example, does agricultural advice help a farmer develop a more innovative attitude, or do innovative farmers seek out agricultural advice.

Finally, it is worth noting that few farmer characteristic are associated with a single attitudinal typology. Thus, while a useful aid to inform policy, it is important to emphasize that the approach presented in this paper may offer an over-simplification of what is a very complex issue. For example, an off-farm job had a positive impact on a more innovative attitude. This may expose farmers to new ideas and skills, leading to an open-minded attitude to change and thus encouraging adoption of new farming practices. However, practically, off-farm employment may lead to part-time farming with a reduced focus towards on-farm production, thus discouraging adoption of new farming practices.

Conclusions

Mitigating agricultural GHG emissions will require widespread adoption across a range of different agricultural technologies and practices. Better understanding what motivates farmers to adopt certain desirable farm practices (such as those that mitigate GHG emissions) is necessary when designing and delivering policy initiatives (Austin et al., 1998). While recognizing that farmers' attitudes are based on a complex set of underlying factors (Mills et al., 2013) and caution is advised when claiming correlation between attitudes expressed through a questionnaire and actual behaviours (Midmore et al., 2001), greater knowledge of farmer attitudes can inform policy formation.

The most obvious conclusion from this paper is that technology adoption is a complex decision, influenced by a range of farm/farmer characteristics. When viewed as a process this becomes even more complex, with the adoption decision now just one stage. In addition, the impact of farm/farmer characteristics now extends to multiple points within this process.

Focusing on the adoption decision may suggest simpler policy interventions, such as, extension efforts targeted to younger farmers, as they are more likely to adopt new farming practices. When viewed as a process the policy interventions may not be as clear or simple, but this paper would argue that they can be more effective. By viewing adoption as a process, policymakers develop a better understanding of the individual farmer, including the drivers and barriers to adoption. This means not only stating that attitudes impact the adoption decision, but also questioning the basis for such attitudes. For example, understanding the reason for a more conservative attitude amongst older farmers can identify policy interventions that address key barriers such as uncertainty and shorter planning horizons.

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Appendix: Farming/non-farming Attitudes: Factor loadings

Statements	**Innovative Orientation**	**Productivity Orientation**	**Positive Caretakers**	**Conservative Orientation**	**Agricultural Optimism**
To be successful in farming it is important for me to adapt and use new technologies	**0.7373**	0.0255	0.0254	-0.1137	-0.0277
I am good at finding different types of information to help me run my business	**0.679**	0.1019	0.2324	-0.0681	0.1838
I have to keep my farm running to ensure I have something to pass on to my children	**0.6346**	0.0115	0.1241	0.0841	0.1392
Farmers should be allowed to maximise their income irrespective of the environmental consequences	-0.1007	**0.7738**	0.1553	0.0574	0.083
We need to produce more food even if some damage is caused to the environment	0.1808	**0.7344**	-0.1377	0.1043	0.118
It makes more sense for me to join a scheme if my neighbours are also joining	0.3974	**0.5012**	-0.0948	0.3226	-0.0305
Farmers are good caretakers of the countryside	0.1223	0.0768	**0.7629**	0.1244	0.0436
Farmers have a strong positive role to play in protecting the environment	0.2104	-0.1263	**0.6057**	0.0953	0.1266
I enjoy farming much more than I would other potential sources of employment	0.1713	-0.1289	**0.5409**	0.2765	0.2128
Farmers have caused damage to the environment in the past	0.1615	-0.442	**-0.5166**	0.2146	0.3381
I don't think it is a good idea to take too many risks when it comes to farming	0.0007	0.0858	0.1286	**0.7631**	-0.012
I am cautious about adopting new ideas and farm practices	-0.3367	0.2287	0.0241	**0.6375**	0.1179
It is important for me to be respected by other farmers	0.441	-0.1146	0.1574	**0.5134**	-0.092
Agricultural land in Ireland is under-utilised	0.002	0.0697	0.037	0.0138	**0.8142**
My economic future on this present farm is bright	0.2789	0.176	0.1448	-0.0171	**0.5514**
General eigenvalue	2.83266	1.78214	1.44514	1.21033	1.06117