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The Role of Communication Framing in Agricultural Climate Action

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This article investigates effective communication strategies to enhance farmers' engagement with climate change mitigation. Through an online survey experiment of more than 500 Irish livestock farmers, it examines the impact of message framing—focused on reputation concern or expenses—on information engagement, knowledge, and intentions to adopt greenhouse gas mitigation measures. The findings reveal that while framing significantly reduces engagement with the information, it does not affect knowledge or implementation intentions. This underscores the complexity of motivating climate action, suggesting that advisory programs should employ positively framed messages to generate interest, despite challenges inherent in discussing climate change mitigation.

Key words: climate change communication, economic experiment, greenhouse gas mitigation, livestock agriculture

Introduction

Meat and dairy consumption has become increasingly central to public debates on sustainable food consumption. In line with increasing concerns about climate change and the urgency needed to address it, greenhouse gas (GHG) emissions from livestock production have dominated those public debates. Worldwide, food systems are responsible for one-third of global GHG emissions (Crippa et al., 2021). In industrialized countries, almost 50% of food system GHG emissions are land-based (Crippa et al., 2021); meat, aquaculture, eggs, and dairy are responsible for more than half of these emissions (Poore and Nemecek, 2018).

Hence, the development and implementation of improved technologies on farms is seen as an important strategy to mitigate agricultural GHG emissions (Parlasca and Qaim, 2022). In fact, environmental impacts are often dominated by producers with very high impacts, which provides opportunities for mitigation at the farm level (Poore and Nemecek, 2018). Key GHG mitigation strategies are the implementation of climate-smart practices (e.g., feed additives, improved grazing management, reduced fertilizer application, and improved breeding). Determining how to facilitate widespread uptake is important for international food policies that aim to mitigate climate change. This underscores the need to effectively communicate climate change mitigation practices to farmers, highlighting their pivotal role in advancing agricultural sustainability.

In this article, I study how to improve climate action communications to farmers to facilitate reductions in GHG emissions from agriculture. The urgency of adopting climate change mitigation technologies in the agricultural sector highlights the key role of effective knowledge transfer programs as policy responses to initiate widespread adoption. To adopt new technologies, farmers

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must not only be aware that these exist, but also be convinced of their merit (Chavas and Nauges, 2020). This is particularly important in the context of determining how best to encourage farmers to adopt climate action practices. Best practices in this area remain an open question (Ferraro et al., 2021). In fact, most agricultural extension services focus on economic outcomes (Balaine et al., 2023). Moreover, communicating climate action goes beyond standard agricultural extension work because traditionally disengaged audiences must be reached (Whitmarsh and Corner, 2017). This can be particularly challenging in the farming community (Arbuckle et al., 2013), where perceptions of agricultural emissions and their contribution to GHG emissions can be disconnected (Hyland et al., 2016). Successfully communicating climate action measures to farmers is of major importance but has received scant attention.

This need to communicate information on climate change action is the focus and main contribution of this article. Specifically, I test means to increase farmers' information engagement with climate change mitigation information by varying the way in which the information is communicated. In particular, I assess the effect of message framing on engagement with the information, knowledge, and stated intentions to adopt and intensify the use of farm practices. Farmers were randomly assigned to one of two treatments or to a control group. One treatment focused on reputation concern by stating the importance of retaining agriculture's sustainable image. This treatment is based on the idea of conditional co-operation (i.e., people are more likely to contribute to climate change if others also make an effort) (Fischbacher, Gächter, and Fehr, 2001; Andre et al., 2024) and the "working together norm," which invites people to join in to achieve a common goal (Howe, Carr, and Walton, 2021; Vlasceanu et al., 2024). The other treatment was based on loss aversion and focused on the potential to reduce expenses, following the prospect theory (Kahneman and Tversky, 2013). This was motivated to challenge the effectiveness of the standard agricultural extension message, which emphasizes gains in profit from adopting new farm practices.

The behavioral economics literature shows that the framing of information can have an important impact on subsequent behavior changes (Kahneman, 2003; Tversky and Kahneman, 1974). A framing effect occurs if changes in the presentation induce changes of opinion (Chong and Druckman, 2007) and lead to better engagement. This concept has received limited attention in relation to agricultural extension, but precedents exist. A recent study by Balew et al. (2023), for example, explored loss-framed messages in relation to knowledge diffusion among farmers in Ethiopia but found no effect. Wallander, Ferraro, and Higgins (2017) examined the effect of framed outreach messages on conservation program uptake in a field experiment. They provided evidence of inattentive behavior and showed that peer comparisons and social norm messaging did not affect contract enrollment. However, in relation to communications about climate change specifically, framing has been found to initiate constructive dialogue about climate change with audiences that are more difficult to reach (Whitmarsh and Corner, 2017) and to affect attitudes toward meat consumption (Graham and Abrahamse, 2017). However, no consensus has emerged on how to communicate climate change effectively (Ceyhan and Saribas, 2022). A recent study by Vlasceanu et al. (2024) found that different ways of communicating climate change had small effects, largely limited to those who were not skeptical of climate change. In relation to climate skeptics, Ferraro et al. (2021) studied whether communicating the link between climate change and agricultural production discourages conservation action in a randomized control trial in the United States. In contrast to their expectation, they found no evidence that this discourages the uptake of climate action. As such, how to effectively communicate climate change is still an open question, particularly in the agricultural sector, where skepticism may prevail (Arbuckle et al., 2013; Islam, Barnes, and Toma, 2013).

This article directly contributes to the scant research on farmer communication about climate change. As such, it adds to the important topic of how to encourage farmers to adopt climate change mitigation measures. The adoption of mitigation technologies and practices is seen as a key step to reducing GHG emissions from food production (Parlasca and Qaim, 2022). To this end, I conducted an experiment using an online survey of over 500 Irish livestock farmers to test ways to effectively communicate climate action among farmers. The Irish agricultural sector contributes almost 40%

of national GHG emissions; hence, reducing agricultural GHG emissions is at the forefront of the political agenda. In the survey experiment, farmers were randomly allocated to two treatments and a control group to assess the effect of message framing on engagement with the information, knowledge, and stated intentions to implement climate action measures. The findings show that information framing significantly affects engagement with the provided information. However, against expectations, it reduces engagement but does not significantly impact knowledge or stated intentions. In addition, the data also suggest inattentive behavior among farmers.

The Irish Agricultural Sector

The Irish agricultural sector depends on livestock. Dairy and beef are the dominant agricultural systems in terms of output: About 87% of the 135,000 farms in Ireland report having some livestock (Central Statistics Office Ireland, 2022). Beef production (74,000 farms) is the dominant farm system in terms of farm numbers, while there are about 15,300 dairy and 17,000 sheep farms. The remaining farms are mixed grazing livestock, cereal farms, or pig and poultry farms.

Beef and dairy production is mainly grass-based, with cows calving in the spring to maximize grass intake. At the end of 2023, there were over 6.5 million cattle in Ireland, representing an increase of 5.5% from 2008; total cattle numbers have remained relatively stable over the last decade. In contrast, dairy cow numbers increased by almost 50% between 2008 and 2023, while the number of other cows (i.e., suckler cows) decreased by 24% over the same period (Central Statistics Office Ireland, 2024).

This change in the composition of the cattle population was initiated by the abolition of EU milk quotas in 2015. The end of milk quotas was preceded by a "soft landing" period that allowed gradual increases in milk quota production in each EU member state. In Ireland, dairy farming is generally associated with high farm incomes, while cattle farming achieves much lower incomes (Carter and Läpple, 2019). The opportunity for unconstrained production growth led many dairy farmers to expand their milk production; as a result, significant intra- and interfarm substitution from beef to dairy production occurred. Ireland was one of the few countries to significantly expand its milk production. For example, milk production increased by over 75% between 2008 and 2021 in Ireland, while total EU milk production increased by only about 7% between 2014 and 2020 (European Commission, 2021).

However, Ireland's livestock-focused agricultural production has implications for GHG emissions: The Irish agricultural sector accounts for 37.5% of national GHG emissions, unique among developed countries.[1] In the European Union and the United States, agriculture accounts for about 10% of national GHG emissions. Ireland is committed to reducing GHG emissions as part of the EU's target of being climate neutral by 2050. In addition, Ireland has its own national target to reduce GHG emissions by 51% by 2030 compared to 2018. The 2021 Climate Action Plan, which introduced sector-specific targets, requires the agricultural sector to reduce GHG emissions by 25% by 2030 compared to 2018.

A key measure to reduce agricultural GHG emissions is based on farmers increasing their adoption of GHG mitigation measures (e.g., reduced fertilizer use, improved breeding, and low-emission slurry spreading). To this end, Ireland launched the "Signpost Program" in May 2021 to facilitate and support farmers in the adoption of climate action measures. The Signpost Program is run by Teagasc, the Irish Agricultural and Food Development Authority. Among other initiatives, the Signpost Program created more than 100 demonstration farms to showcase best practices. The Signpost Program also hosts regular (online) seminars and disseminates information via newsletters and on their website.

In general, information use in agriculture is a complex process. While farmers learn from many different sources, agricultural extension services and other farmers are seen as the most prevalent

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[1] One exception is New Zealand, where nearly half of GHG emissions come from agriculture (Ministry for the Environment New Zealand, 2022)

means of knowledge diffusion (Birkhaeuser, Evenson, and Feder, 1991; Case, 1992; Foster and Rosenzweig, 1995). Agricultural extension services provide information to farmers through a variety of means—including one-to-one advice, farm visits, group advice, and information events—but information delivery has changed over time (Norton and Alwang, 2020), with an increasing focus on information and communication technology (Kahsay, Garcia, and Bosselmann, 2023). For example, online information provision has become more important in recent years, further stimulated by the COVID-19 pandemic, when in-person (group) meetings were not possible. Given the fact that widespread farm-level changes are required to mitigate climate change, online communication will likely further increase in importance over time and is an important part of the Signpost Program, as it can be a cost-effective means of reaching a large number of farmers.

Methodology

Survey Experiment

An online survey experiment was conducted in which farmers were randomly assigned to a treatment or control group. Because different livestock farm systems were included, I used stratified randomization to assign participants to groups. Participants were stratified by farm system (dairy and drystock, i.e., beef and/or sheep) and assigned to blocks. Simple randomization was performed within each block to assign subjects to one of the two treatments or the control group.

The treatments were based on the idea that the farmer is provided with a preview of information that is framed in a particular way. This is expected to influence the farmer's expected utility and affects how attentively the farmer engages with the information. More attentive engagement with the information will increase knowledge about the promoted technologies. As such, the more closely the farmer engages with the provided information, the more likely it is that the farmer will perceive that the promoted technology will yield some benefit when implemented. In other words, it is important to convince the farmer of the merits of a new technology (i.e., they need to believe that this new technology has some benefits). This is based on the assumption that the perceived rather than the actual benefit of a new technology influences the adoption decision (Chavas and Nauges, 2020).

Treatment 1 motivated the information by aiming to generate farmer's reputation concerns:

> *Increasing concerns by society about agricultural GHG emissions threatens the reputation of the Irish agricultural sector. It is important that every farmer adjusts farm practices to help reduce agricultural GHG emissions. Every contribution, regardless how small, is valuable. Together we can make a difference and ensure Irish agriculture retains its environmentally sustainable reputation. In the following, we will give you some information on how you can contribute to this common goal.*

This treatment is influenced by the concept of conditional co-operation, suggesting that individuals are more inclined to take action against climate change when they observe similar efforts by others (Fischbacher, Gächter, and Fehr, 2001; Andre et al., 2024) and the "working together norm," which invites people to participate to achieve a common goal (Howe, Carr, and Walton, 2021; Vlasceanu et al., 2024). As such, the treatment was aimed to enhance intrinsic motivation by highlighting the importance of working together to achieve a common goal. Altruism is seen as a motivator for providing a public good, and industry reputation concerns have been found to be related to altruism (Läpple and Osawe, 2023). Industry reputation of the agricultural sector is a public good in the sense that all farmers can benefit from it and it is also nonrivalrous. The idea for this treatment emerged based on previous research that revealed that Irish dairy farmers are concerned about the reputation of the Irish dairy industry, albeit in a different context (Osawe et al., 2021): general Irish media coverage that may impact the traditionally "green" reputation of the Irish agricultural sector as well as discussions with peers, farmers and agricultural advisors.

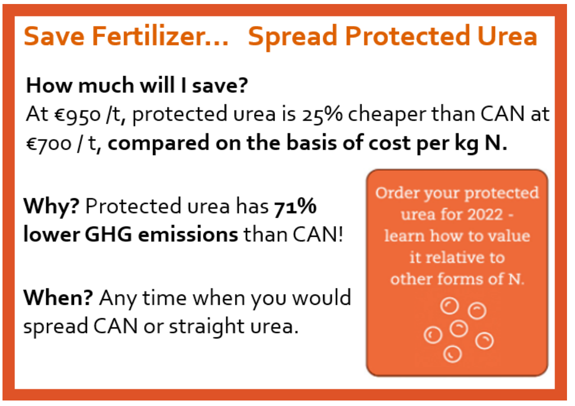

Figure 1. Infographic from Survey

Treatment 2 focuses on expenses and introduced the information by reminding farmers to

> *Avoid unnecessary expenses! … and save the environment too. In the following, we will give you some information on how you can avoid reductions in your income by introducing simple measures on your farm.*

This treatment highlights loss aversion and is based on prospect theory (Kahnemann and Tversky, 1979), which posits that losses have greater impact than gains. The main focus is also on economic outcomes, with environmental motivations included as a positive "add-on." The idea is to challenge and test conventional agricultural extension messages that focus on economic gains.

All three groups received the following introduction:

> *We are now interested in your opinion on how the information is distributed to farmers. Please look at the information. We will then ask you some questions that will help us to improve how information is delivered to farmers.*

Farmers who were assigned to the control group received no additional text and moved directly to the infographics. The two treatment groups received the previously described framing texts after the introduction before moving on to the infographics.

Both treatments and the control group received the same three infographics that provided information on how to save chemical nitrogen (N) fertilizer. Reducing the application of chemical N fertilizer was promoted as one of the main actions to reduce agricultural GHG emissions in Ireland at the time of data collection. Specifically, the focus was on the application of lime, the implementation of clover, and increased usage of protected urea. The application of lime increases soil pH, reducing fertilizer requirements. Including clover in grazing swards is a substitute for fertilizer, and protected urea is an "environmentally friendly" fertilizer that releases fewer greenhouse gases compared to traditional fertilizers.

Figure 1 shows the infographic related to protected urea. All infographics followed the same structure, providing an economic and environmental motivation as well as information on how to implement the practice.

The study was conducted in collaboration the Signpost Program. The information provided aligned with messages due to be distributed by the program shortly after the study was completed. Part of the Signpost Program strategy to initiate climate action relies on online newsletters, so the treatments of this study are designed to test how to improve engagement with information delivered online via text and graphics. Further, the infographics were developed in collaboration with farm advisors and discussed with farmers in a small online focus group of four farmers and one advisor. The objective of the focus group was to design the infographics in an engaging and understandable way and to decide on effective treatments to motivate engagement with climate change information. For example, during these discussions, farmers suggested putting the economic information before the environmental information, as the farmers in the focus group felt that economic information is more important to farmers. A social norms treatment was also discussed, but the focus group farmers felt that the reputation and loss aversion treatment were more effective. Due to sample size constraints, it was not possible to include three treatments.

The outcome variables are information engagement, knowledge, and stated intentions to change farm practices. Information engagement was elicited by measuring how many seconds farmers spent looking at each infographic. Participants' knowledge in relation to the provided information was assessed with two multiple choice questions for each infographic: one question focused on management-related issues and one focused on environmental implications.[2]

Stated intention was measured by asking farmers about their plans for 2022 in relation to the three promoted farm practices (i.e., plans to increase lime application, clover, and protected urea in 2022) and one general question about fertilizer application reduction plans (i.e., "In 2022, I plan to reduce chemical N fertilizer"). The answer choices were "yes," "no," and "unsure," with follow-up questions for reasons if "no" or "unsure" was selected.

The survey also elicited current farm practices, farmers' attitudes toward agricultural GHG emissions and climate change, and farm information usage. The complete survey and experimental measure is provided in the online supplementary material (see www.jareonline.org. The survey received ethical approval and has been preregistered on Open Science Framework.[3]

Empirical Methods

I used econometric methods to estimate the treatment effect on the respective outcomes (i.e., engagement, knowledge, and intention). Specifically, I estimated the following equations:

$$y_i = \alpha + \sum_{k=1}^{K} \beta_k T(x_i = x^k) + \beta_3 X_i + \epsilon_i, \tag{1}$$

where y_i is the respective outcome for each farmer i i.e., engagement, knowledge, and stated intention. (Outcome variables are described in more detail in the next subsection.) $T(x_i = x^k)$ is a dummy variable indicating that respondent i received treatment k, where k are the two treatments and the control group, which acts as the base category. X_i is an $n \times m$ matrix of n observations for m control variables that include farm size and system, use of best practices, attitude toward climate change, age, and awareness of the Signpost Program. α is a constant, β are parameters to be estimated, and ϵ_i is a normally distributed error term. The coefficient of interest is β_k; based on the preregistered hypotheses, I expect β_k to be positive and statistically significant.

Different estimators are used depending on the outcome variable, y_i. The models with the outcome variables—engagement, overall knowledge, and intention—use an ordinary least squares (OLS) estimator. The remaining models are based on maximum likelihood estimation. Specifically, ordered probit models are applied to estimate the impact of the treatments on overall knowledge and on knowledge in relation to the specific practices (i.e., lime, clover, and protected urea) as well as on overall intention. In addition, binary probit models are used to estimate the impact of the treatments on intention to use the respective practices. All models described above estimate a causal impact as treatments have been randomly assigned.

[2] An example of an environmental-related question is "How much fertilizer can you save by spreading lime?" followed by five choices: 30 kg/ha, 50 kg/ha, **70 kg/ha**, 90 kg/ha and don't know. The correct answer is in bold. The information needed to provide the correct answer was provided in the infographic. Participants did not have the option to return to the infographics to look for the information.

[3] See details here: https://osf.io/qyvgt.

Table 1. Outcome Variables by Treatment

Outcome Variables	Reputation ($N = 174$)	Expenses ($N = 174$)	Control ($N = 180$)	Full Sample ($N = 528$)	Difference
Engagement (viewing time in seconds)	50.47 (48.02)	57.54 (46.99)	65.92 (44.24)	58.06 (46.76)	$p = 0.0001$
Knowledge (range: 1–6)	3.63 (1.40)	3.82 (1.37)	3.72 (1.52)	3.72 (1.43)	$p = 0.293$
Intention (range: 0–4)	2.84 (1.12)	2.64 (1.16)	2.71 (1.08)	2.73 (1.12)	$p = 0.372$

Notes: Difference: Kruskal–Wallis test between groups for continuous variables, and χ^2 tests for categorical variables.

Data

The study was conducted in January 2022 and administered in Qualtrics. An online link was sent to farmers through their local advisor. An incentive of 30 €50 online gift vouchers was provided. The vouchers were randomly allocated to respondents who opted to participate in the draw. In total, 528 completed responses were received. Of those completed responses, 300 were dairy farmers and 228 were drystock farmers, comprising of 108 suckler (i.e., calf-cow operations), 92 cattle finishing, and 28 sheep farmers. Dairy farmers in the sample reported on average 129 dairy cows, significantly more than the national average of 92 dairy cows (Central Statistics Office Ireland, 2021). Suckler farms had on average 31.74 suckler cows, cattle finishers have an average cattle herd of 91.22 head, and sheep farmers lambed on average 169.75 ewes/hoggets. When comparing this to the national average reveals that suckler farms have an average 36.9 livestock units, cattle finishers have an average of 47 livestock units, and sheep farms have an average of 140 ewes (Dillon, Moran, and Donnellan, 2022).

Table 1 reports the average values for the outcome variables—engagement, knowledge and intention—for the sampled farmers. In relation to engagement, as can be seen, farmers viewed the three infographics for an average time of 58 seconds. The first infographic (lime) was viewed for 26.46 seconds, the second (clover) for 13.41 seconds, and the last (protected urea) for 18.93 seconds.[4] Viewing times are consistent with what was expected. The first infographic was viewed the longest, which can be explained by the fact that respondents needed time to familiarize themselves with the way the information was presented in addition to reading the text. When looking at the second infographic, farmers were familiar with the format, and the clover infographic also included less text, which explains the shorter viewing times. Finally, the last infographic (protected urea) included more text, which explains longer viewing times compared to the clover infographic. It is reassuring that viewing times for the last infographic increased, as this suggests that survey fatigue may not be a serious issue.

In relation to knowledge, the data arising from the multiple choice questions were converted to an ordinal score. A correct answer was coded as 1 while all other answer choices were coded as 0. All six questions were added to form an overall knowledge score, ranging from 1 to 6. Since only eight farmers answered no questions correctly (i.e., total score of 0) the first two categories were merged, which explains the range from 1 to 6, see Table 1. Similarly, scores for the two knowledge questions relating to each infographic were added, resulting in a range from 0 to 2 (see Table S3 in the online supplement). On average, farmers answered 3.7 questions correctly, with no significant differences between treatment and control groups (see Table 1). Importantly, farmers answered management-related questions better than questions related to environmental implications of the respective farm practice (see Table S2 in the online supplement). This may suggest selective attention (Schwartzstein, 2014). In addition, only 10% of respondents answered all questions correctly, which suggests that inattention may be an issue.

The third outcome variable, stated intention, was also converted to an ordinal score. If the respondent indicated that they planned to improve the use of a practice in 2022 (i.e., reduce fertilizer, apply more lime, increase the amount of clover/mixes species, increase the use of protected urea),

[4] See Table S1 in the online supplement (www.jareonline.org) for more details.

Table 2. Control Variables by Treatment

Outcome Variables	Reputation (N = 174)	Expenses (N = 174)	Control (N = 180)	Full Sample (N = 528)	Difference
Farm size	60.56 (49.61)	56.77 (37.16)	64.96 (55.32)	60.81 (48.08)	$p = 0.314$
Farm system (% dairy farms)	57.47	57.47	55.55	56.82	$p = 0.915$
Age (% in category)					
18–35	15.52	14.37	16.11	15.34	$p = 0.899$
36–45	23.56	20.69	23.89	22.27	$p = 0.734$
46–55	31.03	32.18	28.33	30.49	$p = 0.721$
56–65	22.99	20.69	25.56	23.11	$p = 0.554$
65+	6.09	12.07	6.11	8.33	$p = 0.090$
Signpost (% aware)	72.41	65.52	65.00	67.61	$p = 0.252$
Reduced N application in last 3 years (% yes)	45.40	48.85	43.33	45.83	$p = 0.576$
Protected urea (% of fertilizer N in 2021)	21.72 (31.72)	23.92 (31.18)	20.61 (27.32)	22.07 (30.08)	$p = 0.554$
Clover (% of farmers having any clover in 2021)	91.38	89.08	88.89	89.77	$p = 0.693$
Lime (% of farmers applied lime in 2021)	68.97	68.97	63.89	67.23	$p = 0.500$
Climate change attitude (range 4–20)	14.62 (3.33)	14.77 (3.42)	14.77 (3.43)	14.68 (3.37)	$p = 0.886$

Notes: Difference: Kruskal–Wallis test between groups for continuous variables, and χ^2 test for proportions.

their answer was coded as 1. All other answer choices were coded as 0. All four intention questions were summed to form an overall intention score, ranging from 0 to 4 (see Table 1). In addition, scores for the individual intention questions were calculated, resulting in dummy variables equal to 1 if the farmer indicated to use the practice in 2022 and 0 otherwise (shown in Table S4 in the online supplement, expressed as percentages). On average, farmers plan to use 2.7 of the practices to reduce chemical N fertilizer (including the general intention to reduce chemical N fertilizer), with no significant difference between treatment and control groups. In general, farmers expressed great intentions for reducing chemical N fertilizer, which may partly be driven by high fertilizer prices at the beginning of 2022. Just under 60% of dairy farmers plan to increase the use of protected urea, while less than 40% of drystock farmers plan to use more protected urea. Overall, dairy farmers have significantly greater intentions to increase the use of environmentally friendly measures. The online supplement provides more detail on farmers' intentions.

I hypothesized that the outcome variables would be significantly influenced by the treatments; Table 1 also provides an overview of the outcome variables divided by treatment. Beginning with engagement, it is evident that information framing influenced how long farmers viewed the infographics, but the direction of the effect is against the initial hypothesis. In fact, farmers in the treatment groups spent less time looking at the infographics than those in the control group. This difference is confirmed by a Kruskal–Wallis test. As mentioned previously, there is no significant difference between the treatment and control groups in relation to knowledge and stated intention. I test these effects in more detail with econometric methods; these the results from the econometric analysis are presented below.

Table 2 reports control variables by treatment and for the full sample; Table S5 in the online supplement control variables by farm system. Kruskal–Wallis and χ^2 tests reveal that there are no statistically significant differences among the three treatment groups in relation to control variables (see the last column of Table 2). This confirms that farmers were randomly assigned to treatment groups.

Survey respondents farm 60.81 ha on average (see Table 2). In the sample, 15% of farmers are younger than 35 and 8% are older than 65. Sampled farmers are significantly younger than the national average; almost one-third of Irish farmers are older than 65 (Central Statistics Office Ireland, 2021). The majority of farmers (almost 70%) were aware of the Signpost Program. However, this differs between farm systems. Over 80% of dairy farmers were aware of the program, while just half of drystock farmers knew of the Signpost Program.

Of particular interest are current usage rates of the practices promoted by the infographics; Table 2 provides an overview of current practices on the sampled farms. As mentioned, reductions in chemical N fertilizer are a key measure for reducing agricultural GHG emissions in Ireland at present. Spreading lime and implementing clover are steps to achieve lower fertilizer application rates, while protected urea is marketed as "environmentally friendly" fertilizer.

About 45% of sampled farmers reduced chemical N fertilizer application over the last 3 years, and 22% of that fertilizer that sampled farms applied as protected urea. This differs between farm systems: Almost 30% of fertilizer spread by dairy farmers was applied as protected urea relative to only 12% of the total applied by drystock farmers. When interpreting this difference, it is important to realize that dairy farmers' absolute fertilizer application rates are generally much higher than those of drystock farmers. To mitigate GHG emissions, the target is that 100% of chemical N fertilizer be applied as protected urea. There is great potential among sampled farmers to further increase this practice: 47% of sampled farmers indicated that they are not using any protected urea, while only 3.41% of sampled farmers indicated that more than 95% of their fertilizer application was protected urea. These statistics indicate that the infographic about protected urea is relevant for almost all (96.6%) of the sample.

In relation to clover, almost 90% of sampled farmers indicated that they have some clover in their grassland swards. However, this measure does not provide detailed insights into the intensity of clover uptake.[5] Current recommendations for farmers are to establish at least 20% clover content in all grassland areas (Hennessy et al., 2022). Incorporating clover into grazing swards is a key farm practice to reduce GHG emissions because it reduces fertilizer application needs (Lanigan et al., 2018); however, the uptake of clover in grazing swards has remained low (Environmental Protection Agency Ireland, 2022), underlining the importance of this infographic for sampled farmers.

In relation to spreading lime, 67% of sampled farmers spread lime in 2021. Exploring this by farm system reveals that the majority (81%) of dairy farmers spread lime on their fields last year, while only about half of drystock farmers spread lime. In general, the application of lime is strongly encouraged for all farmers, but correct application rates depend on soil pH and are thus hard to assess by a survey. Table S5 in the online supplement shows control variables by farm system.

Farmers were also asked about their opinions about GHG emissions from agriculture and climate change: "GHG emissions from agriculture are an important issue"; "GHG emissions from agriculture are cause for alarm,"; "Addressing climate change is urgent"; "I can make a contribution to mitigating climate change on my farm," all of which were assessed using a 5-point Likert scale ranging from strongly disagree to strongly agree. A "climate change attitude" variable was created based on the sum of the four Likert-scale scores.[6] The choice of the statements was informed by the Cronbach's alpha value, which was highest for the selected four statements. Specifically, the four statements achieved a Cronbach's alpha of 0.715. The average score of the sampled farmers was 14.68.

Overall, the sample is biased toward larger farms operated by younger farmers. This is similar to other studies that rely on online surveys of farmers (see, e.g., Kuhfuss et al., 2016; Läpple and Osawe, 2023). This also reflects the difficulty of reaching farmers in the absence of panel providers for agriculture in many countries. Nevertheless, this sampling bias is considered in the analysis and interpretation of the results.

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[5] While the survey asked about the proportion of grassland swards that contained clover and/or mixed species, answers indicated that not all farmers correctly interpreted this question. Hence, only whether or not the farmer implemented any clover/ multi species is used.

[6] The full set of questions can be found in the survey provided in the in the online supplement.

Table 3. Regression Results: Information Engagement (N = 528)

Information Engagement	All Model 1	Lime Model 2	Clover Model 3	Pr. Urea Model 4
Reputation	−15.450***	−8.322***	−4.405***	−2.409
	(4.860)	(3.113)	(1.268)	(1.965)
Expenses	−9.420*	−5.620**	−1.867	−1.386
	(4.822)	(2.773)	(1.575)	(1.668)
Farm size	0.014	0.006	0.018	−0.004
	(0.043)	(0.026)	(0.019)	(0.011)
Farm system	−2.437	2.181	−1.962	−0.135
	(5.119)	(2.661)	(1.417)	(1.712)
Pr. urea usage	0.079			−0.029
	(0.081)			(0.022)
Liming	6.085	2.676		
	(4.485)	(2.253)		
Clover	3.948		0.176	
	(5.561)		(2.061)	
Climate change attitude	0.961	0.841*	0.137	0.098
	(0.642)	(0.431)	(0.165)	(0.229)
Age (36–45)	9.247	4.581	1.256	2.838
	(6.677)	(4.697)	(1.484)	(2.323)
Age (46–55)	10.051*	2.791	3.564*	3.258
	(5.830)	(3.635)	(1.860)	(2.329)
Age (56–65)	20.384***	8.333**	5.578***	6.076**
	(6.910)	(4.095)	(1.847)	(2.615)
Age (65+)	24.018***	9.817**	6.782***	6.654**
	(6.961)	(4.020)	(1.940)	(2.849)
Signpost	−3.471	−1.743	1.162	−2.070
	(4.757)	(2.513)	(1.314)	(1.876)
Constant	33.766***	11.828	9.301***	16.785***
	(12.068)	(7.367)	(2.961)	(3.880)
R^2	0.054	0.040	0.050	0.026

Notes: Values in parentheses are robust standard errors. Single, double, and triple asterisks (*, **, ***) indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

Results and Discussion

In line with the preregistered hypotheses, I test the impact of the treatments on the time spent looking at the infographics (engagement), knowledge, and stated intentions. Table 3 reports the results of a linear regression model with overall information engagement as dependent variable and separate models for engagement with each infographic (i.e., the time spent looking at lime, clover, and protected urea infographics). As outlined in equation 1, treatments are included as dummy variables with the control group as the base category. The models also include control variables for farm size and system, climate change attitude, the use of the respective practice (i.e., lime, clover, protected urea), farmer's age measured in categories, and awareness of the Signpost Program.

As can be seen in Table 3, the reputation treatment significantly affected the time participants viewed the infographics, but the direction of the effect differs from what was expected. In contrast to prior expectations, the treatment significantly reduced the time farmers engaged with the provided information. More specifically, the reputation treatment reduced total engagement by 15 seconds. Exploring this effect by infographic (Models 2–4) reveals that the effect is mainly due to an 8-second reduction in viewing the lime infographic, followed by a 4-second reduction in viewing the clover infographic. However, the treatment did not significantly impact how long farmers viewed the protected urea infographic.

A similar pattern is evident with the expenses treatment, which reduced total engagement with all infographics by almost 10 seconds. Focusing on individual infographics reveals that the loss-aversion treatment significantly reduced viewing time of the lime infographic but did not significantly influence how long farmers viewed the remaining two infographics.

The results from Table 3 suggest that the treatment effect diminishes over time, as the effect is stronger for the first infographic (lime) and neither treatment significantly influences how long the last infographic (protected urea) is viewed. While this is not encouraging in relation to the strength of the treatment effect, it suggests that the additional reading related to the treatments over the control group does not cause additional survey fatigue. Otherwise, we would expect to see a significantly shorter engagement in the treatment groups compared to the control group in the infographics that were presented later. Furthermore, there is no statistically significant difference between the two treatment effects; both significantly reduce engagement.

Overall, it appears that a close link between message framing and the infographic is required to exert an effect in the desired direction (i.e., increase information engagement). For example, Graham and Abrahamse (2017) suggested that framing a message to align with people's value sets is an important factor in communicating climate change messages. Despite close collaboration with farm advisors and farmers, the treatments may not have been aligned with farmers' preexisting beliefs, leading them to reduce engagement with the information.[7]

In addition, Golman, Hagmann, and Loewenstein (2017) stated that the expectation of bad news leading to negative feelings can increase inattention.[8] For example, some media articles blame farmers for climate change (see Loughlin, 2021; McGee, 2021; Duffy, 2023, for examples), and it has also been shown that Irish farmers are concerned about climate change and see climate change as an overstated problem (Läpple, 2023). This could be an indication that farmers may perceive climate change to be bad news. As such, the reputation treatment may have triggered preexisting beliefs (i.e., blame for climate change) and therefore evoked negative feelings, which have also been found to be associated with farmers' information avoidance (Läpple and Arpinon, 2024). Furthermore, this may have even been aggravated by confirmation bias, where people confirm their preexisting beliefs (Rabin and Schrag, 1999) (i.e., the feeling of being blamed for climate change). In this context, confirmation bias can reduce information engagement (Reisch, Sunstein, and Kaiser, 2021). Moreover, negative news seems to have no impact on preferences, indicating that respondents may be unwilling to process adverse information. These findings align with recent studies, suggesting that people are more inclined to accept positive news over negative news (Cerroni, Notaro, and Raffaelli, 2019).

In relation to the expenses treatment, it may be the case that the phrase "avoid unnecessary expenses" evoked negative emotions as opposed to triggering the anticipated loss-aversion effect and therefore reduced engagement. In this instance, it would be desirable to have detailed information on reasons for increased disengagement. However, the literature provides clear evidence that both financial concerns and bad news (e.g., unnecessary expenses) reduce information engagement (Golman, Hagmann, and Loewenstein, 2017; Sharot and Sunstein, 2020; Reisch, Sunstein, and Kaiser,

[7] One possible explanation is that the focus group farmers did not represent the general opinion of the farming population, due to self-selection.

[8] In this experiment, only seven farmers looked at each infographic for less than 3 seconds, while only 10% of farmers answered all knowledge questions correctly. This suggests that inattention (i.e., not paying attention while viewing the information) may be more important than information avoidance (i.e., deliberately avoiding the information by skipping the information). However, it is also important to note that the experiment was not set up to measure information avoidance per se. In addition, the majority of sampled farmers expressed concern about agricultural GHG emissions, and 70% of farmers stated that they were interested in information about climate actions, which further suggests that active information avoidance is likely not a concern.

2021). An alternative explanation may be receiving discouraging advice; for example, Möbius et al. (2022) showed that people are more likely to follow advice when they receive a positive signal than when they receive a negative signal.

In relation to control variables, farm size, farm system, and current use (intensity) of the promoted practices are not significantly related to engagement with the information. In contrast, with increasing age, infographics are viewed for longer. This is in line with findings that reading comprehension is a process that changes throughout the lifespan (Locher and Pfost, 2020).

Next, I test the effect of the treatments on knowledge (see Table 4).[9] Models 1 and 2 relate to overall knowledge: Model 1 is an ordered probit model, while Model 2 is a linear regression model. Models 3–5 each focus on a specific practice promoted by the infographics. Based on the ordinal nature of the knowledge score, these are ordered probit models. The highest category means that the farmer answered all questions correctly (see Table S3). As before, treatments are included as dummy variables, and all models include a set of control variables for farm size and system; lime, clover and protected urea usage; climate change attitude; age categories; whether or not the farmer is aware of the Signpost Program.

Neither of the treatments had a significant impact on knowledge. Thus, despite impacting engagement in terms of viewing times, the treatments do not influence knowledge. However, the fact that farmers in the reputation treatment viewed the infographics for a shorter time with no significant difference in knowledge to the other treatment groups may suggest that farmers in the reputation treatment focused better (but for less time) on the task.

In relation to control variables, the models assessing overall knowledge (Models 1 and 2) indicate that increasing farm size and usage of protected urea is positively related to knowledge. In contrast, current usage of clover or liming is not significantly related to knowledge on these practices. Greater concern about climate change and being aware of the Signpost Program are also positively related to overall knowledge, while some differences emerge in relation to the individual practices. For example, climate change attitude is not statistically significant in Model 3, which focuses on knowledge of liming. Despite the fact that liming is pushed as a climate change mitigation strategy in Ireland, a stronger climate change attitude does not seem to be related to knowledge about the practice. In addition, being aware of the Signpost Program is not significantly related to knowledge about protected urea. While the Signpost Program promotes increased use of protected urea, the knowledge questions in this survey may not adequately pick up this effect. Finally, in relation to overall knowledge, knowledge on these practices declines with increasing age.

In relation to the last outcome variable (stated intention), the results of the treatment effect on stated intention are reported in Table 5. Models 1 and 2 focus on overall intention. Model 1 is an ordered probit model, while Model 2 is a linear regression model. Models 3–5 are binary probit models and focus on each specific practice promoted by the infographics. Treatments are included as dummy variables with the control group as base category, and all models include the following control variables: Farm size and system, lime, clover and protected urea usage,[10] climate change attitude, age categories and whether or not the farmer is aware of the Signpost Program.

As can be seen, neither of the treatment variables significantly affect stated intentions, which is against the preregistered hypothesis. The previous finding that the treatments affected viewing times with diminishing effect for subsequent infographics may suggest that the treatments were not strong enough to influence farmer decisions in a lasting way. However, it is important to note that the variables controlling for current extent of the use of the respective practices are all significantly and positively related to the overall stated intention to increase the use of the practices. It is also interesting to note that being aware of the Signpost Program is significantly related to a higher stated intention to use the promoted practices and that age is not significantly related to intentions.[11]

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[9] Note that increased knowledge may also reflect better attention.

[10] In each model the respective practice is included as control variable.

[11] I also tested whether the treatment effect on intention differs with the use of the current practice (by including interaction terms), but the effects are not statistically significant.

Table 4. Regression Results: Knowledge (N = 528)

Knowledge	All Model 1	All Model 2	Lime Model 3	Clover Model 4	Pr. Urea Model 5
Reputation	−0.101	−0.103	−0.052	−0.179	0.062
	(0.111)	(0.151)	(0.124)	(0.121)	(0.121)
Expenses	0.084	0.114	0.064	−0.008	0.186
	(0.112)	(0.151)	(0.125)	(0.121)	(0.122)
Farm size	0.002*	0.002**	0.002	0.002**	0.001
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Farm system	−0.070	−0.105	−0.056	−0.191*	−0.045
	(0.110)	(0.147)	(0.119)	(0.114)	(0.118)
Pr. urea	0.004**	0.005**			0.004**
	(0.002)	(0.002)			(0.002)
Liming	0.129	0.183	0.264**		
	(0.106)	(0.146)	(0.117)		
Clover	−0.125	−0.179		−0.067	
	(0.150)	(0.204)		(0.163)	
Climate change attitude	0.037***	0.046**	0.012	0.041***	0.031**
	(0.014)	(0.019)	(0.015)	(0.015)	(0.015)
Age (36–45)	−0.287*	−0.380**	−0.217	−0.401**	−0.054
	(0.151)	(0.192)	(0.170)	(0.165)	(0.164)
Age (46–55)	−0.358**	−0.481***	−0.260	−0.448***	−0.192
	(0.142)	(0.185)	(0.161)	(0.157)	(0.156)
Age (56–65)	−0.277*	−0.362*	−0.170	−0.411**	−0.068
	(0.150)	(0.192)	(0.169)	(0.165)	(0.164)
Age (65+)	−0.584***	−0.765***	−0.307	−0.702***	−0.378*
	(0.202)	(0.269)	(0.225)	(0.219)	(0.219)
Signpost	0.226**	0.294*	0.210*	0.307***	0.027
	(0.107)	(0.153)	(0.119)	(0.115)	(0.116)
Constant		3.158***			
		(0.450)			
R^2		0.092			

Notes: Values in parentheses are standard errors. Single, double, and triple asterisks (*, **, ***) indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

Conclusion

Agricultural advisory services are not always successful in convincing farmers to implement changes on their farms (e.g., Aker, 2011; Birkhaeuser, Evenson, and Feder, 1991; Läpple and Hennessy, 2015). Sometimes, just providing information has very little impact (Karlan, Knight, and Udry, 2015). This issue is particularly pertinent considering that reaching climate targets will require large-scale adoption of GHG mitigation practices by farmers, which calls for effective climate change communication. Many farmers certainly use new information and are willing to embrace changes on their farms. However, reaching enough farmers with information and asking them to change their farm practices to contribute to achieving climate targets will be challenging. Therefore, finding ways to increase engagement with information provision and encourage climate action is important.

Using data from an online survey of over 500 farmers, this study assessed the impact of information framing with the aim to achieve more effective climate change communication that promotes

Table 5. Regression Results: Intention (N = 528)

Intention	All Model 1	All Model 2	Lime Model 3	Clover Model 4	Pr. Urea Model 5
Reputation	0.096	0.088	0.034	0.090	0.074
	(0.115)	(0.111)	(0.149)	(0.143)	(0.137)
Expenses	−0.083	−0.092	−0.001	−0.141	−0.015
	(0.115)	(0.115)	(0.149)	(0.141)	(0.137)
Farm size	0.001	0.001	0.001	0.003**	−0.000
	(0.001)	(0.001)	(0.002)	(0.002)	(0.001)
Farm system	0.308***	0.321***	0.091	0.301**	0.358***
	(0.114)	(0.113)	(0.145)	(0.136)	(0.131)
Pr. urea usage	0.005***	0.005***			0.005***
	(0.002)	(0.001)			(0.002)
Liming	0.231**	0.229**	0.218		
	(0.109)	(0.110)	(0.137)		
Clover	0.334**	0.347**		0.829***	
	(0.153)	(0.163)		(0.187)	
Climate change attitude	0.010	0.010	−0.017	0.018	0.006
	(0.014)	(0.014)	(0.019)	(0.017)	(0.017)
Age (36–45)	−0.208	−0.220	−0.187	−0.331*	−0.257
	(0.155)	(0.147)	(0.202)	(0.195)	(0.184)
Age (46–55)	0.063	0.035	0.091	−0.192	0.056
	(0.147)	(0.128)	(0.198)	(0.187)	(0.175)
Age (56–65)	0.027	−0.003	−0.200	−0.146	0.001
	(0.155)	(0.142)	(0.201)	(0.196)	(0.184)
Age (65+)	−0.099	−0.110	−0.296	−0.252	−0.133
	(0.206)	(0.212)	(0.261)	(0.254)	(0.247)
Signpost	0.231**	0.234**	0.407***	−0.054	0.244*
	(0.110)	(0.112)	(0.140)	(0.136)	(0.130)
Constant		1.671***	0.492	−0.708**	−0.516*
		(0.293)	(0.337)	(0.359)	(0.303)
R^2		0.133			

Notes: Values in parentheses are standard errors. Single, double, and triple asterisks (*, **, ***) indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

agricultural GHG mitigation. Specifically, by randomly allocating farmers into treatment and control groups, I estimated a causal effect of information framing on engagement, knowledge, and stated intention to adopt and increase the use of GHG mitigation practices. One treatment aimed to generate reputation concern for the agricultural industry, while the second treatment focused on avoiding unnecessary expenses. As hypothesized, I found that the treatments significantly affected information engagement, but the direction of the effect was negative, against expectations. In addition, I did not find significant effects of the treatments on knowledge or stated intention. In relation to knowledge, positive attitude toward climate change mitigation and awareness of the Signpost Program were positively related, while the farmer's age was negatively related to knowledge. The findings also revealed that farmers have greater knowledge of management-related issues of GHG mitigation practices than of environmental implications.

A number of findings from this study are worth highlighting. First, the results show that information framing influences engagement with the information. However, the negative impact of the treatments seems to suggest that the framing of the information may have initiated the expectation of bad news, which is related to increased inattention (Golman, Hagmann, and Loewenstein, 2017). For example, Möbius et al. (2022) showed that people are more likely to follow advice when they receive a positive signal about their ability than when they receive a negative signal. In addition, a reduction in engagement may be further aggravated by confirmation bias (Rabin and Schrag, 1999), which reinforces preexisting beliefs (i.e., farmers are blamed for climate change, as suggested by several media articles). This triggers negative feelings that the reputation treatment may have reinforced, causing further disengagement. As such, empirical evidence from this study in combination with previous literature findings suggests that climate change communication may need to be motivated in a way to trigger expectations about positive news in order to increase information engagement. If confirmation bias is at play, this bias can then also have a positive impact on information engagement (Reisch, Sunstein, and Kaiser, 2021).

Second, the negative impact of the reputation treatment may point toward a social dilemma. Addressing climate change is a collective action problem, where immediate short-term gains are known to outweigh long-term collective strategies (Ostrom, 2010). However, working together—inviting people to join in to achieve a common goal (Vlasceanu et al., 2024)—does not seem to trigger interest in climate change mitigation of Irish farmers.

Finally, results from the knowledge questions provide useful insights into potential issues with inattention. Shorter engagement in the reputation treatment did not reduce knowledge, suggesting that attention may be higher for a shorter time. However, the findings also reveal that all farmers have significantly better knowledge of how to implement new farm practices than of their environmental impact. This may suggest that information on how to implement practices is more important to engage farmers than highlighting the environmental performance of new farm practices. Nevertheless, these findings also suggest inattentive behavior.

A number of limitations in relation to internal and external validity are important to consider in relation to this study. First, in relation to internal validity, the absence of an active control group (i.e., providing text of similar length without relevant information) implied different reading times and cognitive burden for survey respondents. This could mean that the treatment effect also picked up survey fatigue. While longer engagement with the last infographic compared to the second infographic does not point toward survey fatigue, this possibility cannot be excluded without an active control. Second, the order of the infographics was not randomized. However, as the order is the same in both treatments and the control group, this should not cause concerns about the treatment effect. In relation to external validity, the study also suffers from a common problem of studies that rely on convenience sampling of farmers (see Kuhfuss et al., 2016; Läpple and Osawe, 2023, for examples). As is often observed, the sample is not representative of the farming population but rather represents the behavior of younger farmers who manage larger farms. As these farmers may have different attitudes about the need for climate change mitigation, it is possible that the negative treatment effect may even be larger in the wider farming population. However, despite these limitations, the study provides interesting insights and underlines the importance of successfully communicating GHG mitigation measures among farmers to combat the climate crisis.

Further research in this area is needed. One interesting possibility would be to devise and explore positive framing of climate change information to establish whether this piques farmers' interest in climate change mitigation. This could include economic benefits (e.g., access to premium prices and new markets), adapting to market demands, or emphasizing co-benefits of climate change mitigation (e.g., biodiversity of water quality enhancements). Another interesting option would be to assess whether it is possible to devise tailored information based on farmers' values and how this impacts engagement and subsequent behavior changes. Options would be to let farmers endogenously choose information or test information provision as narratives or science-based facts, as in Yang and Hobbs (2020).

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Online Supplement: The Role of Communication Framing in Agricultural Climate Action

Doris Läpple

Engagement

Table S1. Engagement by Infographic

	Reputation (*N* = 174)	Expenses (*N* = 174)	Control (*N* = 180)	All (*N* = 528)
All infographics	50.47	57.54	65.92	58.06
	(48.02)	(46.99)	(44.25)	(46.76)
Lime	22.56	25.70	30.97	26.46
	(31.76)	(24.08)	(27.55)	(28.13)
Clover	11.03	13.66	15.47	13.41
	(11.46)	(17.23)	(12.83)	(14.14)
Protected urea	16.88	18.17	19.48	18.19
	(20.45)	(15.82)	(15.44)	(17.37)

Notes: Mean time spent looking at infographic, measured in seconds. Values in parentheses are standard deviations.

Knowledge

Farmers were asked to answer six multiple choice questions about the information provided in the infographics. We ensured farmers that this was not a test of their knowledge but rather a test of how well information was provided. S2 reports the questions and percentage correctly answered. It is evident that farmers answered management-related questions better than questions related to the environmental implications of farm practices.

For the analysis, the knowledge questions were coded as follows: a correct answer received a score of 1, and all other answers received a score of 0. For the individual knowledge questions (i.e., two questions related to each infographic), this resulted in the categories shown in Table S3. These are used for the ordered probit models shown in Table **??**. Farmers' knowledge in relation to the information provided in the infographics differs. Specifically, in relation to the lime infographic, almost half of the sampled farmers (47%) answered both questions correctly. This is quite different for questions about the clover infographic, where less than one-third of sampled farmers (29%) answered both questions correctly, and the protected urea infographic, where 35% of farmers answered both questions correctly.

Intention

Farmers were asked about their intentions to implement the promoted practices on their farms in 2022. Figure S1 summarizes these intentions. As can be seen, almost all farmers planned to reduce

Table S2. Knowledge Questions

Question	Percentage Correct (%) Dairy	Drystock	All
How much fertilizer can you save by spreading lime?	59.33	46.93	53.98
Where should you apply lime?	86.00	83.33	84.85
How much fertilizer can you save by incorporating clover?	39.33	25.44	33.33
When should you sow clover?	80.33	70.18	75.95
By how much does protected urea reduce GHG emissions when compared to CAN?	40.33	37.72	39.20
Protected urea is cheaper than CAN when compared per [possible answers displayed as MCQ]	86.33	79.82	83.52

Table S3. Knowledge Categories

Knowledge Categories	Percentage Correct (%) Lime	Clover	Protected Urea
0 (both wrong)	8.52	19.51	12.69
1 (one correct)	44.13	51.70	51.89
2 (both correct)	47.35	28.79	35.42

fertilizer applications in 2022. While this is an important step for reducing GHG emissions, it is also important to realize that fertilizer prices were very high at the time the data were collected, which likely influenced farmers' motivations to reduce fertilizer applications.

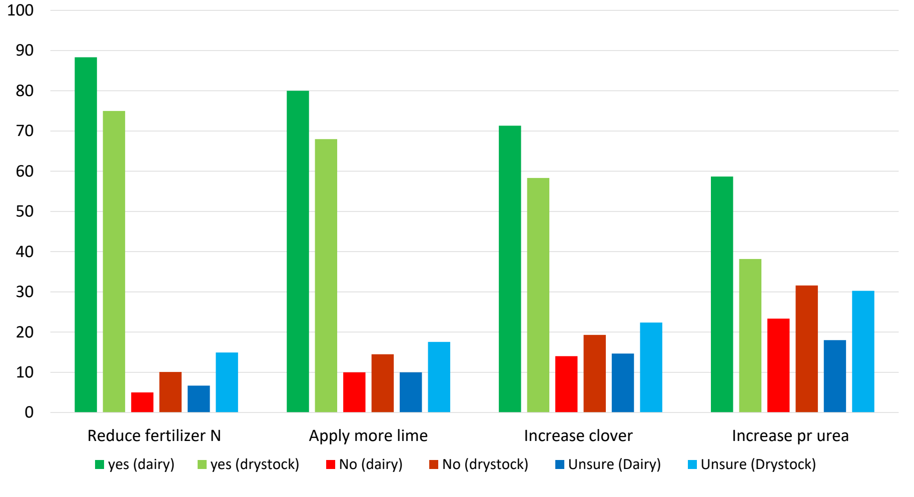


Figure S1. Stated Intentions for 2022

Farmers' stated intentions were then converted into a dummy variable, where positive intentions were coded as 1, and no and unsure were coded as 0. These data were used to calculate overall intention scores (see Table 1) and intentions in relation to respective farm practices, as shown in Table S4, which are used for the models presented in Table 5.

Table S4. Intentions by Farm Practice and Treatment

Intention	Reputation (*N* = 174)	Expenses (*N* = 174)	Control (*N* = 180)	All (*N* = 528)
Reduce fertilizer (% indicated yes)	85.63	80.46	81.67	82.57
Lime (% indicated yes)	76.44	74.14	73.89	74.81
Clover (% indicated yes)	69.54	60.92	66.67	65.72
Protected urea (% indicated yes)	52.29	48.85	48.33	49.81

Table S5. Control Variables by Farm System

Control variables	Dairy (*N* = 300)	Drystock (*N* = 228)	All (*N* = 528)
Farm size	74.50	42.79	60.81
	(44.06)	(47.30)	(48.08)
Age (% in category)			
18–35	17.33	12.71	15.34
36–45	23.67	21.49	22.27
46–55	33.67	26.31	30.49
56–65	21.00	25.88	23.11
65+	4.33	13.6	8.33
Signpost (% aware)	82.33	48.24	67.61
Reduced N application in last 3 years (% yes)	43.67	48.68	45.83
Protected urea (% of fertilizer N in 2021)	29.98	11.65	22.07
	(32.16)	(23.39)	(30.08)
Clover (% of farmers having any clover in 2021)	89.00	90.79	89.77
Lime (% of farmers applied lime in 2021)	81.33	48.68	67.23
Climate change attitude (range: 4–20)	14.60	14.79	14.68
	(3.22)	(3.56)	(3.37)

Notes: Values in parentheses are standard deviations.

Information Provision Survey

Introduction

Survey on the Effectiveness of Information Messages for Farmers.

Many thanks for participating in this study. Your opinion is very important to us.

Please note, you have to be a livestock farmer in the Republic of Ireland (RoI) to participate. Please do NOT complete this survey if you are not a farmer. This will bias our results.
The aim of the study is to seek farmers' opinions on how to improve information messages on best agricultural practices. The survey also assesses environmental attitudes and farm practices. This study is conducted by xxx.

The survey should take around 8 min to complete.

At the end, you can participate in a draw for thirty vouchers.

Consent

Before you begin with the survey, please read the text and indicate your consent below.

Your participation is entirely voluntary and you are free to exit the survey at any time. You have to be a farmer and at least 18 years of age to participate in this study. By participating, you are agreeing that the information collected will be used for research publications and to inform the design of advisory messages for farmers. Please be assured that your name or other identifying information will NOT appear in any output and your information will be treated as strictly confidential. If you want more information or have a complaint about any aspect of the study, you can contact the principal investigator directly at xx or you can contact an independent person at xxx.

I confirm that I am a farmer in the RoI, at least 18 years of age, and I consent with the information provided above.

- ○ Yes
- ○ No

Farm System

First, please tell us about your farm.

My main farm system is

- ○ Dairy
- ○ Beef and/or sheep
- ○ Other

Farm Characteristics- Dairy

How many cows did you milk in 2021? ______________________________________

Farm characteristics - beef/sheep

How would you classify your main farm enterprise?
○ Suckler farming
○ Cattle farming
○ Sheep farming

Display This Question: If How would you classify your main farm enterprise? = Suckler farming

How many suckler cows did you have in 2021? ________________________________

Display This Question: If How would you classify your main farm enterprise? = Suckler farming

At what stage do you sell your animals?
☐ Weanlings
☐ Yearlings
☐ Year and a half old
☐ Two years or older
☐ Other (please specify) ________________________________

Display This Question: If How would you classify your main farm enterprise? = Cattle farming

How many cattle did you have in 2021? ________________________________

Display This Question: If How would you classify your main farm enterprise? = Cattle farming

At what age do you buy-in your animals?
☐ Calves
☐ Weanlings
☐ Yearlings
☐ Year and a half
☐ Two years or older
☐ Other (please specify) ________________________________

Display This Question: If How would you classify your main farm enterprise? = Cattle farming

At what age do you sell your animals?
☐ Weanlings
☐ Yearlings
☐ Year and a half
☐ Two years and older
☐ Other (please specify) ________________________________

Display This Question: If How would you classify your main farm enterprise? = Sheep farming

How many ewes/hoggets did you lamb in 2021? ________________________________

Display This Question: If How would you classify your main farm enterprise? = Sheep farming

How many lambs did you sell in 2021? ____

How many acres/hectares did you farm in 2021?
○ acres ____
○ hectares ____

Was any of your farm classified as upland/hill in 2021?
○ Yes
○ No

Farm practices

We would like to learn more about what farm practices you implement on your farm. This will help us to better target advice for farmers.

In the past 3 years, have you reduced your fertiliser N usage?
○ Yes
○ No
○ Unsure

In 2021, what proportion of your fertiliser N was applied as protected urea? *(please include approximate* ***percentage*** *in the box below).* ____

Display This Question: If If In 2021, what proportion of your fertiliser N was applied as protected urea?(please include approximate percentage in the box below).Text Response Is Less Than or Equal to 10

Please let us know why your protected urea application was low.
○ I could not source protected urea
○ I'm not interested in using protected urea
○ It does not suit my farm system
○ Other ____

In 2021, what proportion of your grassland swards contained clover and/or mixed species? *(please include approximate* ***percentage*** *in the box below).*

____

In 2021, did you apply lime to your fields?
○ Yes
○ No

Climate Change Attitudes

Please tell us about your opinion in relation to climate change and GHG emissions from agriculture. For you personally, are GHG emissions from agriculture . . .

	Strongly disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Strongly agree
An important issue	○	○	○	○	○
An overstated problem	○	○	○	○	○
Cause for alarm	○	○	○	○	○

Please read each item carefully and indicate your level of agreement for each statement.

	Strongly disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Strongly agree
Addressing climate change is urgent	○	○	○	○	○
I can make a contribution to mitigating climate change on my farm	○	○	○	○	○
Reducing GHG emissions on my farm will lower profits	○	○	○	○	○
Climate change impacts my farming through weather change	○	○	○	○	○

Information Use- Control

We are now interested in your opinion on how information is delivered to farmers.

Please look at the information. We will then ask you some questions that will help us to improve how information is delivered to farmers.

Information Use - Reputational Concern

We are now interested in your opinion on how information is delivered to farmers.

Please look at the information. We will then ask you some questions that will help us to improve how information is delivered to farmers.

Increasing concerns by society about agricultural GHG emissions threatens the reputation of the Irish agricultural sector.

It is important that every farmer adjusts farm practices to help reduce agricultural GHG emissions. Every contribution, regardless how small, is valuable. Together we can make a difference and ensure Irish agriculture retains its environmentally sustainable reputation.

In the following, we will give you some information on how you can contribute to this common goal.

Reducing chemical N fertilizer is one important step to lowering agricultural GHG emissions.

We give you some tips on how to start.

Information Use- Loss Aversion

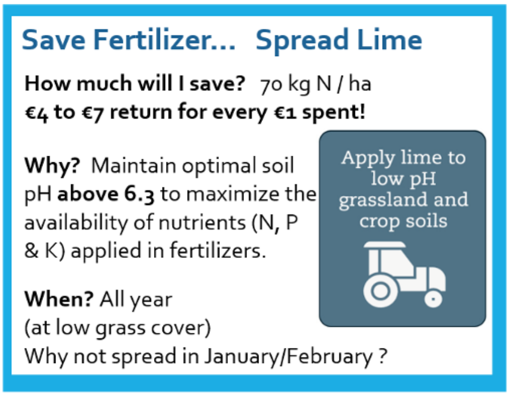
We are now interested in your opinion on how information is delivered to farmers.

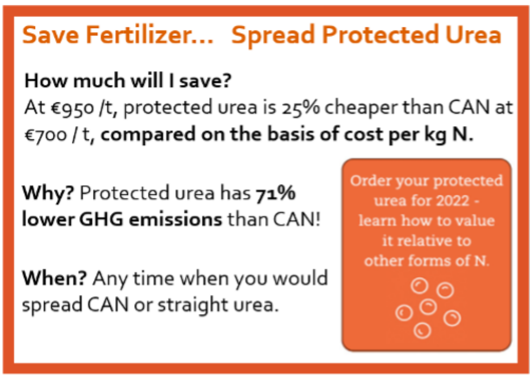
Please look at the information. We will then ask you some questions that will help us to improve how information is delivered to farmers.

Avoid unnecessary expenses!

. . . and save the environment too.

In the following, we will give you some information on how you can avoid reductions in your income by introducing simple measures on your farm.





Information Assessment

In relation to the infographics, please read the statements below and indicate your level of agreement with each statement.

	Strongly disagree	**Somewhat disagree**	**Neither agree nor disagree**	**Somewhat agree**	**Strongly agree**
The information on the infographic was useful	○	○	○	○	○
I learned something new	○	○	○	○	○
The information was difficult to understand	○	○	○	○	○
I don't believe the presented facts are correct	○	○	○	○	○
I'm not interested in information about climate action	○	○	○	○	○

The goal of this survey is to improve the way information is provided for farmers. Therefore, we need you to be part of the solution.

We would like to know what you remember from the infographics. **This is not a test of your knowledge**, but rather a test of how successful we provided information to you.

Your answers will help us to improve the information we provide to farmers.

How much fertilizer can you save by spreading lime?
- ○ 30 kg/ha
- ○ 50 kg/ha
- ○ 70 kg/ha
- ○ 90 kg /ha
- ○ Don't know

Where should you apply lime?
- ○ Grasslands with low pH levels
- ○ Grasslands with high pH levels
- ○ Any grasslands regardless of pH level
- ○ Don't know

How much fertilizer can you save by incorporating clover?
- ○ 40 kg/ha
- ○ 60 kg/ha
- ○ 80 kg/ha
- ○ 100 kg/ha
- ○ Don't know

When should you sow clover?

- ○ January/February
- ○ Early spring
- ○ Late April to mid-July
- ○ Autumn
- ○ Don't know

Q325 By how much does protected urea reduce GHG emissions when compared to CAN?

- ○ 35%
- ○ 53%
- ○ 71%
- ○ 90%
- ○ Don't know

Protected urea is cheaper than CAN when compared per

- ○ Tonne of fertilizer
- ○ Cost per kg of N
- ○ It is more expensive
- ○ Don't know

If you have any suggestions how we can improve advice for farmers, please let us know.

____
____
____
____
____

Intention

Please tell us about your plans for 2022.

This will help us to target our farm advice for 2022.

In 2022, I plan to reduce chemical N fertilizer.

- ○ Yes
- ○ No
- ○ Don't know yet

Display This Question: If In 2022, I plan to reduce chemical N fertilizer. = No Or In 2022, I plan to reduce chemical N fertilizer. = Don't know yet

Please tell us why your are unsure or are not planning to reducer chemical N fertilizer.

- ○ I already reduced chemical N fertilizer and can't do more
- ○ It does not suit my farm system
- ○ Other (please specify) ____________________________________

In 2022, I plan to apply more lime.
- ◯ Yes
- ◯ No
- ◯ Don't know yet

Display This Question: If In 2022, I plan to apply more lime. = No Or In 2022, I plan to apply more lime. = Don't know yet

Please tell us why you are unsure or not planning to apply more lime.
- ◯ I already use enough
- ◯ It does not suit my farm system
- ◯ I'm waiting for soil test results
- ◯ Other (please specify) ________________________________

In 2022, I plan to increase the amount of clover/mixes species in my forage area.
- ◯ Yes
- ◯ No
- ◯ Don't know yet

Display This Question: If In 2022, I plan to increase the amount of clover/mixes species in my forage area. = No

Please tell us why you are not planning to increase the amount of clover/mixes species in your forage area.
- ◯ I already have clover/ mixed species and can't add more
- ◯ It does not suit my farm system
- ◯ Too difficult/labour intensive
- ◯ Other (please specify) ________________________________

In 2022, I plan to increase the use of protected urea.
- ◯ Yes
- ◯ No
- ◯ Don't know yet

Display This Question: If In 2022, I plan to increase the use of protected urea. = No Or In 2022, I plan to increase the use of protected urea. = Don't know yet

Please tell us why your are unsure or not planning to use more protected urea.
- ◯ I already use protected urea and can't use more
- ◯ It does not suit my farm system
- ◯ I can't source it
- ◯ Other (please specify) ________________________________

Advisory Service Use and Socio-economic Characteristics

You are nearly at the end of the survey. We just need a little bit of information about your use of advisory services.

Are you a member of a discussion group? *(Please tick all that apply)*
- ☐ No
- ☐ Yes - KT group
- ☐ Yes - Private group

Are you aware of the Teagasc Signpost programme?
- ○ Yes
- ○ No

Display This Question: If Are you aware of the Teagasc Signpost programme? = Yes

What Signpost initiatives have you used or participated? (Please tick all that apply)
- ☐ Visited Signpost demonstration farms
- ☐ Participated in online seminars
- ☐ Read newsletters
- ☐ None
- ☐ Other (please specify) ________________________________

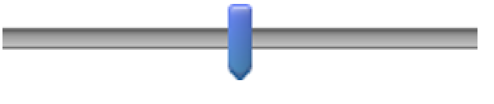
What is your age category?
- ○ 18 - 25
- ○ 26 - 35
- ○ 36 - 45
- ○ 46 - 55
- ○ 56 - 65
- ○ 65+

In what county is your farm located?
- ▼ Dropdown of counties provided

Last question!
In relation to your efforts to reduce GHG emissions on your farm, how do you think you are doing?

0 1 2 3 4 5 6 7 8 9 10

Please rate your own effort



Voucher

____