Extended Abstract
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Paper/Poster Title	Heterogeneity in the effect of GHG mitigation strategies on Irish dairy farms

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Abstract	***200 words max***

The agricultural sector is increasingly under pressure to participate in the greenhouse gas (GHG) emission reduction effort. At the farm level, significant improvements can be achieved through the adoption of new technologies. Nevertheless, to date, little is known about differences in effect reduction across farms.

This study specifically explores the heterogeneity in the effect of GHG mitigation strategies across the distribution of GHG emissions on Irish dairy farms. It also analyses differences in farm profiles depending on their level of GHG emissions. The econometric analysis is performed on an unbalanced panel dataset by using fixed effects (FE) unconditional quantile regression models and FE ordered logits.

The preliminary results reveal that GHG mitigation strategies have a differential effect across the distribution of GHG emissions, with two main implications. First, the findings suggest that relying on estimations of a technology's effect at the mean can be somewhat misleading as this does not reflect the effect of heterogeneity. Second, the study shows that the effect of GHG mitigation strategies is larger for high emitting farms than for low emitting farms. These farm groups also vary in terms of current adoption levels as well as farm and farmer characteristics.

Keywords	Greenhouse gas emissions; Mitigation; Panel data analysis; Irish dairy farms.
JEL Code	Agriculture; Econometric modelling; Environmental economics see: www.aeaweb.org/jel/guide/jel.php?class=Q)

Introduction	***100 – 250 words***

The agricultural sector is increasingly under pressure to reduce greenhouse gas (GHG) emissions. In regions such as Ireland where agriculture is mainly livestock based, this is a difficult task due to fixed environmental costs associated with animal maintenance.

This study is concerned with the effect of mitigation strategies on GHG emissions on Irish dairy farms. While GHG mitigation strategies have been previously identified and are currently promoted through agricultural extension, little is known about differences in their reduction effect across farms. This is a common issue in the technology adoption literature. While it is acknowledged that technology effect may vary depending on farm performance, few empirical studies have examined this heterogeneity in depth. As the timeframe to reduce GHG emissions is becoming

shorter, failing to understand heterogeneity in technology effect may be problematic as various pools of farmers may not only adopt at different speeds but also with differential returns. Indeed, concerns of further delaying the achievement of desired GHG outcomes would arise if the majority of mitigation to occur were to come from the slowest adopters of new technologies.

We fill this gap in the literature in two ways. First, we examine whether the effect of potential GHG mitigation strategies varies across the distribution of GHG emissions, where GHG emissions are analysed per unit of output and per hectare. Second, in order to better understand which farmers are at different points of the GHG distribution, we explore differences in farm profiles, categorised as low, low to medium, medium to high, and high emitters.

Methodology	***100 – 250 words***

This study uses an unbalanced panel dataset from the Teagasc National Farm Survey (NFS) from 2013 until 2019. The Teagasc NFS is collected on a yearly basis as part of the European Union Farm Accountancy Data Network and gathers information from a representative sample of Irish farms. The analysis is restricted to specialised dairy farms, which constitute a sample of 1,905 observations.

Estimates of dairy GHG emissions are modelled using a cradle-to-farm-gate life cycle assessment model. As for the GHG mitigation strategies under study, their selection is guided by the specificities of the Irish grass-based milk production system and extension focus. Notably, these include improvements in grassland management and nutrient utilisation, and enhancements of milk yield and quality. Other farm and farmer characteristics are also accounted for in the analysis.

In a first step, we estimate two-way fixed effects (FE) unconditional quantile regression models to explore the heterogeneity in the effect of mitigation strategies across the distribution of GHG emissions. The models are estimated at three points of the distribution, i.e., the 25th percentile, the median, and the 75th percentile. In this way, estimation results can reflect the effect of farming practices on low, medium, and high emitting farms. Results are also compared to estimates of two-way FE Ordinary Least Squares (OLS) regression models (estimated at the mean).

In a second step, we examine the predictors of farm profiles by estimating two-way FE ordered logit. For each outcome variable, farmers are categorised into four groups according to the quartiles of the sample's GHG emission distribution.

Results	***100 – 250 words***

The preliminary results of the unconditional quantile regression models show that the effects of GHG mitigation strategies vary across the distributions of GHG emissions per unit of output and per hectare. More precisely, their effects are higher at the 75th percentiles (i.e., for high emitting farms) than at the 25th percentiles (i.e., for low emitting farms). Additionally, while some of the mitigation strategies recommended by Irish extension (i.e., improving milk yields and nitrogen use efficiency) are positively associated with GHG emissions per unit of output, we find that their effect is negative on the per-hectare measure.

As for the ordered logit, the preliminary findings show that herd size, stocking rate, nitrogen surplus, and nitrogen use efficiency are positively associated with the likelihood of being in a high emitting group. Conversely, the degree of specialisation

in dairy production and the share of homegrown grass in the diet of dairy cows is positively associated with the likelihood of being in a low emitting group.

Discussion and Conclusion	***100 – 250 words***

This study shows that GHG mitigation strategies have a differential effect across the distribution of GHG emissions on Irish dairy farms, with two main implications. First, the findings suggest that relying on estimations of technology effect at the mean can be somewhat misleading as commonly used FE OLS regression models cannot reflect the heterogeneity in the effect. Second, the study shows that the effect of GHG mitigation strategies in reducing emissions is larger for high emitting farms than for low emitting farms. These groups of farms also vary in terms of current adoption levels, and farm and farmer characteristics.

Overall, this study is expected to advance the level of knowledge in the technology adoption literature, as well as to provide insights on how to reduce GHG emissions on dairy farms.