Extended Abstract
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Paper/Poster Title	**Measuring the technical efficiency of the Irish dairy sector using a generalized gamma distribution**

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Abstract	***200 words max***
Technical efficiency is an important indicator of competitiveness and sustainability at the farm level. Inefficiency is usually viewed as an outcome of poor management and it is assumed in Stochastic Frontier Analysis (SFA) to follow a half-normal or exponential distribution. Although these assumptions are convenient, they fail to capture possible multimodality or skewness arising from the diversity in farmers' efficiency behaviour. This study measures the technical efficiency of the Irish dairy sector, using a mixture of generalized gamma distribution with two components (GG2C) for the inefficiency term (Griffin and Steel 2008), which can accommodate the potential multimodality and skewness of the inefficiency term. Our aim is to provide a structural explanation of why inefficiency exists in the Irish dairy sector and inform policies that aim to foster competitiveness and sustainability at the farm level. We find that the GG2C fits the data better than the half-normal and exponential distribution model, indicating the existence of multimodality in farmers' efficiency behaviour. We also explain multimodality on farmers' characteristics. We find that older farmers, and farmers with lower stocking density are more likely to be in the more efficient group.	

Keywords	Stochastic frontier analysis, technical efficiency, Irish dairy sector

JEL Code	D24, Q12, O33 see: www.aeaweb.org/jel/guide/jel.php?class=Q)

Introduction	***100 – 250 words***

Stochastic Frontier Analysis (SFA) is widely used to measure the technical efficiency in agricultural production. The drawback of the SFA is that the inefficiency term lacks of any specific structural interpretation of why inefficiency exists (Kumbhakar et al. 2018). Inefficiency may arise from sub-optimal use of inputs or other reasons which are not observed by the researcher (Kumbhakar et al. 2018).

In agricultural production, inefficiency is almost always viewed as an outcome of poor management and it is assumed to follow a non-negative distribution. The latter assumption may be very restrictive although it is convenient from a methodological and conceptual perspective. For example, farmers may use production factors for wider sustainability goals other than purely productivity improvements and as as a result part of inefficiency is attributed to “rational” production decisions and not poor management (Hansson et al. 2018). Such behavioural differences may result in multimodality and various skewness in efficiency analysis, which cannot be captured by the usual choice of half normal or exponential distributional (Griffin and Steel 2004; Griffin and Steel 2008).

In this study, we measure the technical efficiency of the Irish dairy sector using a generalised gamma mixture of two components distribution for the inefficiency term. This distribution can accommodate possible multimodality and skewness of the data, which we further explain it on farmers’ characteristics. Our overall aim is to provide possible explanations of why technical inefficiency exists in order to assist policies that aim to foster technical efficiency of the farming sector.

Methodology	***100 – 250 words***

We use a representative sample of Irish dairy farms between 2008 and 2017, taken from Teagasc, the Irish Agriculture and Food Development Authority. Two categories of outputs are defined: revenues of milk and the aggregated revenues of other commodities. Four categories of inputs are defined. The capital is measured by the value of machinery and buildings and total livestock value. Labor is measured in total labour units working on the farm. Land is measured in hectares. Materials comprises of expenditures of seeds and plants, fertilizers, crop protection, energy, contract work and purchased feed, upkeep of buildings, machinery hire and upkeep of land.

We assume a distance function to represent the technology of Irish dairy farmers due to their multi-output nature of production and we employ Stochastic Frontier Analysis using three different distributions: 1) an exponential distribution, 2) a half-normal distribution and 3) a mixture of generalised gamma with two components (GG2C). We compare the performance of the three models using the Deviance Information Criterion (DIC) (Griffin and Steel 2007).

The analysis is conducted in Bayesian inference. For the first two distributions, we choose the priors following van den Broeck et al. (1994) and Griffin and Steel (2007). The choice of the priors for the GG2C and the determinants of the allocation of farms on the components are based on Griffin and Steel (2008).

We choose the stocking density (cows per hectare), age and the degree of specialisation as determinants of farmers' allocation on the components of inefficiency.

Results	***100 – 250 words***

Our preliminary results are obtained from data augmentation techniques of another 330000 draws. The first 50,000 iterations were disregarded in order to reduce the influence of the initial values, and for the rest 280,000 draws, 1 out of every 30 was retained to remove any potential autocorrelation.

The GG2C has the lowest DIC value which indicates that it fits the data better compared to the half-normal (HN) and exponential (Exp) model stochastic frontier model. The output elasticities of the three models are similar but differ with respect to the elasticity of capital, which comprises of the value of buildings, machinery and livestock.

While the average efficiency scores of the HN and Exp are 0.70 and 0.72 respectively, the average efficiency score of the GG2C is 0.43. The efficiency histograms confirm the findings of Griffin and Steel (2004; 2008) that the HN and Exp model overestimate efficiency scores. The posterior probability of a firm to be allocated in the very efficient group is 0.27, which indicates that the data favour the two component model over the one component generalised gamma distribution.

Furthermore, we find that farmers who use higher stocking density are less likely to be in the more efficient group. Older farmers are more likely to be in the more efficient group. More specialised farmers are less likely to be in the more efficient group but the impact is insignificant (i.e. there is zero in the credible interval).

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

Discussion:
The result that farmers at higher stocking density are less likely to be in the more efficient group contradicts the findings of other studies (e.g. Alvarez and del Corral 2010; Skevas et al. 2021; Ma et al. 2021). This finding can be explained by the fact the grass-based feed system is the main source of competitiveness of the Irish dairy sector (Thorne et al. 2017). Given the low land mobility in Irish agriculture, farmers who are more profit oriented, increase purchased feeds per cow and become more cost inefficient. Farmers with less stocking density may use their production inputs for other goals than productivity, such as better animal welfare as argued by Hansson et al. (2018). Thus, farmers with less stocking density provide an important quality aspect, which is not observed in our data, and it turn, it is erroneously captured as inefficiency under the assumption of HN or Exp inefficiency distribution.

Conclusion:

The results have implications for policies and advisory services that aim to alleviate inefficiency in agricultural production. Specifically, while accounting for possible multimodality and skewness of the data, we found that farmers at higher density are more likely to be less efficient. Given the low land mobility in the Irish agriculture, these farmers need to use more efficiently their inputs in order to to reduce their nutrient loss to water, greenhouse gases (GHG) and ammonia emissions according to the Irish national policy targets.