Extended Abstract
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Paper/Poster Title	**The impact of different GHG estimation methodologies on the derivation of the marginal abatement cost for dairy farms in Lombardy**

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Abstract	***200 words max***
This paper identifies the effect of adopting alternative GHG emissions estimation methodologies in deriving marginal abatement costs (MACs) in agriculture. More specifically, we compare the classic Tier 1 approach with common emission factors to Tier 2 with farm-specific emission factors. Our application is based on a sample of 223 specialized dairy farms from the Italian Lombardy region from 2008 to 2020. Due to data availability, the Tier 2 approach is only applied to the enteric fermentation estimation, representing more than 67% of the total GHG emissions. The MACs are estimated using the by-production approach (multiple equations representation of the technology). Our results reveal a higer MAC under Tier 1 (230 euros/ton of GHG) compared to Tier 2 (35 euros/ton of GHG).	

Keywords	Marginal abatement cost, shadow price, GHG emissions, dairy farms
JEL Code	D24, Q10, Q50, see: www.aeaweb.org/jel/guide/jel.php?class=Q)

Introduction	***100 – 250 words***
Marginal abatement costs (MACs) have become one of the main policy tools in assessing the cost of GHG emissions reduction at the farm level and defining climate change mitigation options. Several studies have attempted to estimate marginal abatement costs of GHG emissions using available data, but significant variations in final estimates have been observed (Kuosmanen and Zhou, 2021, Zhou et al., 2014). Two major sources of uncertainties in the derivation of MACs: i) the MACs estimation methodologies; and ii) data availability and approaches for estimating GHG emissions. This paper focuses on the second of these empirical issues and aims to identify the effect of adopting alternative GHG emissions estimation methodologies in deriving MACs in agriculture. In particular, it compares MACs estimates obtained using common emission factors across farms and a farm-specific emission factor for some emission sources to appraise the eventual impact of finer estimates on the MACs. The application concerns Italian FADN farms that specialized in dairy farming from the Lombardy region from 2008-2020.	

Methodology	***100 – 250 words***

Following the theoretical results of Murty et al. (2012), a polluting technology lies at the intersection of two sub-technologies: one that produces marketed outputs and the other that generates pollution. The derivation of the MAC is associated with the shadow price of pollution, as the MAC is obtained as the minimum of all possible shadow prices. Empirically, we assume a quadratic directional distance function for each technology. The model parameters are estimated in two steps in light of Henningsen and Henning (2009). In the first step, a within estimator is used, and in the second step, a quadratic program is solved to determine the closest parameters that satisfy the monotonicity properties necessary for obtaining meaningful economic MACs.

The MAC is estimated for the case of 223 specialized Italian dairy farms from Lombardia between 2008 and 2020. Two outputs and six inputs are considered to represent the good outputs technology: milk production, other outputs, land, labor, herd size, capital assets, polluting intermediate consumption, and non-polluting intermediate consumption. For the GHG emissions technology, two inputs are considered polluting: herd size and polluting intermediate consumption. This implies that farmers have two strategies to mitigate GHG emissions. The MAC is then estimated considering these two strategies and given milk price.

Results	***100 – 250 words***

Under Tier 1, on average the MAC is about 230 euros per ton of GHG emissions, while under Tier 2 it falls to 35 euros per ton. The results reveal that the average MAC under Tier 1 is five time higher than under Tier 2. A closer look at the descriptive statistics reveals that, on average GHG emissions under tier 1 are about 652 tons per farm. In contrast, under tier 2, GHG emissions rise to 3,096 tons, more than four times the emissions under Tier 1. We hypothesize that since the tier 2 approach implies more GHG emissions for the same production level, this is reflected in a lower marginal abatement cost. In terms of strategy, in all cases, most farms will mitigate GHG emissions by the reduction of the herd size. Regarding the evolution, both MACs show different trajectories. Under the Tier 1 approach, the MAC on average exhibits a decreasing trend in the second half of the period. On the contrary, the MAC obtained under the tier 2 approach, reveals a steadily increasing trend over the whole period (2008-2020).

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

This paper examines the question of MACs estimation in the case of the Lombardian dairy farms comparing Tier 1 and Tier 2 approaches. The results reveal that the MAC under Tier 2 is five times lower than the MAC obtained under Tier 1. These results can be explained by the fact that using a more precise GHG estimation methodology results into a higher (four times more) level of pollution for the same amount of inputs and outputs. These preliminary results imply that environmental policies based on Tier 1 GHG estimation potentially overestimate the cost of mitigation. As the EU common agricultural policy is subsidy oriented, this may lead to resource waste if a compensation for GHG emission was to be implemented. From a methodological perspective, one important point of discussion here is whether both MACs under Tier 1 and Tier 2 can be compared given that the GHG emissions are of different level.

Future research could investigate the MAC for Tier 2 approach but with the same level of GHG emissions as for Tier 1.
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