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The evolution of agricultural GHG emissions in Italy and the role of the CAP

A farm-level assessment

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Abstract.

This paper firstly proposes a methodology to reconstruct the agricultural GHG emissions and the consequent Carbon Footprint (CF) at the farm level. This allows investigating how the emission performance of Italian farms evolves over time, distinguishing among typologies of farms and territories. Secondly, the paper attempts to put forward some hypotheses explaining the observed heterogeneous evolution of the farm-level CF. In particular, the attention focuses on the possible role of the Common Agricultural Policy (CAP). The empirical analysis concerns a balanced panel of Italian FADN (Farm Accountancy Data Network) farms observed over years 2003-2007. Results, although interesting and encouraging, deliver unclear and ambiguous evidence on the role of the CAP on the observed CF performance and evolution. Several improvements seem needed to achieve more conclusive evidence to make this assessment more sound and robust, in order to inform the debate and the decisions about the proper policies to mitigate agricultural GHG emission.

Keywords: agricultural greenhouse gases emissions, carbon footprint, farm-level data, CAP

JEL codes: O130, Q120, Q150, Q540

1. Introduction

The agricultural sector represents in Italy the second largest source of Greenhouse Gases (GHG) emissions (with 7.5% of national emissions in 2012), after the energy sector (83%) (ISPRA- Institute for Environmental Protection and Research, 2014).

Agricultural GHG emissions have become a central issue in the debate on policies contrasting climate change in developed countries (European Commission, 2009). In the EU, in particular, not only climate policy pays attention to agricultural GHG emissions, but also the Common Agricultural Policy (CAP) has increasingly acknowledged the relevance of this aspect of agricultural production. This clearly emerges in the reform proposal for the programming period 2014-2020, where GHG emission mitigation has a central role both in first pillar (the so-called greening practices, beneficial for the environment and the climate) and, above all, in the second pillar, where climate change mitigation has become one of the policy priorities.

During the last years, many studies have explored the mitigation potential of different farm-level technical and production options to curb emissions in the agricultural sector (UNFCCC, 2009; Coderoni et al., 2015). These options may be-directly or indirectly-influenced by the CAP support. Thus, the CAP seems to play a central role also to achieve climate policy targets.

Moreover, looking at the long run, emission reduction targets for the agricultural sector are becoming more and more ambitious (European Commission, 2011a and 2014). According to European Commission (2011a; 2011b) to obtain the decarbonisation of European economy (-80/95% of GHG emission compared to 1990 level), the agricultural sector must contribute with a reduction of 42/49% of its GHG emissions. The first step of this process, the so-called 20-20-20 target (European Commission, 2008), has been translated into a 10% reduction target for European Union (EU) NON-ETS (Emission Trading System) sectors (i.e. sectors like agriculture, transport and waste that are not included in the EU-ETS. Directive 2003/87/EC). The second step of this roadmap, is the newly established Europe 2030 mitigation agenda (European Commission, 2014); in this framework EU GHG emissions should be cut off 40% in 2030 (compared to 1990) and emission of sectors outside the ETS (thus including agriculture) should contribute with a -30% emissions (compared to 2005). To ensure that all sectors contribute in a cost-effective way to the mitigation efforts, land use, land-use change and forestry emissions (the so-called LULUCF sector) for the first time should be included in the GHG reduction target for 2030 (European Commission, 2014). This will be possible thanks to the Decision No 529/2013/EU of the European Parliament and of the Council on accounting rules on GHG and removals resulting from activities relating to LULUCF sector. This decision sets out common European rules to harmonise accounting of GHG emission across EU, delaying the establishment of reduction targets to when the data reported will have proved to be robust and reliable. The Commission's Green Paper, for climate and energy targets for 2030, asked for views on the most appropriate range and structure of the policy approach to realise all sectors mitigation potential. Even if further analysis will be undertaken, it is clearly stated that accompanying policy measures should also build on the experiences from the Common Agricultural Policy (and ensure coherence with other Union policies) (European Commission, 2014).

Therefore, it seems helpful to analyse the impact of past CAP measures and reforms on farmers' choices of production mixes and level and, thus, on farm-level GHG emissions, to understand to what extent the current reform proposal may improve the emission performance and, thus, contribute to reach the European ambitious mitigation targets, also at sectorial level.

Although there are some studies that have evaluated the ex-ante impact of the 2003/2005 reform of the first pillar of the CAP (also known as the Fischler Reform; henceforth, FR) on agricultural GHG emissions at European level or for some specific countries (Behan et alet al. 2003; Dixon and Matthews, 2006), there is almost no empirical literature on the ex-post evaluation of these impacts, especially for Italian agriculture. The aim of this paper is to define a methodology for the reconstruction of agricultural GHG emissions at farm level and of its evolution over time. Computation of the emission performance and of the consequent Carbon Footprint (CF) at the micro level is itself a challenging research objective as most of protocols and applications in this respect refer to aggregate data. Once emission records are properly computed at the farm level, a second objective of the present study is to put forward some tentative interpretations of the differences observed across farm typologies and territories and, above all, of the farm-level CF evolution over time with specific reference to the possible role of the CAP here intended both as the 2005 reform of its first pillar and those second pillar's measures targeted to activities and practices that have a direct impact on the CF.

Given the numerosity of the farm sample and repeated observations over the time dimension, this micro data (in practice a panel dataset) allow empirically assessing the drivers of agricultural GHG emissions across space and over time and, consequently, also testing some assumptions in this respect; for instance, the role of CAP and its reform. The present empirical investigation concerns a balanced panel of Italian FADN (Farm Accountancy Data Network) farms observed over years 2003-2007. This period covers the FR as well as the full application of the second pillar's measures for the 2000-2007 programming period. Though results are, in fact, inconclusive on the possible contribution of the CAP to the observed CF patterns, they are still informative with respect to the expected effects of the 2014-2020 CAP design. At the same time, these results suggest the need of further empirical investigation by exploring other farm samples and periods as well as developing more sophisticated econometric approaches to reinforce the evidence on the possible role of the CAP and, thus, inform the policy makers on the more suitable directions of reform.

2. Agricultural GHG Emissions at the Farm Level

Monitoring, reporting and verification of GHG emission, is a fundamental step of every policy framework for GHG abatement. In order to fulfil the commitments made under the UNFCCC (United Nation Framework Convention on Climate Change) and the European Union's Greenhouse Gas Monitoring Mechanism, every Member State has to prepare the annual National Inventory of emissions and removals of GHG, which is the official tool to monitor commitments (ISPRA, 2014). Within the UNFCCC, the IPCC (Intergovernmental Panel on Climate Change), that is the scientific and technical body of the Convention, has given the role to establish a common methodology to estimate emissions and removals from all sectors, using simple and available data, because they have to be adopted all over the world for reporting purposes. As mentioned, agriculture is one of the most important sectors in this context and the respective emissions' calculation remains one of the most challenging issues in this field.

Agricultural GHG emissions are a typical example of non-point source pollution, so this kind of emissions must be computed indirectly. As already mentioned, the common methodology to perform this indirect computation is provided by the UNFCCC/IPCC (IPCC, 2006) guidelines that represent a widely applicable and, above all, internationally recognized standard. Nonetheless, this standard, and the consequent protocols and applications, refer to aggregate data and does not seem particularly suitable for micro data. In the present paper, in fact, the IPCC methodology is not applied to aggregate data to compute aggregate emissions as typically done in previous works (Coderoni and Esposti, 2013, 2014). The novelty, here, is that the IPCC methodology is adapted and applied at the farm level (Coderoni *et al.*, 2013; Coderoni and Bonati, 2013). Using these farm-level data, methane (CH_4), nitrous oxide (N_2O) and carbon dioxide (CO_2) emissions are estimated for five emission sources: livestock production, crops, land use, fuel and fertilizers use. These emission coefficients allow the farm-by-farm reconstruction of the emission levels across a balanced panel dataset. Therefore, the variation of emission performance can be observed across space, i.e. across the heterogeneous farming types (in terms of farms' characteristics and specialization, geographical localization, economic dimension, etc.) and over time. Evidently, the extreme variety of environmental and management systems in Italian farming represent the main problem when computing these farm-level emissions. Thus, the developed methods are expected to be strongly connected to the different production processes and to use activity data that are strictly and properly linked to emission production.

A further characteristic of the IPCC approach to agricultural emission estimation is that it refers to the production stage while disregarding the consumption stage. This means that is the "process level", and not the "product level", emission that counts. The main objective of the present study proposed is to carry out a sectoral analysis and to inform sectoral policies, not to measure GHG emissions associated to specific product life cycles or consumption paths. Therefore, the IPCC "process-based" methodology seems the most suitable approach even in the present case. In fact, it better fits the purpose of computing the Carbon Footprint (CF) at farm level estimating the emissions that occur within the "farm gate" and on which the farmer has a "direct" control, with a focus on the production processes associated to the farm characteristics (specializations, natural processes, methods of production, resource management, etc.) and not on subsequent supply chain and consumption of the respective agricultural products.

2.1. The IPCC methodology with micro data

The choice of adapting the IPCC methodology at farm level could be questioned, as there are many methodologies that allow estimating agricultural GHG emissions even more accurately than IPCC guidelines. However, IPCC Guidelines represent an internationally recognized standard; they are the reference in assessing the compliance with international commitments and provide a widely applicable default methodology, whose efficiency is internationally recognized (De Cara et al., 2005). Many studies dealing with the estimation of agricultural GHG emissions make the same choice (De Cara et al., 2005; Dick et al, 2008; Perez et al., 2009). Moreover, as specified in Dick et al. (2008) the IPCC methodology also allows a uniform accounting of emissions related to both agriculture and forestry.

Nonetheless, as the purpose of the IPCC methodology is to estimate GHG emission at national level, scaling down these guidelines at systems with narrower boundaries and high heterogeneity, is not an easy task (Dick et al., 2008). In particular, when estimating GHG emissions, defining the system "boundaries" is a very crucial issue especially at the individual farm level. In fact, the boundaries of the emissions and removals calculation can lead to high differences in total amount of emission estimated. Currently there is no international standard methodology to indicate which these boundaries are and, in particular, which emissions have to be attributed to the producers and which to the consumers. Given the purposes of the present work, we decided to consider only the direct emissions up to the farm gate, that is, strictly related to farm production. Hence, emissions caused by the production of agricultural inputs and the transport of food and feed products are not accounted for.

As stated also in other studies (Dick et al., 2008), this "farm gate" approach has two main advantages. When used in order to make a farm level assessment of emissions, in fact, it has the advantage to highlight the use of best practices at every stage of production and the emissions of which the farmer has direct control. Secondly, this approach allows the evaluation and formulation of policies implemented at farm level, particularly those that expected to affect farmers' behaviour in terms of production choices and inputs use, while disregarding the policy impact on pre or postproduction phases.

2.2. The application to the Italian FADN sample

The methodology used in this study to reconstruct a GHG-emission farm balance, is based on an adaptation of the IPCC methodology (IPCC, 1997 and 2006) at the farm level, using activity data connected to the main agricultural activities. These data are derived from the FADN and the Italian emission factors (EF), as described in the official documents of the Institute for Environmental Protection and Research (ISPRA, various years; Condor *et al*. 2008). In Italy, ISPRA is in charge of estimating and reporting the National Inventory of GHG emissions according to the IPCC Guidelines. A more detailed description of this methodology can be found in Coderoni and Bonati (2013) and Coderoni *et al*. (2013). This standardized approach, using FADN, has the advantage to make the collection of data on farm activities easier and transparent across all the different agricultural practices and all types of agricultural farms. Furthermore, the use of the FADN datas*et al*lows to link GHG emissions to other farm-level economic indicators, policy support included, to formulate hypotheses on the possible causes of different emission performance and evolution.

More in detail, according to the IPCC methodology the "Agriculture" sector (thus, the farm) produces emissions mainly of two non-CO_2 greenhouse gases: methane (CH_4) and nitrous oxide (N_2O), from six different categories (five of which are relevant in Italian GHG inventory: enteric fermentation, manure management, agricultural soils, field burning of agricultural residues). On the contrary, emissions of carbon dioxide (CO_2) (from the use of machinery, buildings, agricultural operations and transport of agricultural products) are accounted in the "energy" sector and emission and removals of CO_2 from agricultural soils and biomass are estimated in the LULUCF sector (Land Use, Land Use Change and Forestry).). However, in order to properly estimate the emissions within the farm gate, the methodology here adopted tries to account for GHG emissions from all sources listed in table 1, with a crosscutting approach that combines three different sectors (Agriculture, LULUCF and Energy) that, in fact, the IPCC estimates separately.

From a policy perspective, these emissions (and removals) are nowadays treated in different parts of the EU's climate policy framework. Non-CO_2 emissions from agriculture are included in the Effort Sharing Decision, while CO_2 emissions and removals related to LULUCF sector are accounted for under the international commitments of the Kyoto Protocol, while are excluded from the EU's domestic reduction target , but should be included in the GHG reduction target for 2030 (European Commission, 2014). Thus, in view of the forthcoming EU policy framework, that is aimed to ensure that all sectors contribute in a cost-effective way to the mitigation efforts, it could be useful to estimate all these emissions from different IPCC categories.

To express all these emissions in a unique unit of measure, i.e., total CO_2 equivalent (CO_{2e}), any different GHG is multiplied by its Global Warming Potential (GWP). GHG emissions expressed in CO_{2e} represent what we define, for the purposes of this study, the Carbon Footprint (CF)[1].

Generally speaking, the basic approach of the IPCC methodology (Tier 1) to compute agricultural GHG emission assumes a linear relationship between emissions and activity data. In the present study, activity data are mostly derived from FADN dataset and are listed in table 2, for each single source of emission. Emission factor used for each source of emissions are the Italian country-specific emission factors whenever available in 2009 or 2011 national communication to the UNFCCC (ISPRA, 2011 and 2013); otherwise, IPCC default values are used. Resulting GHG emission values are aggregated in different ways to enable more detailed analysis at farm and production level. The main aggregates obtained are the CF for five macro categories of emissions: livestock, crops, fertilizers, energy and land use.

As FADN sample is not designed to collect all the information needed to the estimation of farm-level GHG emission, several assumptions have been made to overcome the information gap in order to achieve the five CF values listed above. The CF of livestock production has been obtained by multiplying an emission factor which takes into account the level of direct and indirect emissions of animal livestock, for each animal category. In some cases FADN data on livestock population is not separated into male and female (e.g. in the case of swine and buffalos). To overcome this problem, the emission factor is calculated as a weighted average between the female and the male values, whose proportion is assumed to be the same of the national one for each livestock category.

The CF of crops has been obtained distinguishing among three main categories: rice production (methane emissions), agricultural residues and N-fixing crops. For what concerns rice emission, as at present FADN information does not include data on rice cultivation methods and it is not possible to

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[1] A carbon footprint is defined by Wright *et al*. (2011) as a measure of the total amount of GHG emissions "of a defined population, system or activity, considering all relevant sources, sinks and storage within the spatial and temporal boundary of the population, system or activity of interest. Calculated as carbon dioxide equivalent (CO2e) using the relevant 100-year global warming potential (GWP100). Wright, L.; Kemp, S.; Williams, I. (2011). 'Carbon footprinting': towards a universally accepted definition. *Carbon Management* **2** (1): 61–72. doi:10.4155/CMT.10.39.

distinguish between single and multiple aeration, the multiple aeration EF is used; this assumption might evidently represent a slight overestimate of the respective emissions. For the CF from agricultural residues, the main activity data on which the estimations is based, is the Utilized Agricultural Area or the total amount of production, depending on the single crop. For N-fixing crops the activity data used was Utilized Agricultural Area (UAA).

The CF deriving from fertilizers consumption has been estimated using total fertilizers expenditure at farm level. Both direct and indirect emission (due to nitrogen leaching and run-off) are accounted for. The estimation are based on the assumption that 1 euro of expenditure in fertilizers (N, P or K) at constant 1995 prices, corresponds to the same amount of N input as derived from the Agrefit dataset (Rizzi and Pierani, 2006). According to this assumption, every euro spent on fertilizers corresponds to 0.54 Kg of nutrients (N, P or K). The CF of energy consumption has been estimated using total agricultural fuel expenditure at farm level, by dividing for the average price of agricultural diesel observed over time and across different Italian provinces (available online). This allows computing the year-by-year farm-level use of fuel and, thus, the consequent CF.

The CF of land use has been calculated in two alternative ways, to reflect different assumption made on the underling methodology.

The firs approach (CF Land Use A) has been obtained adapting ISPRA (2014) Implied Emission Factors (IEF) for the purposes of this study and multiplying it by the UAA cultivated with respective crops. More in detail, land uses have been distinguished in forest, other wooded land; perennial woody crops, plantation and coppices. Land use changes have not been considered in at this stage of the methodology, if not as a consequence of reduced UUA surface. Following ISPRA (2014: 209) "the change in biomass has been estimated only for perennial crops, since, for annual crops, the increase in biomass stocks in a single year is assumed equal to biomass losses from harvest and mortality in that same year", coherently with the IPCC Good Practice Guidance (GPG) for LULUCF. However, since the IEF obtained with this approach for perennial wood crops is negative (thus, represent a source of emissions), for the value of this carbon stocks at maturity, a different IEF has been used to take into account that perennial crops give both with soils and biomasses a higher contribution in C sink than annual crops. This second approach (CF Land Use B) thus considers a positive value for perennial wood crops using, in the absence of country specific values, an average value of 10 t C ha-1 (for carbon stock at maturity), deduced by the values adopted in Spain, suggested by JRC experts to ISPRA (2014) considering a cycle of 20 (ISPRA, 2014: 210).

3. Agricultural GHG Emissions and the CAP

In Europe, and in Italy, agricultural GHG emissions have already achieved a significant reduction (EEA, 2012). However, mitigation of agricultural sector contribution to climate change, is becoming an increasing issue, gaining more importance for different kind of drivers: the increasing long term trend in emissions (mostly in developing countries), the need for resource efficiency in the sector and, mostly, the sharing of the emission reduction effort among countries and economic sectors.

The European strategy to combat climate change, for the agricultural sector, is represented by the Effort Sharing Decision (ESD. Dec. n. 406/2009/EC) that establishes annual binding GHG emission targets for sectors not included in the EU Emissions Trading System (ETS) (such as transport, buildings, agriculture and waste) for the Member States for the period 2013-2020. The EU-level reduction target is -10% in 2020 from the 2005 baseline and each Member State is expected to contribute to this effort in different percentages, according to its GDP per capita.

While agricultural emission reduction targets are clear, however, policies that are expected to assist these achievements are more questionable. On the one hand, several EU environmental policies, e.g., the Nitrates Directives and the Renewable Energy Directive, may have a direct influence on agricultural activities. On the other hand, the Common Agricultural Policy (CAP) itself plays a critical role. Most CAP measures have the potential to influence greenhouse gas emissions from agriculture, even if they are not directly aimed to GHG mitigation. The European Environment Agency database on climate change policies and measures[2] acknowledges that, within the agricultural sector, most EU or Member States policies are generally not specifically aimed at climate change mitigation but they are still relevant. For instance, they are likely to have a significant positive/negative effect on agricultural N_2O emissions by reducing/increasing the amount of nitrogen inputs (Doorn A. van *et al.*, 2012). Thus, the Common Agricultural Policy is one of the main drivers of emission trend in the agricultural sector, even it has not a climatic objective *strictu sensu*.

The impact of the CAP, and of its reforms, on agricultural GHG emissions over time is the combination of measures supporting production and income, on the one hand, and of more recent environmentally targeted interventions, on the other hand. In the last two decades, in particular, a major role in this respect can be attributed to the gradual shift of support from coupled to decoupled payments, and to the progressive introduction of measures providing incentives, or obligations, towards sustainable and low-impact practices and activities (European Environment Agency, 2012 :439; Baldock *et al*. 2007).

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[2] Available at the following url: http://www.eea.europa.eu/themes/climate/pam

The FR and the “new” rural development policy approved in 2005 include a series of measures that are expected to contribute to the protection of the environment and nature conservation. In the first pillar, the combination of decoupling of support and of the mandatory Cross Compliance and Good Agricultural and Environmental Conditions (GAEC) regulation was expected to provide a stimulus towards better emission performance. More importantly, several second pillar measures might have been associated to a reduction of GHG agricultural emission: measures supporting compliance with environmental legislative requirements (e.g. *Water Framework Directive payments*); measures supporting the provision of environmental services on a voluntary basis (*agri-environmental measures*); measures related to animal welfare. The emphasis on agricultural GHG emission performance increases in the recent CAP reform. For programming period 2014-2020, climate action is one of the three key objectives of the CAP, both in pillar I, with the greening payment linked to the duty of agricultural practices beneficial for the climate and the environment, and in pillar II, with the climate action being a cross cutting objective of the whole rural development policy (RDP) and of two specific priorities (4 and 5) (Council of the European Union, 2013a and 2013b).

According to Coderoni and Esposti (2014), during its history the CAP initially favoured activities with higher GHG emission intensity, while, successive reforms helped to mitigated the emission potential of agriculture especially reorienting production to market and favouring more environmental-friendly practices and technologies. In fact, Coderoni (2010) concludes that EU policy interventions and reforms, mostly the CAP, that affected more the agricultural GHG emissions concerned dairy and meat (mostly beef) production, as they induced a substantial reduction of the number of animals. In any case, the actual role of the CAP in affecting the agricultural CF is still questionable. Hence, analysing the impact of the FR and of specific second pillar’s measure on farm-level GHG emissions is crucial to understand to what extent the CAP may really affect and possibly improve the emission performance and, thus, contribute to reach the European ambitious mitigation targets also at the sectoral level.

4. The FADN Sample

As the objective here is to assess the evolution of the GHG emission and of the CF in Italian farms with specific attention on the role played by the CAP (the 2005 first pillar’s reform and some specific second pillar’s measures), the sample under investigation has to satisfy some specific requisites. The sample must be a balanced panel not just a cross-sectional sample and must contain all the needed information to compute the GHG emission and CF at the farm level as well as all the other farm-level variables that might significantly affect these performances. Finally, with respect to the time dimension, sample farms have to be observed over the pre and post-treatment periods (before and after 2005).

These conditions can be met by extracting a constant sample of farms yearly observed over the pre and post-2005 period. This balanced panel is extracted from the FADN (RICA) database. Though FADN database also covers years prior to 2003, the sampling and data collection procedures and criteria do not allow reconstructing a balanced panel backward. Moreover, adding years 2000-2003 in the pre-treatment period can be troublesome as they may still incorporate some effects of the previous CAP reform (Agenda 2000). Thus, a 2001-2007 comparison, for instance, would overlap different CAP reforms and would mix-up different policy treatments. Year 2008 could also be added but some significant changes in FADN data collection would make year-by-year comparison more difficult. Moreover, the huge price turbulence observed in agricultural markets in 2008 (Esposti and Listorti, 2013) suggests particular caution in adding this year to the post-treatment period. Farmers' behaviour, as well as farms' performance, might be strongly affected by this price bubble and this year could confound permanent responses due to policy treatment with those temporarily induced by peculiar market conditions.

It is worth reminding that the FADN sample is not fully representative of the whole national agriculture. The reference population from which the FADN sample is ideally drawn, in fact, excludes a significant (at least in terms of numerosity) amount of Italian farms (those with Economic Size<4 ESU, that is, less than 4,800 Euro of Standard Gross Margin).[3] In this respect, the FADN sample is only representative of a sub-population of Italian farms, those farms that can be here refereed as professional or commercial farms (Cagliero *et al.*, 2010; Sotte, 2006). A second aspect to be considered here is that the Italian RICA sample is not entirely obtained drawing a random sample from this reference population. A small part of the sample is actually constituted by voluntary participation of farms. Nonetheless, it is possible to extract from the larger FADN constant sample a restricted sample of farms containing all the needed information to compute the respective CF and that can be actually considered as a random extraction from the underlying FADN reference population according to the ISTAT (the Italian Institute of Statistics) criteria (Cagliero *et al.*, 2010). This sub-sample contains 6,542 farms observed over years 2003-2007. The present analysis is performed on this balanced panel. The annex 1 displays the geographical distribution of these sample farms over the Italian provinces (NUTS III level). It may be noticed that these farms are quite homogeneously distributed across the national territory. Though the sample may tend to concentrate

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[3] According to 2000 Census data, more than 82% of Italian agricultural holdings had an economic size smaller than 8 ESU but they accounted for just 27% of total Italian agricultural area (Sotte, 2006). According to 2010 Census data, about 67% of Italian agricultural holdings has an economic size smaller than 18 ESU but they account for just 17% of total Italian agricultural area (Sotte and Arzeni, 2013).

in some specific provinces and, thus, the across-province distribution may be biased and not representative, the scattering of farms across the Italian macro-regions (North-West, North-East, Centre, South and Islands) well represents the pretty diverse agricultural conditions and structures of these different parts of the country.

5. The empirical evidence

This section reports the results of the CF calculation, expressed in tonnes of CO_{2e}, over the balanced FADN sample. The analysis of the emerging evidence only concerns some descriptive indicators about the evolution of the CF over time and the difference across farm typologies (section 5.1) and, then, about the relationships emerging between this evolution and the first and second pillar of the CAP (section 5.2). Though the objective here is not to formally test for the causal relationship between CAP measures and reforms and the CF performance, this latter evidence will be interpreted as a possible empirical support to the existence of this causal linkage.

5.1 Agricultural GHG emission over sectors, space and time

Table 3 reports the evolution of per farm average CF from 2003 to 2007 distinguishing the total emission performance among its five emission categories. Some major regularities clearly emerge. First of all, of the categories under consideration, some are clearly dominating the total amount of emissions while others are, in fact, negligible. In the latter case, we may appreciate how the CF associated to land use and its changes are insignificant compared to all other categories. In the former case, we can mention the CF associated to livestock and related activities, representing by large the most important source of emission at the farm level. Fertilizers CF also as a remarkable role like fuel CF, an expect that it is often disregarded in the empirical studies on the agricultural contribution to the GHG (Coderoni and Esposti, 2014) as it is attributed to the transportation (i.e. energy) sector rather, than to agriculture.

It is worth acknowledging that, as detailed in previous sections, the CF associated to land use here only considers the agricultural land use. So forestry and related activities are not investigated due to the lack of appropriate and complete information in the FADN dataset in this respect; only data on poplar plantations and few other species are accounted for. Nonetheless, it remains true that these results seem to downsize the emphasis put on land use changes in terms of mitigation of the agricultural contribution to overall GHG emissions, at least in the way that these emissions are accounted following IPCC methodology (see chapter 2.2). As a consequence, also the relevance of the appropriate procedures to compute this component (Land Use – A vs. Land Use – B, in the present case) seems to be slightly overemphasised, thus in the following analysis, only the Land Use – A will be used to obtain the total CF, as it more coherent with the other CF estimation methodology.

A second major evidence emerging from Table 3 consists in the very high cross-farm variability of the computed CF and that can be observed, without significant difference, in all CF categories. On the one hand, this variability can be considered the natural consequence of the large farm heterogeneity that eventually affects also the respective CF performance: size, production specialization, all these aspects largely affect the CF at the individual farm-level. On the other hand, a large variability prevent from deriving clear-cut conclusions on the evolution of the CF over time since, in fact, confidence intervals built around the observed average values across years are largely overlapping.

Though inconclusive, however, this evolution indicates no CF categories experience a decrease, on average, over the period under study. Many CF categories are almost stable: livestock CF and fuel CF show a very limited growth like Land use CF, whose impact on overall CF's evolution is, however, negligible. On the contrary, the largest increase in terms of CF can be observed for the cultivation CF.

Such major heterogeneity in terms of emission performance emerges in Table 4 where the total CF is reported per group of farms in terms of economic size (ES), physical size (UAA) and production specialization. Size evidently matters: the larger the economic and physical size of the farm, the larger is its expected CF. The correlation coefficient between the farm-level CF and the farm UAA is positive (0.2). Nonetheless, the highest growth over the 2003-2007 period is observed in smaller farms though, once again, the large variability of the computed CF makes such comparison across sub-samples largely inconclusive.

Among the different agricultural specializations, Table 4 clearly highlights that only activities associated to livestock show a stabilization (0.1) of CF over the period under study. This is not generalized, in fact, mixed farm-a very large category according to this classification-still show an increase of the CF. Nonetheless, it is confirmed that the largest, if not the only, significant experience of GHG emission stabilization within the Italian agricultural of the last decades is essentially related to the decline of livestock activities or, at least, to major changes in the their organization and management (Coderoni and Esposti, 2014).

To conclude this overview of the 2003-2007 evolution of the farm-level CF, it is worth providing some details on the geographical differences. Map 1 reports the per farm average CF at the geographical level of Italian NUTS 3 regions (provinces). It must be noticed that, even if the geographical coverage of the adopted FADN balanced sample is quite homogeneous across whole country, it remains true that statistical representativeness may be severely questioned in several provinces. For this same reason, it seems not appropriate to investigate CF evolution at a more disaggregated geographical level (for instance, municipalities). Moreover, to take the different average farm size across the highly heterogeneous Italian agriculture, the comparison is made on the basis of the CF per hectare of UAA (CF/UAA). Having these caveats in mind, Map 1 shows how the highest average CF values tend to concentrate in those provinces with the highest livestock specialization (especially milk and beef production), that is, most provinces between the alps and the Pianura Padana. A different picture emerges when the 2007-2003 variation is considered. Though positive and negative cases are spread over all the Italian territory, highest growth values tend to concentrate in the North-East and in the South of the country, while the best performance are mostly observed in Central Italian provinces. This trend is highly linked to livestock intensity as shown in annex 2 which plots the distribution of livestock units across Italian municipalities, based on 2010 agricultural census data.

5.2. GHG emissions and the CAP's pillars

The possible linkage between CF evolution over time and the CAP is twofold. On the one hand, we may argue that the reform of the first pillar of the CAP approved in 2003 and implemented (at least in Italy) in 2005, has an impact on farm-level CF both because the decoupling of support reoriented farm's production choices to market and because of the cross-compliance environmental constraints introduced therein (Section 5.2.1). On the other hand, the second pillar of the CAP (2000-2006 programming period) delivers several measures that directly and indirectly concerns activities and practices that affect the farm-level CF (Section 5.2.2).

5.2.1 Pillar I

Table 5 reports the per farm average CF within sub-samples distinguished in terms of the intensity of the first pillar support. This intensity is expressed as the ration between the amount of first pillar payments (FPP) received by a given farm and its gross production value. Both values are taken as the yearly averages over the 2003-2007 period. This ratio evidently get rid of the size effects on both FPP and GPV and take into account the shift from coupled payments (years 2003 and 2004) to decoupled payments (or single farm payments) (years 2005, 2006 and 2007). Three sub-samples are compared: farms for which the incidence of FPP on GPV on is almost negligible (<10%) that are almost 3,500 farms; farms for which it is moderate (>10%, <30%) almost 800 farms; farms for which it is high (>30%), almost 700.

Results show that in all sub-samples the CF increases over time but this growth is higher in farms with a lower incidence of the CAP while, on contrary, farmers depending on first pillar's support show less growing emission performance. The statistical correlation occurring between FPP and CF tends to be negative in the levels and with the variation of the CF, however, and when the variation is considered, this correlation is lower.

5.2.2 Pillar II

Table 6 finally shows a preliminary assessment of the linkage between second pillar's payments and the farm-level CF and its evolution. Actually, all 2003-2007 second pillar's payments refer to the 2000-2006 programming period and, therefore, to the respective RDP policy (measures) as even the 2007 payments still were the finalization of the previous programming period. Here we consider two different sub-samples of farms. The "With second pillar payments" group includes farms that received, over the 2003-2007 period, at least one of the following payments: F1-Low environmental impact; F2-Organic Farming; H-Afforestation-costs of planting; H-Afforestation-maintenance; H-Afforestation-loss of revenue; I1-Afforestation non-agricultural areas; E-LFA; I6-Reforestation for natural disturbances. The "No second pillar payments" group includes all other farms. The same simple argument is adopted to separate the sub-sample "With F1 payments" from the group of "No F1 payments" farms. This latter comparison (lower part of Table 6) aims at assessing the specific role of measure F1 ("Low environmental impact") on CF performance and evolution.

Results highlight that if we consider the whole second pillar support, clear difference emergences between farms that receive the payments and those that do not receive anything. The latter, however, tends to have an higher CF in 2003 but a much more virtuous behaviour over time with a strong decline than makes the CF of the excluded farms higher than the supported ones. This also explains why the correlation coefficient between second pillar payments and CF is positive in both 2003 and 2007 but becomes negative when the 2007-2003 variation is take into account.

6. Some Concluding Remarks

This paper wants to represent a first step in the direction of investigating the role of the CAP in affecting the agricultural GHG emission, i.e., the agricultural footprint. This is one of the main declared objectives of the 2014-2020 CAP reform so it deserves appropriate empirical investigation and support. Nonetheless, this empirical background is largely lacking mainly because it requires an appropriate farm-level reconstruction of the emission performance, that is, of the farm-level CF. Then, the possible causal relationship between the observed evolution of the CF over time and specific CAP payments and measures can be also investigated. The present papers aims at providing a tentative estimation of the farm-level CF and linking it to the farm-level delivery of CAP payments (both first and second pillar).

In this respect, results here obtained are interesting and encouraging but several improvements seem needed to achieve more conclusive evidence and, thus, to inform the debate and the decisions about the proper policies. Therefore, this works represents just an initial, though necessary, step in the direction a more formalized test on the contribution of the CAP (both pillars), to mitigate agricultural GHG emission. Starting from here, future researches are expected to put forward appropriate theoretical concepts, models and econometric approaches to make this assessment more sound and robust.

Tables and Figures

Table 1. Agricultural emission sources considered in the study

IPCC CATEGORY	SOURCE	GHG
4A	Enteric Fermentation	CH_4
4B	Manure Management	N_2O, CH_4
4C	Rice	CH_4
4D	Agricultural Soils	N_2O, CH_4
1A	Energy	CO_2
5A	Forest land	CO_2
5B	Cropland	CO_2
5C	Grassland	CO_2

Table 2 Summary of GHG emission sources considered and the respective FADN activity data used

Emission sources	**CF category**	**FADN data**
N_2O manure management	CF livestock	Animal numbers
CH_4 manure management	CF livestock	Animal numbers
CH_4 enteric fermentation	CF livestock	Animal numbers
CH_4 rice cultivation	CF cultivation	Rice area (UAA)
N_2O agricultural soils	various	
Direct emissions		
Use of synthetic fertilisers	CF fertilizer	Fertilisers expenditure
Biological N fixation	CF cultivation	N-fixing crop area
Crop residues	CF cultivation	Crop area (UAA)
Indirect emissions[1]		
Atmospheric deposition	CF fertilizer/IC cultivation	Fertilisers and animal numbers
Leaching and run-off	CF fertilizer/IC cultivation	Fertilisers and animal numbers
CO_2 Energy	CF Fuel	Fuel expenditure
CO_2 Forest land	CF Land use	UAA
CO_2 Cropland	CF Land use	UAA
CO_2 Grasslands	CF Land use	UAA

Source: Authors' elaborations

[1] Indirect emissions of N_2O linked to N application to agricultural soils are accounted for in the CF fertilizers and CF crops.

Table 3 2003-2007 evolution of the farm-level CF distinguished into the five macro categories of emissions (ton CO_{2e} per farm avg.; standard deviation in parenthesis)

Emission category:	**2003**	**2004**	**2005**	**2006**	**2007**	**Var. 2007-2003 (%)**
CF Fuel	25,9	27,1	29,8	31,4	32,6	0.9
	(60,0)	(60,4)	(67,4)	(68,7)	(70,5)	(10.2)
CF Cultivation	14,1	14,3	14,3	14,8	14,9	53.4
	(137,1)	(138,9)	(139,4)	(140,7)	(141,3)	(792.4)
CF Fertilizers	45,0	57,6	58,8	58,3	64,8	2.1
	(157,1)	(178,2)	(198,9)	(179,0)	(190,5)	(14.5)
CF Livestock	99,2	100,4	101,0	101,6	100,0	0.1
	(432,3)	(451,3)	(474,7)	(503,8)	(491,2)	(2.9)
CF Land Use – A [1]	-3,3E-03	-3,3E-03	-3,1E-03	-3,1E-03	-3,1E-03	0.02
	(1,4E-02)	(1,5E-02)	(1,9E-02)	(1,8E-02)	(1,8E-02)	(0.9)
CF Land Use – B[1]	5,8E-03	6,0E-03	6,0E-03	6,0E-03	6,0E-03	0.04
	(1,9E-02)	(2,1E-02)	(2,3E-02)	(2,3E-02)	(2,3E-02)	(0.9)
CF Total – A	184,1	199,3	203,9	206,1	212,4	14.3
	(563,7)	(584,5)	(623,7)	(642,9)	(644,3)	(1087.5)
CF Total – B	184,1	199,3	203,9	206,1	212,4	14.3
	(563,7)	(584,5)	(623,7)	(642,9)	(644,3)	(1087.5)

[1] CF of land use reports negative values for emissions and positive values for removals

Source: own elaboration

Table 4 2003-2007 evolution of the farm-level total CF across different farm typologies (ton CO_{2e} per farm avg.; standard deviation in parenthesis)

Farm typology:	**2003**	**2004**	**2005**	**2006**	**2007**	**Var. 2007-2003 (%)**
ES:						
ES 3-4	25.2	29.3	30.0	32.1	32.6	33.7
	(25.3)	(26.3)	(32.9)	(41.5)	(37.2)	(1697.2)
ES 5-6	120.0	132.7	134.3	120.3	124.8	0.8
	(152.9)	(154.4)	(147.2)	(128.2)	(129.1)	(4.0)
ES>=7	887.4	932.8	992.1	965.4	989.2	0.7
	(1304.7)	(1336.5)	(1461.9)	(1473.1)	(1462.1)	(3.1)
UAA:						
UAA < 10 ha	46.6	53.3	54.1	53.7	53.9	29.2
	(140.3)	(144.0)	(166.1)	(142.6)	(135.0)	(1576.3)
UAA 10-50 ha	145.2	157.8	157.3	158.1	166.9	0.8
	(254.7)	(251.5)	(250.6)	(252.2)	(263.6)	(2.6)
UAA >50 ha	719.0	762.7	784.0	791.7	804.9	0.5
	(1238.4)	(1282.4)	(1374.3)	(1427.2)	(1416.2)	(1.6)
Correlation coefficient UAA-CF						0.2
Specialization:						
Crops	149.2	168.4	174.4	175.4	185.1	1.0
	(425.2)	(425.2)	(486.8)	(470.9)	(485.9)	(4.3)
Permanent crops	44.4	59.8	62.1	64.2	70.0	1.3
	(121.9)	(121.9)	(131.9)	(144.0)	(154.5)	(3.8)
Livestock	425.2	434.5	439.8	442.8	442.8	0.1
	(885.5)	(885.5)	(1002.0)	(1018.8)	(979.8)	(0.5)
Mixed crops and livestock	196.2	211.6	216.4	219.9	229.2	83.3
	(651.2)	(651.2)	(678.8)	(767.1)	(820.0)	(2696.7)

Source: own elaboration

Table 5 Farm-level total CF (ton CO_{2e}) and first pillar payments, FPP (avg. 2003-2007) (per farm avg.; standard deviation in parenthesis)

Farm groups:	**2003 CF**	**2007 CF**	**Var. CF 2007-2003 (%)**
FPP/GPV <10%	201.5	212.7	36.5
	(588.5)	(664.9)	(1,906.9)
FPP/GPV 10-30%	46.3	48.2	3.0
	(84.7)	(82.9)	(9.9)
FPP/GPV 30%	31.7	35.0	3.7
	(70.4)	(76.1)	(15.1)
Correlation coefficient FPP – CF	-0.10	-0.09	-0.01

Source: own elaboration

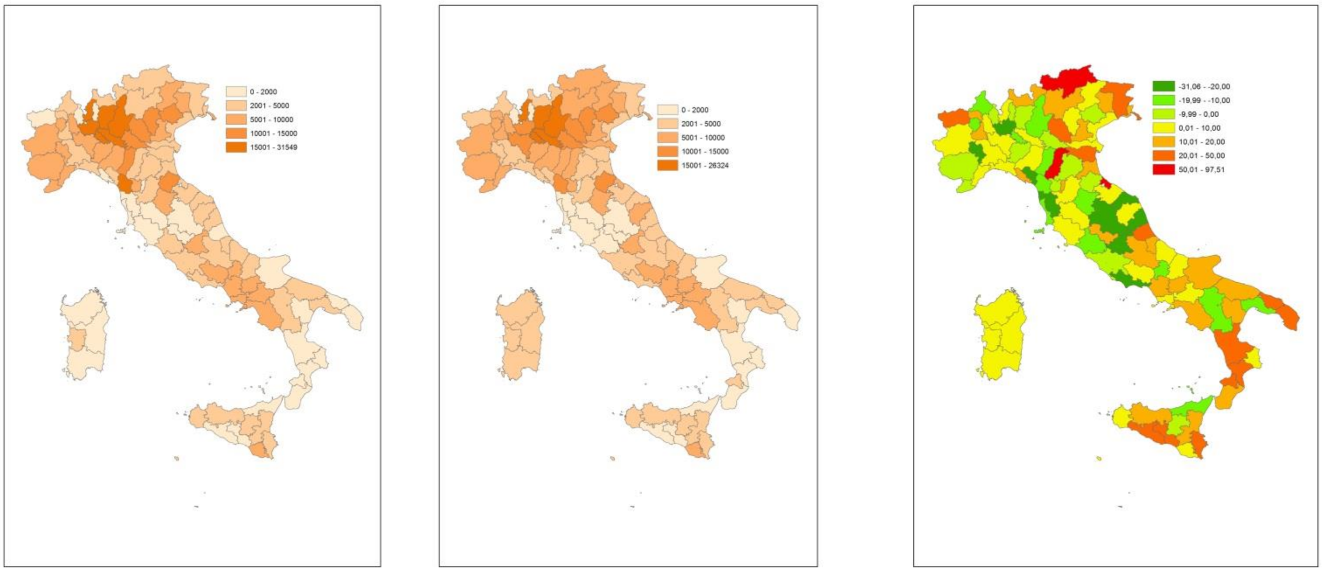
Table 6 Farm-level total CF (ton CO_{2e}) and second pillar 2003-2007 payments (per farm avg.; standard deviation in parenthesis)

Farm groups:	**2003 CF**	**2007 CF**	**Var. CF 2007-2003 (%)**
With second pillar payments	242.0	141.1	-42.0
	(812.2)	(314.5)	(84.49)
No second pillar payments	145.0	162.0	12.0
	(461.6)	(579.3)	(16,628.1)
Correlation coefficient second pillar payments-CF (a)	0.4	0.5	-0.1

Source: own elaboration

(a) only farms with second pillar payments

Map 1 Farm-level total CF/UAA (Kg CO_{2e}) across Italian provinces and over time: 2003 (a), 2007 (b), var. 2007-2003 (%) (c)


(a) (b) (c)

Source: own elaboration

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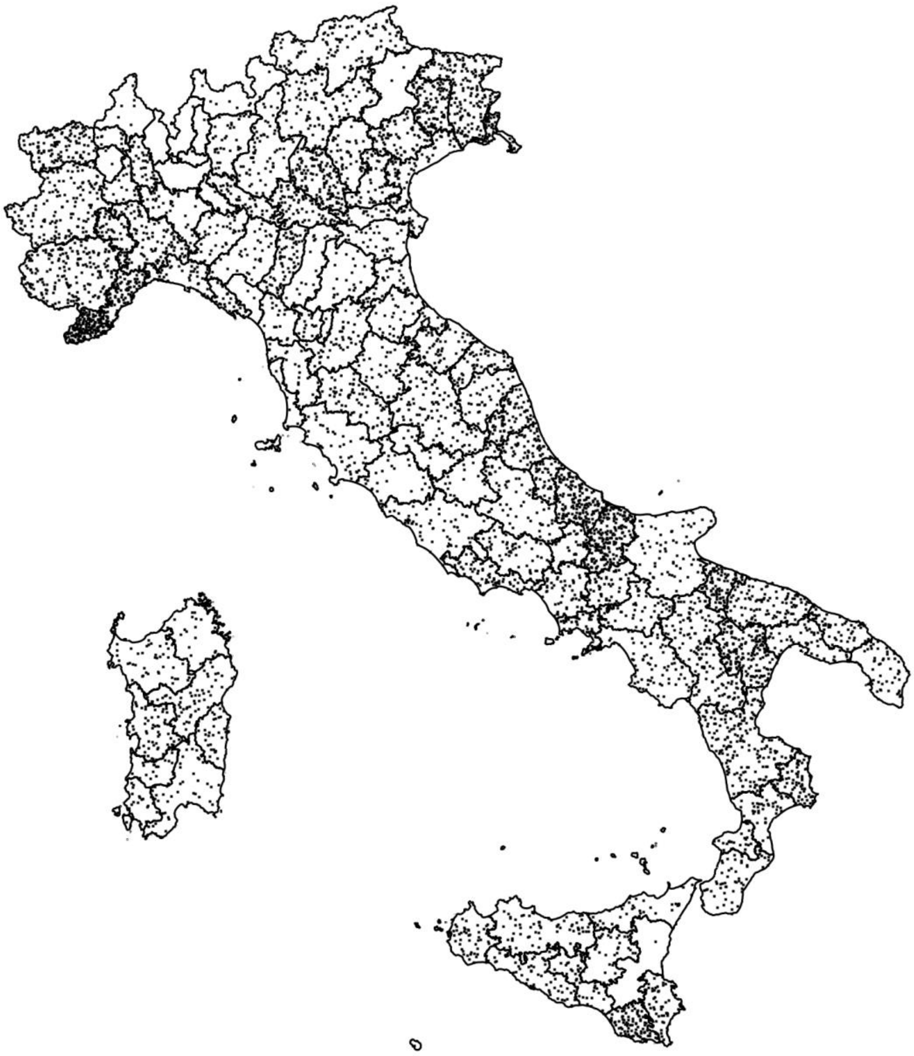
ANNEX 1**:** Distribution of the sample farms across Italian provinces (NUTS III level).



ANNEX 2**:** Distribution of livestock unit per UAA across Italian municipalities in 2010

Source: own elaboration