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Keywords: *Animal welfare; Emission; EU policy; Livestock; Rural development.*

JEL codes: Q18, Q51, Q53, Q56

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Abstract

The livestock sector has a large influence on direct and indirect (via land use change) greenhouse gas emissions, with potential negative impacts on climate change. We quantify the environmental impacts related to the introduction of a voluntary animal-based policy supported by the European Union (EU), the Measure 14 of Rural Development Programmes 2014-2020 on animal welfare. In particular, we focus on methane and nitrous oxide emissions (direct impacts), and on carbon-based and nitrous oxide emissions from land use change (indirect impacts). Our case study is the dairy sector of the EU Member States. We found that the animal-based measures have (on average) limited environmental impacts, although marked differences exist across Member States.

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1. Introduction

Agriculture, while sustain food production, is responsible of large environmental impacts (Tricase et al., 2018). Agricultural activities, such as intensive livestock, fertilisation, land use and management, are important contributors of greenhouse gas (GHG) emissions with consequences in terms of climate change (Baldoni et al., 2018). The global emissions from agriculture are expected to increase, due to a growing demand for food and diet changes (Hadorn et al., 2015; Santeramo et al., 2018).

The sustainable intensification of agriculture has become a political priority to address food security and environmental concerns (Baldoni et al., 2018; Santeramo et al. 2019), and looked for through marketing strategies, such as labels and claims (Santeramo and Lamonaca, 2020). At the farm level, increasing agricultural production per unit of input, while ensuring the minimisation of environmental emissions, is a win-win strategy that allows the equilibrium between sustainability and productivity (Feliciano et al., 2013).

A trade-off between efficient production and environmental sustainability may be achieved through agricultural policies that link mandatory measures with specific voluntary measures at a regional scale (Berger et al., 2006). Mandatory and voluntary measures have been longstanding part of the Common Agricultural Policy (CAP) of the European Union (EU). In the CAP 2014-2020, mandatory measures of cross-compliance[1] are reinforced in order to achieve better environmental performances: the EU farmers receive financial support, conditional to the respect of strict rules on human, animal, and plant health and welfare, in the form of direct payments (Cortignani and Dono, 2018). The direct payments include a basic payment and additional (green) payments for farming methods that go beyond a basic environmental protection (Coderoni and Esposti, 2018). By complementing mandatory measures, voluntary measures are part of regional Rural Development Programmes (RDPs) (Venghaus and Hake, 2018): they compensate farmers for costs arising from specific management activities defined by the environmental requirements (Berger et al., 2006).

Several recent studies highlight the positive role of the support provided by the CAP, particularly via the green payments, in influencing environmental performances of the agricultural sector (e.g. Solazzo et al., 2016; Cortignani et al., 2017; Cortignani and Dono, 2018). However, to the best of our knowledge, studies on the environmental implications of policies covering the livestock sector are lacking. The livestock sector is a main contributor of environmental burdens

[1] The Council Regulation (EC) No. 73/2009 ratifies a mandatory 'cross-compliance' (Chapter I), based on which a farmer receives direct payments conditional to the compliance with Statutory Management Requirements (Article 5, Annex II) and Good Agricultural and Environmental Condition (Article 6, Annex III).

(Steinfeld et al., 2006): although animal-based policies are thought improve productive efficiency of livestock, their implications in terms of climate change should not be neglected.

At the EU level, a mandatory measure of cross-compliance lays down minimum standards for the protection of animals that Member States have to achieve (Council Regulation (EC) No. 73/2009, Article 5(1c)). In addition, a voluntary compliance scheme supported by the Regulation (EU) No. 1305/2013 (Article 33(4)), the Measure 14 of Rural Development Programmes (RDPs) 2014-2020, compensates livestock farmers for the incremental costs of ensuring higher animal welfare levels (e.g. improvement of the housing conditions), providing annual subsidies (Ingenbleek et al., 2012). A simulation of the environmental impacts would help in understanding if animal-based policies move in the same direction of greening requirements of the CAP and address the challenge of mitigating the adverse effects of climate change.

We quantify direct (methane and nitrous oxide emissions) and indirect (carbon-based and nitrous oxide emissions from land use change) environmental impacts associated with the adoption of the Measure 14. Our focus is on dairy cattle farms in the EU Member States. We comment on technical and political considerations and conclude on how the measure may conciliate environmental and ethical issues. Our contribution would be of interest for policymakers that are planning to implement animal-based policies.

2. The livestock sector: environmental quality and animal welfare

The livestock sector is recently receiving high pressures to improve production practices in two seemingly opposite directions: environmental quality and animal welfare (Place and Mitloehner, 2014). While livestock production contributes to increase soil carbon stocks by compensating approximately one-third of on-site grassland carbon sequestration (Soussana et al., 2010), it may also threaten the quality of the environment. Indeed, the livestock sector exerts a large influence on global greenhouse gas (GHG) emissions (Feliciano et al., 2013), responsible of climate change: livestock-related emissions mainly concern methane (CH_4), nitrous oxide (N_2O), and carbon dioxide (CO_2).

A by-product of enteric fermentation is CH_4, ruminants (e.g. cattle) being main contributors; the manure management system influences the amount of CH_4 and N_2O emissions produced; deposition of dung results in additional direct and indirect N_2O emissions (Garnett, 2009).

Studies suggest that direct CO_2 emissions are negligible as compared to CH_4 and N_2O emissions (e.g. Schils et al., 2005; Olesen et al., 2006; Garnett, 2009). However, CO_2 emissions do matter if land (the main input of livestock rearing) is taken into account (Garnett, 2009). In fact, the progressive land use change, due to expansion of pasture and feed crops, determines 8% of global CO_2 emissions, causing second order impacts on the environment, by contributing to change climatic conditions. Further issues, related to the land use change, include: increase of water consumption; trade-off between growing crops for feeding animals versus humans; opportunity cost of using land to rear livestock, rather than to grow food for direct consumption (Steinfeld et al., 2006). For instance, CO_2 emissions are significantly lower for plant-based food than for livestock products (e.g. 0.4 kg of CO_2 per kg of in-season lettuce as compared to 16 kg of CO_2 per kg of beef) (Edwards-Jones et al., 2008). However, Mekonnen and Hoekstra (2012) suggest that the relatively large water footprint of animal products as compared to crop products with equivalent nutritional value[2] may be associated with the unfavourable feed conversion efficiency for animal products. Thus, it is advisable to give attention to feed composition, feed water requirements and feed origin. Similarly, Grossi et al. (2017), by comparing the carbon footprint intensity of cow milk and soymilk in relation to their nutritional values, demonstrate that GHG emissions associated with animal food products approximately lie within the range of emissions related to vegetal origin products, due to the greater biological value of proteins and higher content of fat.

[2]Mekonnen and Hoekstra (2012) found that the average water footprint per calorie is 20 times larger than for cereals and starchy roots, and the water footprint per gram of protein for milk, eggs and chicken meat is 1.5 times larger for beef than for pulses.

Overall, studies on the GHG emissions associated with livestock rearing conclude on the higher intensity of GHG emissions, at the farm stage, of livestock products as compared to other food production (e.g. Cederberg and Stadig, 2003; Casey and Holden, 2006; Lovett et al., 2006). However, differences in nutritional values of animal- and plant-based products should not be neglected[3].

Given the relevant contribution of livestock in terms of direct and indirect (land use related) GHG emissions (table 1), great environmental burdens are likely to be associated with the increasing demand for animal-based food, with potential consequences on climate change. In this regard, the livestock sector is likely to experience increases in productivity in the next future, in order to meet new consumption patterns of meat and dairy produce, expected to be 73% and 58% greater by 2050 (FAO, 2011). The increase in productivity levels in the livestock sector may have a twofold effects in terms of emissions, depending on the efficiency of farm. Farms producing in a regime of efficiency may be able to reducte the emissions per unit of production: for instance, Dono et al. (2013) suggest that reducing the calving interval is an efficient and green practice due to the reduction of the amount of food provided to animals and of the lower enteric fermentation per unit of product. Differently, less efficient farms need to plan investment and to modernize their production processes in order to meet the challenge of reducing emissions while maintaining high production levels.

[3] As suggested by a reviewer, the environmental impacts of food products may be significantly different compared to the nutritional value of products.

Table 1. A synthetic outline of the literature on the environmental impacts of the livestock sector.

Environmental impacts	Greenhouse gas emissions	Determinants	References
Direct	Methane (CH_4)	Enteric fermentation Manure management	Cederberg and Stadig (2003) Casey and Holden (2006) Lovett et al. (2006) Steinfeld et al. (2006) Garnett (2009) Havlík et al. (2012) Feliciano et al. (2013)
	Nitrogen (N_2O)	Leaching nitrates	
Indirect	Carbon dioxide (CO_2)	Deforestation Expansion of pasture and feed crops Water consumption Competition human/animal feed	Cederberg and Stadig (2003) Schils et al. (2005) Casey and Holden (2006) Lovett et al. (2006) Olesen et al. (2006) Steinfeld et al. (2006) Edwards-Jones et al. (2008) Garnett (2009)

Further, the need for farmers to produce efficiently may prevents them from considering ethical issues (Hadorn et al., 2015). A revised problem farming should focus on interventions which aim at ensuring efficient production levels, without reducing animal welfare conditions (Hadorn et al., 2015). Adopted as an indicator of livestock performances, animal welfare may be also a criterion of sustainability and a strategy designed to reduce the carbon footprint of livestock production (Llonch et al., 2017). But how may animal welfare contribute to the reduction of GHG emissions from livestock? Garnett (2009) suggest an approach based on the reduction of livestock numbers, which leads to genuine GHG benefits: the trade-off consists in higher emissions per unit, outweighed by a significant reduction in numbers of unit[4]. Such an approach affects, in particular, the housing conditions and is in line with the European Convention for the

[4] As suggested by a reviewer, an approach based on the reduction of livestock numbers certainly have a high ethical value, but a less defined outcome in reducing emissions. Indeed, the positive effects in terms of GHG saving of a reduction in the livestock numbers are more likely to be associated with efficient farms, rather than with less efficient ones..

Protection of Animals kept for Farming Purposes, which outlines general principles intended to avoid unnecessary pain, suffering or injury due to unsuitable housing, environmental, and feeding conditions.

3. Methodological approach

3.1 The study area

According to data from Rural Development Programmes (RDP) 2014-2020, in the European Union (EU), the Measure 14 has been adopted in 13 Member States (Austria, Bulgaria, Croatia, Cyprus, Czech, Estonia, Germany, Hungary, Italy, Slovakia, Slovenia, Spain, Sweden) and in most of cases refers to the improvement of the housing conditions[5] (table 2).

In 2013, 24% of total EU livestock units (LUs) are cattle (Faostat, 2019): the diffusion of cattle livestock raises environmental concerns. In fact cattle, dairy cattle in particular, are main sources of direct greenhouse gas (GHG) emissions from livestock: they account for 58% of livestock nitrous oxide (N_2O) emissions, and for 28% of livestock methane (CH_4) emissions (Hadorn et al., 2015).

[5] The only exceptions are Cyprus and Hungary.

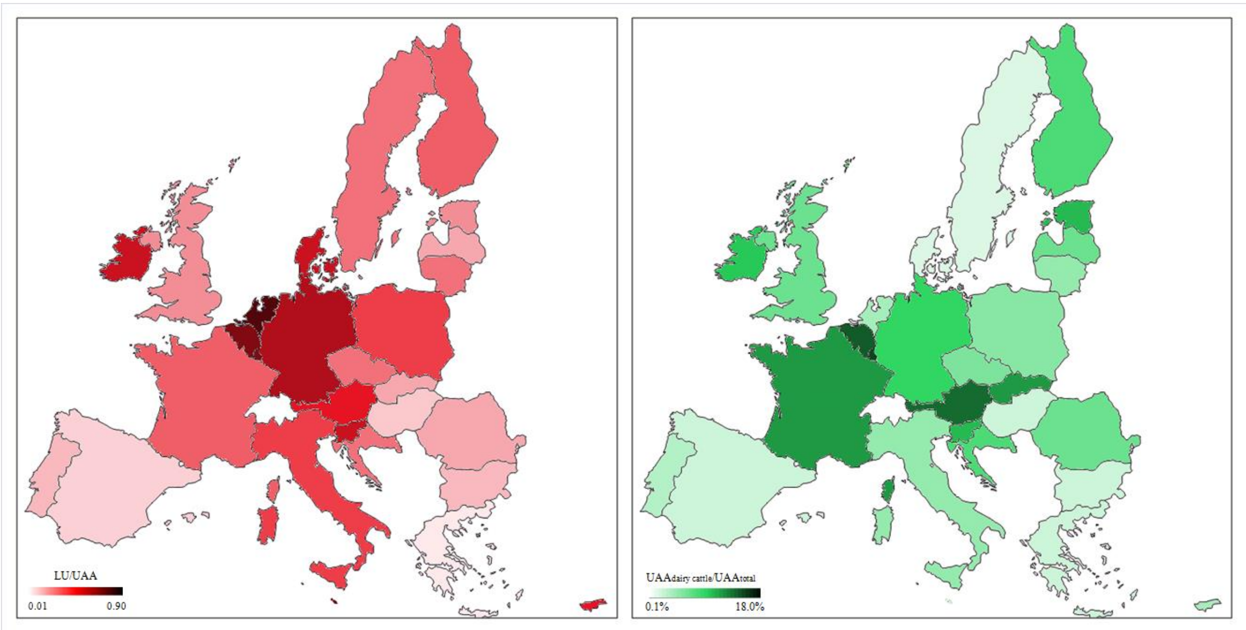
Table 2. Information on the Measure 14 of Rural Development Programmes 2014-2020 and distribution of utilised agricultural area (UAA) and livestock unit (LU) within the study area.

Member States	Measure 14	UAA (ha)		LU (head)	LU/UAA (head/ha)	$UAA_{dairy\ cattle}/UAA_{total}$ (%)
		Total	Dairy cattle			
Austria	Yes	2,726,890	211,610	525,258	0.19	7.76
Belgium	No	1,307,900	142,140	460,307	0.35	10.87
Bulgaria	Yes	4,650,940	13,830	288,749	0.06	0.30
Croatia	Yes	1,571,200	36,800	166,000	0.11	2.34
Cyprus	Yes	109,330	905	20,626	0.19	0.83
Czechia	Yes	3,491,470	51,190	372,748	0.11	1.47
Denmark	No	2,619,340	2,600	582,340	0.22	0.10
Estonia	Yes	957,510	30,890	96,800	0.10	3.23
Finland	No	2,257,630	50,980	283,115	0.13	2.26
France	No	27,739,430	1,243,410	3,697,232	0.13	4.48
Germany	Yes	16,699,580	440,170	4,267,611	0.26	2.64
Greece	No	4,856,780	16,630	159,276	0.03	0.34
Hungary	Yes	4,656,520	13,990	256,000	0.05	0.30
Ireland	No	4,959,450	144,830	1,163,200	0.23	2.92
Italy	Yes	12,098,890	145,990	1,862,127	0.15	1.21
Latvia	No	1,877,720	37,220	164,600	0.09	1.98
Lithuania	No	2,861,250	30,670	323,499	0.11	1.07
Luxembourg	No	131,040	23,130	46,195	0.35	17.65
Malta	No	10,880	30	6,430	0.59	0.28
Netherlands	No	1,847,570	15,640	1,597,000	0.86	0.85
Poland	No	14,409,870	208,810	2,360,597	0.16	1.45
Portugal	No	3,641,590	12,780	231,000	0.06	0.35
Romania	No	13,055,850	263,120	1,162,700	0.09	2.02
Slovakia	Yes	1,901,610	85,520	150,272	0.08	4.50
Slovenia	Yes	485,760	15,670	111,022	0.23	3.23
Spain	Yes	23,300,220	60,340	856,800	0.04	0.26
Sweden	Yes	3,035,920	6,290	344,021	0.11	0.21
United Kingdom	No	17,096,170	359,380	1,794,000	0.10	2.10
EU-28		174,358,310	3,664,565	23,349,525	0.13	2.10

Source: elaboration on Eurostat and Faostat data.

According to Eurostat and Faostat data, in 2013, 174, 358,310 ha in the EU are devoted to agriculture, of which specialists-dairying account for 19%: in particular, cattle-dairying covers 359,380 ha (2% of specialists dairying) (table 2).

Figure 1. Intensity of livestock units (LUs) per hectare of utilised agricultural area (UAA) and percentage of UAA intended for dairy cattle within the study area.



Source: elaboration on Eurostat and Faostat data.

Data from Eurostat and Faostat show that the greatest utilised agricultural area (UAA) intended to dairy cattle, as compared to the national UAA, are in Luxembourg (17.65%) and Belgium (10.87%), which also have higher intensity of LUs per hectare of UAA (0.35 head/ha). Despite the lower extension of UAA for dairy cattle, the Netherlands and Malta show the highest intensity of dairy cattle livestock (0.86 head/ha for 0.85% of UAA, and 0.59 head/ha for 0.28% of UAA) (figure 1).

3.2 A method to quantify the environmental impacts

We assume that animal-based policies, affecting the housing conditions, are likely to influence greenhouse gas (GHG) emissions. In fact, as suggested in Garnett (2009), the lower the intensity of livestock, the higher the GHG saving. The intensity of livestock may be lowered by increasing the housing areas[6]: a strategy achievable through (i) the reduction of livestock units (LUs) being equal the utilised agricultural area (UAA), or (ii) the increase of UAA intended for dairy cattle being equal LUs. The former approach may reduce direct environmental impacts: the lower the LUs, the lower the GHG emissions in terms of methane (CH_4) and nitrous oxide (N_2O). Vice-versa, the latter approach is likely to produce indirect environmental impacts, in terms of carbon-based (CO_2, CH_4) and N_2O emissions, via land use change (land conversion, burning biomass). The environmental impacts ($EI_{i,j}$) are country (j) and time[7] variant, and depend on the degree of improvement of the housing conditions (α_i):

$$EI_{i,j} = \alpha_i \left(X_{i,j} UAA_j^{-1} \right) EF_{i,j} \tag{1}$$

where i indexes direct and indirect impacts; $X_{i,j}$ is the input affected by the improvement of the housing conditions (i.e. LUs for direct and UAA intended to dairy cattle for indirect impacts); UAA_j is the national UAA. The implied emission factor ($EF_{i,j}$) refers to CH_4 and N_2O for direct impacts, and to C, CO_2, CH_4, and N_2O for indirect impacts. We assume α_i to be negative for direct and positive for indirect impacts: in fact, the improvement of the housing conditions is achievable through a decrease in the ratio LU_j/UAA_j or an increase of $UAA_{dairy\,cattle,j}/UAA_j$. Table 3 lists and describes inputs and emission factors classified by type of environmental impacts.

[6] We select a single indicator (i.e. the density of breeding) to the improvement of housing conditions in the EU countries. However, the indicator is more appropriate for Northern European countries (where production systems are based on pasture) rather than for Southern European countries (where production is mostly based on stables).

[7] The subscript *t* has been removed for clarity.

Table 3. List of inputs and emission factors for direct and indirect environmental impacts, and descriptive statistics.

Variable	Origin	Environmental impact	Unit	Mean	Std. dev.	Min	Max
Livestock units of dairy cattle	-	Direct	head	833,912	1,073,322	6,430	4,267,611
Utilised agricultural area of cattle-dairying	-	Indirect	ha	130,877	241,437	30	1,243,410
Utilised agricultural area	-	Direct, indirect	ha	6,227,083	7,299,547	10,880	27,739,430
Implied emission factor for CH_4	Enteric fermentation, manure management	Direct	kg CH_4/head	130.90	20.89	48.00	161.87
Implied emission factor for N_2O	Manure management, manure applied to soil, manure left on pasture	Direct	kg N_2O-N/kg N	0.05	0.00	0.04	0.05
Implied emission factor for CO_2	Net forest conversion	Indirect	t CO_2/ha	287.31	116.04	75.97	481.83
Implied emission factor for C	Cropland and grassland conversion	Indirect	t C/ha	8.08	3.15	5.15	12.50
Implied emission factor for CH_4	Burning biomass	Indirect	g CH_4/kg dry matter	15.74	10.40	4.70	25.89
Implied emission factor for N_2O	Burning biomass	Indirect	g N_2O/kg dry matter	0.34	0.09	0.26	0.48
Implied emission factor for CO_2	Burning biomass	Indirect	g CO_2/kg dry matter	1,702.96	0.03	1,702.89	1,702.99

Source: elaboration on Eurostat and Faostat data.

Notes: Descriptive statistics refer to the EU Member States in 2013.

4. An assessment of the environmental impacts

In order to examine the extent to which animal-based policies are able to affect the environment, we quantify direct and indirect impacts associated with different improved levels of animal welfare (α_i) for the European Union (EU) in 2013 (table 4). For the sake of argument, we assume five levels of improvement of the housing conditions: from 10% to 50%. Accordingly, and on the basis of equation (1), the reduction of livestock units (LUs) being equal the utilised agricultural area (UAA) reduces the direct emissions of methane (CH_4) and nitrous oxide (N_2O). Vice-versa, the increase of UAA intended for dairy cattle being equal LUs increases indirect emissions of carbon dioxide (CO_2) from forest conversion, carbon (C) from cropland and grassland conversion, CH_4, N_2O, and CO_2 from burning biomass.

The greater the improvement of the housing conditions, the higher the direct greenhouse gas (GHG) saving and the lower the benefits from land use changes. As suggested in Garnett (2009), the reduction of livestock numbers leads to genuine GHG benefits.

Table 4. Direct and indirect environmental impacts related to dairy cattle in the European Union (EU).

Degree of improvement of the housing conditions (α_i)	Direct Environmental Impacts		Indirect Environmental Impacts				
			Forest conversion	Cropland and grassland conversion	Burning biomass		
	Methane emissions (kg CH_4 $head^{-1}$)	Nitrous oxide emissions (kg N_2O-N/kg N $head^{-1}$)	Carbon dioxide emissions (t CO_2/ha)	Carbon emissions (t C/ha)	Methane emissions (g CH_4/kg dry matter)	Nitrous oxide emissions (g N_2O/kg dry matter)	Carbon dioxide emissions (g CO_2/kg dry matter)
±10%	-1.7530	-0.0006	0.6039	0.0170	0.0331	0.0007	3.5792
±20%	-3.5059	-0.0012	1.2077	0.0340	0.0662	0.0014	7.1584
±30%	-5.2589	-0.0019	1.8116	0.0509	0.0992	0.0022	10.7376
±40%	-7.0119	-0.0025	2.4154	0.0679	0.1323	0.0029	14.3167
±50%	-8.7648	-0.0031	3.0193	0.0849	0.1654	0.0036	17.8959

Source: elaboration on Eurostat and Faostat data.

Notes: Elaborations refer to 2013.

Table 5. Direct and indirect environmental impacts related to dairy cattle in the European Union (EU): detail by Member States.

Member States	Total historic and projected GHG emissions)	Direct Environmental Impacts		Indirect Environmental Impacts				
				Forest conversion	Cropland and grassland conversion	Burning biomass		
		Methane emissions	Nitrous oxide emissions	Carbon dioxide emissions	Carbon emissions	Methane emissions	Nitrous oxide emissions	Carbon dioxide emissions
	(Mt CO_2 eq)	(kg CH_4 head^{-1})	(kg N_2O-N/kg N head^{-1})	(t CO_2/ha)	(t C/ha)	(g CH_4/kg dry matter)	(g N_2O/kg dry matter)	(g CO_2/kg dry matter)
Austria	80	-5.3164	-0.0018	5.6972	0.1354	0.0729	0.0040	NA
Belgium	120	-9.7136	-0.0033	8.1744	0.2138	NA	NA	NA
Bulgaria	56	-1.3710	-0.0006	NA	0.0070	0.0151	0.0002	1.0128
Croatia	25	-2.9487	-0.0010	2.2571	0.0586	0.0220	0.0012	NA
Cyprus	8	-1.8111	-0.0017	0.1258	NA	NA	NA	NA
Czechia	128	-2.3487	-0.0010	NA	0.0154	0.0138	0.0008	NA
Denmark	55	-6.1361	-0.0021	NA	0.0010	NA	NA	NA
Estonia	22	-2.7902	-0.0009	1.7369	0.0337	0.1644	0.0028	10.9879
Finland	63	-3.4611	-0.0012	NA	0.0236	0.1160	0.0019	7.6909
France	484	-3.7080	-0.0012	2.5543	0.0975	0.2304	0.0042	15.2672
Germany	942	-7.0532	-0.0024	NA	0.0277	0.0248	0.0014	NA
Greece	103	-0.9556	-0.0003	NA	0.0085	0.0174	0.0003	1.1662
Hungary	57	-1.2140	-0.0005	NA	0.0069	0.0028	0.0002	NA

Ireland	58	-6.4734	-0.0022	1.4331	0.0301	NA	NA	NA
Italy	441	-4.3869	-0.0014	NA	0.0302	0.0113	0.0006	NA
Latvia	11	-2.4194	-0.0008	1.1797	0.0208	0.1011	0.0018	6.7512
Lithuania	20	-3.1205	-0.0010	0.5855	0.0112	NA	NA	NA
Luxembourg	11	-9.7297	-0.0033	NA	0.1853	NA	NA	NA
Malta	3	-19.1330	-0.0055	NA	NA	NA	NA	NA
Netherlands	192	-23.8568	-0.0080	NA	0.0089	NA	NA	NA
Poland	395	-3.6040	-0.0015	NA	0.0152	0.0738	0.0012	4.9355
Portugal	65	-1.9193	-0.0006	0.0814	0.0084	0.0178	0.0002	1.1952
Romania	115	-1.9592	-0.0008	NA	0.0480	0.1044	0.0019	6.8642
Slovakia	43	-1.7385	-0.0007	3.6391	0.0472	NA	NA	NA
Slovenia	18	-6.3081	-0.0021	2.5724	0.0711	0.0303	0.0017	NA
Spain	322	-1.0616	-0.0003	NA	0.0061	0.0025	0.0001	NA
Sweden	55	-3.1275	-0.0011	0.0599	0.0021	NA	NA	NA
United Kingdom	566	-2.8962	-0.0010	NA	0.0225	NA	NA	NA
EU-28	4,458	-3.5059	-0.0012	1.2077	0.0340	0.0662	0.0014	7.1584

Source: elaboration on European Environment Agency, Eurostat, and Faostat data.

Notes: NA stands for ‘not available’. Elaborations refer to 2013. The environmental impacts are computed considering a ±20% improvement of the housing conditions.

Let's assume a ±20% improvement of the housing conditions: the assessment of related direct and indirect environmental impacts for each Member States is in table 5.Reducing LUs being equal the UAA would lower CH_4 emissions by -3.5059 kg CH_4 $head^{-1}$ and N_2O emissions by -0.0012 kg N_2O-N/kg N $head^{-1}$ in the EU. The greatest benefits, in terms of reduced direct environmental impacts, are for the Netherland (-23.8568 kg CH_4 $head^{-1}$ and -0.0080 kg N_2O-N/kg N $head^{-1}$) and Malta (-19.1330 kg CH_4 $head^{-1}$ and -0.0055 kg N_2O-N/kg N $head^{-1}$), followed by Luxembourg (-9.7297 kg CH_4 $head^{-1}$ and -0.0033 kg N_2O-N/kg N $head^{-1}$), Belgium (-9.7136 kg CH_4 $head^{-1}$ and -0.0033 kg N_2O-N/kg N $head^{-1}$), and Germany (-7.0532 kg CH_4 $head^{-1}$ and -0.0024 kg N_2O-N/kg N $head^{-1}$)[8]. The results are particularly relevant for Germany, the Netherland and Belgium: according to the European Environment Agency, Germany is the main contributor of GHG emissions in the EU (942 million t CO_2 eq in 2013), whereas the Netherland and Belgium are the 7th and 9th Member States for total GHG emissions (192 million t CO_2 eq and 120 million t CO_2 eq in 2013)[9]. Vice-versa, increasing the UAA being equal LUs would increase indirect emissions from land use changes in the EU: +20% of UAA for dairy cattle implies +1.2077 t CO_2/ha from forest conversion, +0.0340 t C/ha from cropland and grassland conversion, and +0.0662 g CH_4/kg dry matter, +0.0014 g N_2O/kg dry matter, +7.1584 g CO_2/kg dry matter from burning biomass. Belgium and France show the highest indirect environmental impacts from land conversion and burning biomass, respectively.

4. Concluding and policy implications

Our contribution investigated the ability of animal-based policies to address environmental and in general climate change issues, while ensuring higher levels of animal welfare. We assessed direct (methane and nitrous oxide emissions) and indirect (carbon-based and nitrous oxide emissions from land use change) environmental impacts produced by the Measure 14 of the

[8] See table A.1 in the Appendix for further details.
[9] See table A.2 in the Appendix for further details.

European Union (EU) Rural Development Programme (RDP) 2014-2020. In particular, we focused on dairy cattle, the main contributors of greenhouse gas (GHG) emissions).

Our analysis highlighted the side effects of policies intended to improve animal welfare: they allow direct GHG saving and generate negative indirect externalities for the environment of negligible magnitude. As suggested by (Llonch et al., 2017), animal welfare may be a strategy designed to reduce the environmental impacts, and the impacts on climate change, related to livestock production[10].

We found coherence between animal-based policies and other greening requirements of the Common Agricultural Policy (CAP). As suggested in Cortignani et al. (2017), the greening measures have limited environmental impacts. In line with previous literature, we found that the Measure 14 would contribute to reduce nitrous oxide (Cortignani and Dono, 2018) and, in general, GHG emissions (Solazzo et al., 2016).

We also found heterogeneity in the environmental impacts across Member States: direct impacts are particularly relevant in the Netherland, Malta, Luxembourg, Belgium, and Germany, whereas indirect impacts do matter for Belgium and France. Our results are in line with Coderoni and Esposti (2018) who argue that the emission performances of policies are highly differentiated and site-specific. Information on agricultural emissions and land use change at regional level may be important indicators to assess whether the demands for emissions reduction targets, set by the governments, are likely to be met (Feliciano et al., 2013). In this regard, Chiron et al. (2013) suggest testing policies at national level to optimise their effectiveness at the EU levels.

The study is not exempts from limitations: the use of utilised agricultural areas as an indicator of housing areas is a good proxy for Northern European countries, where livestock farming systems are more based on pasture, less for Southern European countries, where cattle are housed. Despite the simplicity of our approach, it shed lights on the importance of deepening on the issue

[10] As suggested by a reviewer, an increase of GHG emissions per unit of product may be associated with mastitis: the load of emissions generated in the production of contaminated milk (i.e. milk with a greater number of somatic cells) falls on the rest of the product.

and enrich the set of indicators to capture the side effects of policy interventions. In addition, the increase in housing areas per cattle is only one of the eligible commitments (despite the most adopted one) for funding in Measure 14 of RDP 2014-2020. The improvement of housing conditions may be achieved also by providing air movements so to prevent heat stress in summer conditions, or by concentrating feeding facilities (EFSA, 2009, 2012). Therefore, in addition to the density of breeding, future studies may consider further indicators of animal welfare, such as the feeding places per-cattle, or presence and type of cooling systems during the warm seasons[11]. There is an urgent need to mitigate the environmental impacts by reducing agricultural, and in particular, livestock emissions while also ensuring an efficient production, respectful of animal conditions. Animal-based policies seem a key solution to improve productivity and environmental performances at once (Baldoni et al., 2018): they may contribute, although marginally, to meet the EU 2020 target of 20% cuts in GHG emissions (EC, 2019).

In order to successfully achieve these goals, policymakers should enable regional-scale strategies and include specific voluntary measures in their national planning context to complement mandatory cross-compliance schemes at the EU level (Bosomworth et al., 2017; Zandvoort et al., 2017).

[11] We gratefully acknowledge the suggestion of an anonymous reviewer to expand the evidence of the present analysis by considering, in future studies, other indicators of animal welfare.

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Appendix

Table A.1. Member States rank arranged by direct and indirect environmental impacts.

Member States	Direct Environmental Impacts		Indirect Environmental Impacts				
			Forest conversion	Cropland and grassland conversion	Burning biomass		
	Methane emissions	Nitrous oxide emissions	Carbon dioxide emissions	Carbon emissions	Methane emissions	Nitrous oxide emissions	Carbon dioxide emissions
Austria	9	9	2	3	7	2	NA
Belgium	4	4	1	1	NA	NA	NA
Bulgaria	25	25	NA	22	13	14	9
Croatia	16	18	6	6	10	9	NA
Cyprus	23	10	11	NA	NA	NA	NA
Czechia	20	17	NA	16	14	11	NA
Denmark	8	8	NA	26	NA	NA	NA
Estonia	18	20	7	9	2	3	2
Finland	13	14	NA	13	3	5	3
France	11	13	5	4	1	1	1
Germany	5	5	NA	12	9	8	NA
Greece	28	28	NA	20	12	13	8
Hungary	26	26	NA	23	16	16	NA
Ireland	6	6	8	11	NA	NA	NA
Italy	10	12	NA	10	15	12	NA
Latvia	19	22	9	15	5	6	5
Lithuania	15	16	10	18	NA	NA	NA
Luxembourg	3	3	NA	2	NA	NA	NA
Malta	2	2	NA	NA	NA	NA	NA
Netherlands	1	1	NA	19	NA	NA	NA
Poland	12	11	NA	17	6	10	6
Portugal	22	24	12	21	11	15	7
Romania	21	21	NA	7	4	4	4

Slovakia	24	23	3	8	NA	NA	NA
Slovenia	7	7	4	5	8	7	NA
Spain	27	27	NA	24	17	17	NA
Sweden	14	15	13	25	NA	NA	NA
United Kingdom	17	19	NA	14	NA	NA	NA

Source: elaboration on Eurostat (2019) and Faostat (2019).

Notes: NA stands for 'not available'. Elaborations refer to 2013. The environmental impacts are computed considering a ±20% improvement of the housing conditions.

Table A.2. Total historic and projected greenhouse gas (GHG) emissions.

Member States	2013 (Mt CO2 eq)	2017 (Mt CO2 eq)	Variation 2013-2017 (%)
Germany	942	905	-4%
United Kingdom	566	470	-17%
France	484	466	-4%
Italy	441	426	-3%
Poland	395	407	3%
Spain	322	339	5%
Netherlands	192	192	0%
Czechia	128	130	2%
Belgium	120	116	-3%
Romania	115	115	0%
Greece	103	94	-9%
Austria	80	82	3%
Portugal	65	72	11%
Finland	63	56	-11%
Ireland	58	61	5%
Hungary	57	64	12%
Bulgaria	56	61	9%
Denmark	55	48	-13%
Sweden	55	52	-5%
Slovakia	43	42	-2%
Croatia	25	24	-4%
Estonia	22	21	-5%
Lithuania	20	21	5%
Slovenia	18	18	0%
Latvia	11	11	0%
Luxembourg	11	10	-9%
Cyprus	8	9	13%
Malta	3	2	-33%
EU-28	4,458	4,314	-3%

Source: elaboration on European Environment Agency (2019).

Notes: NA stands for 'not available'.