The Potential Impacts of an EU-wide Agricultural Mitigation Target on the Irish Agriculture Sector

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Abstract

The recently published Irish Climate Action Plan has outlined the leading role which agriculture will have to take for Ireland in order to achieve national reduction of GHG emissions.

The agricultural sector model CAPRI is used to investigate the impact of an EU-wide agricultural mitigation target on the Irish agriculture sector. Three scenarios developed under the JRC-project EcAMPA2, allowing the endogenous implementation of mitigation technologies, will show the possible impact range that such a policy target could have.

It can be inferred that the Irish agriculture sector can achieve the set mitigation target by adapting livestock production systems, resulting in efficiency gains and implementing specific mitigation technologies. Without a mitigation target, changes are marginal, and voluntary adoption will rarely take place. Subsidising the implementation of mitigation technologies can buffer the impact that a mitigation target will have on the Irish agriculture sector, while achieving the set reduction.

Keywords Irish Agriculture, GHG emission, Agricultural GHG mitigation, CAPRI model

JEL code C54, Q11, Q18, Q54

1 Introduction

The United Nations Paris agreement on limiting global warming has increased the pressure on governments to reduce or at least slow down the growth of total national GHG emissions (UNFCCC, 2015). The recently published Irish Climate Action Plan has outlined the leading role that the agriculture sector is required to take in order to achieve the Irish GHG emission targets in the non-ETS sector[1] of 30% reduction by 2030, relative to 2005 levels, and a net zero target by 2050 (DCCAE, 2019). In order to achieve these targets, the agriculture sector will need to reduce its total GHG emissions and increase carbon sequestration (DCCAE, 2019).

The agriculture sector is one of the fastest-growing sectors in the Irish economy and therefore makes a significant contribution to the economic, social and environmental wellbeing of the country and rural areas (Joint Committee, 2018). Supported through two national agricultural strategy papers – Food Harvest 2020 and Food Wise 2025 - which set not only overall targets for the agri-food sector, but also sector specific ones, especially the dairy and the beef sector have experienced a strong growth since 2011 (CSO, 2019, DAFM, 2010, DAFM, 2015). This growth is project to continue up to 2030, causing an increase in Irish greenhouse gas (GHG) emissions as the growth is mainly based on an increase of ruminant livestock (dominated by dairy and beef cattle) (EPA, 2019, CSO, 2019, DCCAE, 2019).

The aim of the present study is to investigate the impact of a mitigation target on Irish agriculture and to identify which kind of mitigation technologies would best be used to reduce current GHG emissions in the agriculture sector. Using the CAPRI model, we simulate the effect of implementing an EU-wide agricultural mitigation target on the Irish agriculture sector, market balances, prices and emissions. Three scenarios developed under the JRC-project EcAMPA2, allowing the endogenous implementation of mitigation technologies, will show the possible impact range that such a policy target could have.

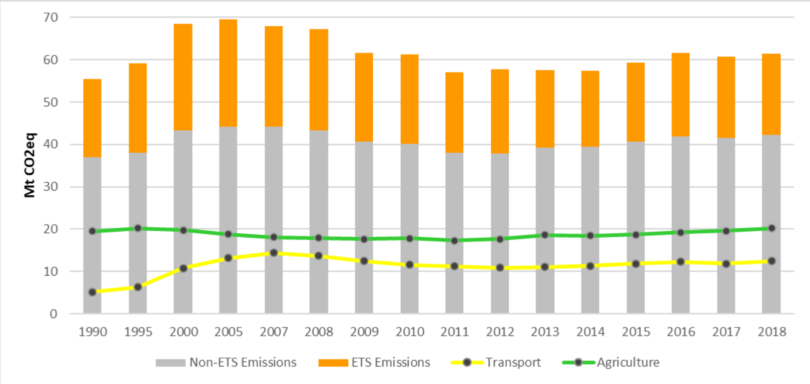
Concluding, the received results will give a first insight on whether the Irish agriculture sector can continue producing efficiently while at the same time meeting the climate targets set under the Irish Climate Action Plan.

2 Irish Greenhouse Gas Emission

The main sources of GHG emissions in Ireland in 2018 are the energy (17%), agriculture (34%) and transport sectors (20.2%) (EPA, 2019b). Further, agricultural and transport GHG emissions as non-ETS emissions account for 75% of the total Irish non-ETS emissions. (Figure 1) These figures highlight agriculture's sizeable contribution to Irish GHG emissions, but also the importance of agriculture when trying to limit overall Irish GHG emissions (DCCAE, 2017, Duffy et al., 2019).

[1] The EU Emissions Trading Scheme (EU ETS) launched in 2005 and covers more than 11,000 heavy energy consuming installations in power generation and manufacturing including food processing and manufacturing (EPA, 2019). The non-ETS sector consists of those sectors not included in the EU ETS including agriculture, transportation, households and waste (EPA, 2019).

Figure 1 Trends in Irish Greenhouse Gas Emissions 1990-2018 (Mt CO_2eq)



Source: Duffy et al. (2019), EPA, 2019b.

Agricultural GHG emissions amounted to 20.2 Mt CO_2eq in 2018. Methane (CH_4) and Nitrous Oxide (N_2O) are the most significant GHGs emitted from agricultural activities in Ireland due to the dominance of dairy and beef cattle and, to a lesser extent, sheep production (Duffy et al., 2019). Cattle account for 90.4% of CH_4 emissions from Irish agriculture (Duffy et al., 2019). Enteric fermentation accounts for 51% of total agricultural emissions (Duffy et al., 2019).

The recent growth especially of the dairy and beef sector in the Irish Agriculture has had a strong impact on agricultural GHG emissions. Since the abolition of the EU milk quota system in 2015, the dairy cow herd has increased by 21% accounting for approximately 21% of the total Irish cattle herd in 2018 (CSO, 2020).[2] Increases in dairy herd size as well as in average milk yield per cow (+10.9%) has led to an increase in overall milk production in 2018 of nearly 38% above 2014 levels up to 7.8 Mt (CSO, 2020, Eurostat, 2020). It is projected that the dairy sector will grow further until 2030, leading to an increase of dairy cow number of +22% on current levels and an increase of nitrogen fertiliser use of +21% on current levels (Lanigan and Donnellan, 2018, EPA, 2019b). Furthermore, the beef sector has increased its value of production by 14.4% in 2018 compared to the 2007-2009 level due to an increase in bovine livestock numbers by 19.1% and increasing prices (CSO, 2020).

Hence, the experienced growth in the agriculture sector has not only led to a full negation of the initially observed decrease in agricultural GHG emissions, currently reaching the 1990 level again (EPA, 2019), agricultural GHG emissions are projected to increase even further by 4% in 2030 (DCCAE, 2019, EPA, 2019b).

This development will present great challenges for Ireland to meet its potential agricultural targets discussed in the Irish Climate Action Plan (DCCAE, 2019) and managing these emissions will become a new challenge for farming (Wreford et al., 2010).

3 Methodology - CAPRI

CAPRI is a large-scale, comparative-static, agricultural sector model (Fellmann et al., 2018). The model consists of two interacting modules: a supply module and a market module. The supply module comprises independent aggregate optimization models representing agricultural activities (28 crop and 13 animal activities) in all NUTS 2 regions within the EU. The market

[2] The presence of the milk quota system up to 2015, effectively capped the number of dairy cows, with the percentage of dairy cows within the national cattle herd remaining relatively stable at around 16-17% (CSO, 2019).

module consists of a spatial, global multi-commodity model for 47 primary and processed agricultural products, covering 77 countries in 40 trade blocks. The link between the modules is based on an iterative procedure (cf. Perez Dominguez et al., 2009, Britz and Witzke, 2015).

The modelling system can endogenously calculate activity based agricultural emission inventories as it incorporates detailed information on nutrient flows and yield per agricultural activity and region (Van Doorslaer et al., 2015). Generally, a Tier 2 approach following the IPCC guidelines is used for calculating the activity based agricultural GHG emission inventories where information is available. Hence, CAPRI can define GHG emission effects of agriculture in response to changes in the policy or market environment (Van Doorslaer et al., 2015).

Within the EcAMPA studies, the CAPRI modelling system was improved by implementing a module where endogenously a range of 14 technologies and management practices for GHG emission mitigation in the single EU Member States can be chosen (Perez Dominguez et al., 2016).[3] The implemented technologies correlate with the mitigation measures identified in the Irish Climate Action Plan for reducing the agricultural GHG emissions (Table 1).

Table 1 Incorporated mitigation measures

CAPRI	Irish Climate Action Plan
Better timing of fertilization	Nitrogen-use efficiency (NUE)
Nitrification inhibitors	Protected Urea Fertiliser
Genetic improvements: Milk yield (dairy cows)	Dairy EBI
Genetic improvements: ruminants	Beef Genetics/ Improved liveweight gain
Increasing legume share on temporary grassland	Inclusion of Clover in pasture swards
Fallowing histosols	Water table management/ Drainage
Low nitrogen feed (LNF)	Extended grazing
Precision farming (reduction in N_2O emissions)	--
--	Low-emission trailing-shoe slurry spreading
Variable Rate Technology	--
Anaerobic digestion: farm scale	--
Feed additives: Linseed	--
Feed additives to reduce CH_4 emissions from enteric fermentation	--
Vaccination against methanogenic bacteria in the rumen	--
Rice measures	--

Note: Feed additives and Vaccination are only considered in scenarios assuming a more rapid technological development.
Source: Perez Dominguez et al. (2016), DCCAE (2019).

The overlap of regarded mitigation technologies enables us to indicate with the results we will receive, whether the Irish agriculture sector can take up the set role defined under the Irish Climate Action Plan in regard to GHG emission reduction.

3.1 Agriculture in the EU-27 in 2030

Being a comparative static model, CAPRI requires a projected equilibrium state of the agricultural sector regarding supply, demand, production, yields and prices in order to perform scenarios in the projection year 2030. Hence, the model generates a baseline which constitutes the reference scenario against which the three GHG mitigation policy scenarios are compared (Perez Dominguez et al., 2016).

In the reference scenario, trends regarding supply, demand, production, yields and prices are assumed to develop further as seen in the past. The mitigation options are available in the

[3] For a more detailed description of the different mitigation technologies and the specification of the cost functions implemented in CAPRI please see Perez Dominguez et al. (2016).

reference scenarios. Mitigation technologies are therefore adopted by the farmers, if the costs occurring through the implementation of the technology do not exceed the profits generated through the impacted agricultural activity (Perez Dominguez et al., 2016). The technical development of mitigation measures is at a normal pace, meaning that the rate of technological development follows the trend experienced in the past. This results in the fact, that two mitigation options (feed additives to reduce methane emissions from enteric fermentation and vaccination against methanogenic bacteria in the rumen) are not considered. In the reference scenario, no agricultural mitigation target for the EU-27 is set and no subsidy for the adoption of mitigation measures is paid (Perez Dominguez et al., 2016).

Regarding policy assumptions which are incorporated through exogenous variables, the reference scenario includes a detailed policy representation of the EU agriculture sector, including agricultural and trade policies approved up to 2015. The measures of the Common Agricultural Policy (CAP) are covered, including measures of the latest 2014-2020 reform (direct support measures implemented at Member State or regional level and the abolition/expiry of the milk and sugar quota systems). The CAPRI reference scenario does not anticipate any potential WTO agreement in the future, and no assumptions are made concerning bilateral trade agreements that are currently under negotiation. Brexit is included in a way that the United Kingdom does not account for the EU-27 anymore, but free-trade is still applied.

Specifically, for Ireland, the strong growth trends in the dairy cow sector regarding numbers and yield have been incorporated into the calibration of the reference scenario in order to receive a more perceived projection for the year 2030.

3.2 Simulated Scenarios

The applied mitigation scenarios have been developed under the JRC-project EcAMPA2. The simulated mitigation policy scenarios rely on the same assumptions as the reference scenario, i.e. the assumptions regarding macroeconomic drivers, CAP, market and trade policy. Different to the baseline, all three scenarios defined aim at a reduction of agricultural GHG emissions by the year 2030. The three scenarios therefore describe possible future developments regarding the mitigation of agricultural GHG emissions, covering the possible impact range as comprehensively as possible. The technical development of mitigation measures is assumed to be at a normal pace similar to the baseline.

Under the first two scenarios a compulsory reduction of the agricultural GHG emissions in the EU-27 of 20% in the year 2030 relative to 2005 is set. This target is heterogeneously distributed among the Member States. [4] For Ireland, this results in a reduction target of -4% by 2030 relative to 2005 (-15% relative to 2030). This derived Irish reduction target is in line with the reduction target derived in the Irish Climate Action Plan for the Irish agriculture sector (DCCAE, 2019).

The two scenarios differ regarding the level of subsidies paid to the farmers for implementing voluntarily mitigation technology. Under the first scenario “no-sub”, no subsidies are paid to farmers. The second scenario “all in” grants subsidies to the farmers for the voluntary application of all mitigation technologies. The subsidies meet 80% of the accounting costs for

[4] This allocation of mitigation targets among Member States reflects the results of running an auxiliary scenario that imposes a carbon price of 50 Euro/tonne CO2 equivalents (Perez Dominguez et al., 2016).

the voluntary uptake and application of the technologies, constituting an incentive for farmers to apply the technologies.

Contrarily to the first two scenario, the third scenario "no-target" does not set a compulsory EU reduction target for GHG emissions. Subsidies are still granted for 80% of the accounting costs for the voluntary uptake and application of the mitigation technologies.

The "no-sub" scenario will give a first insight into how restrictive a compulsory reduction of the agricultural GHG emissions could be on the Irish agriculture sector and what the magnitude of changes would be resulting from this set target. Introducing subsidies in the "all-in" scenario indicates the magnitude of changes that can be buffered, enabling the farmers to adapt easier. In the "no-target" scenario mitigation technologies are applied purely based on cost-effectiveness grounds. Emission reduction is rather a positive side effect and not guaranteed like in the case of a binding emission target. Hence, these mitigation scenarios will show the possible range that such a policy target could have.

4 Model results

The GHG emission reductions achieved under the "no-sub" scenario directly reflects the mitigation target imposed on the EU-27 and Ireland (Table 2). The scenario results show that Ireland can meet the set target. Introducing subsidies under the "all-in" scenario would lead to a reduction of total agricultural GHG emissions exceeding the required target (-16.91% by 2030) (Table 2). Without a binding target, under the "no-target" scenario, the voluntarily achieved reduction is only -2.6% by 2030 (Table 2).

Table 2: Percentage Changes in Total agricultural GHG emissions

	No-Sub	All-in	No-Target
	%-difference to Reference		
EU-27	-17.21	-21.17	-4.56
Ireland	-14.73	-16.91	-2.60

Source: Own compilation.

Reductions for Ireland are mainly achieved through a decrease in CH_4 emissions, accounting for around 65% of the reduction of total agriculture GHG emissions in the no-sub and all-in scenarios and for 92% in the no-target scenario. These GHG mitigation efforts are the result of two main drivers: the uptake of GHG mitigation technologies and changes in agricultural production (Table 3).

Table 3:Share of the emission reduction achieved in Ireland

	No-Sub	All-in	No-Target
	Share in total agricultural GHG reduction		
Mitigation technologies	31.8%	51.9%	33.2%
Change in production	68.2%	48.1%	66.8%

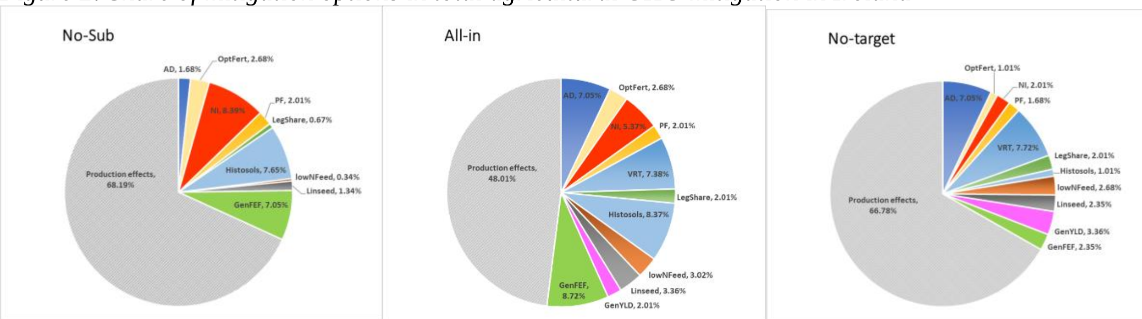
Note: The share of mitigation technologies does not include the effects from measures related to genetic improvements as it is not possible to disentangle these effects from their related production effects. The share of production changes includes all effects of emission reduction that cannot be directly attributed to technological mitigation options (Perez Dominguez et al., 2016).
Source: Own compilation.

The share of the emission reduction achieved through mitigation technologies is thereby strongly dependent on the subsidies paid for the implementation of mitigation technologies. In the case of no payments, as in the "no-sub" scenario, the mitigation technologies only account for 31.8% of the reduction of agricultural GHG emissions (Table 3). If subsidies are paid, as in the "all-in" scenario, the emission reduction is mainly achieved through mitigation technologies (Table 3).

4.1 Implementation of Mitigation technology

The variety and magnitude of mitigation technologies implemented appears to be highly linked to the implementation costs of the mitigation technologies and whether subsidies are paid, reducing costs and increasing profitability. This leads to the implementation of some technologies (around 1% of the maximum implementation share of mitigation option) already in the reference scenario, such as fertiliser timing, increasing precision farming and using nitrification inhibitors. In the case of "no-sub" and "no-target", the implementation magnitude is high for a few specific technologies, whereas in the "all-in" scenario, the GHG mitigation is achieved through a more evenly implementation of a variety of mitigation technologies (Figure 2).

Figure 2: Share of mitigation options in total agricultural GHG mitigation in Ireland



Source: Own compilation.

When a mitigation target is imposed without subsidies ("no-sub" scenario), farmers start adopting technologies that reduce activities' profits but still allow these to remain positive. These are mainly the implementation of nitrification inhibitors, improving the genetics of ruminants and fallowing histosols (Figure 2). The costs for implementing and applying these technologies is generally low allowing for an easier implementation in the farming systems. Together, these mitigation technologies account for 23% of the total agricultural GHG mitigation (Figure 2).

When subsidies are paid in order to meet 80% of the accounting costs for the voluntary uptake of mitigation targets ("all-in" scenario), the adoption rate of mitigation technologies is increased as the costs for implementation is reduced and thus profitability of the mitigation technologies increased. Further, the variety of implemented mitigation technologies is increased as now activities' profits remain positive even with more costly mitigation technologies. Now, next to the implementation of nitrification inhibitors, improving genetics of ruminants and fallowing histosols, GHG emission are also reduced through the implementation of variable rate technology and anaerobic digestion (Figure 2). Together, these mitigation technologies account for 37% of the total agricultural GHG mitigation (Figure 2).

Introducing subsidy payments but not setting an emission reduction target ("no-target") farmers only adopt technologies that minimise their cost structure and maximising their profits. Therefore, GHG emissions reduction is a side-effect resulting from the implementation of mitigation technologies. The mitigation technologies with the highest magnitude are anaerobic digestion, variable rate technology and low nitrogen feed (Figure 2). Together, these mitigation technologies account for 17.5% of the total agricultural GHG mitigation (Figure 2).

It appears that the implemented mitigation technologies throughout the three scenarios highly correlate with the suggested technologies for the agriculture sector under the Irish Climate Action Plan (Table 1)

4.2 Impacts on Irish Agricultural Production

Changes in the agricultural production strongly depend on how binding the mitigation target is and on the implemented mitigation technologies in the different scenarios. As the share of CH_4 emission reduction in the reduction of total agricultural GHG emissions is high, this indicates that some strong effects have to be expected especially in the Irish livestock sector, considering that the livestock sector is responsible for up to 90% of CH_4 emissions from Irish agriculture (Duffy et al., 2019).

In the “no-sub” scenario, decreases in herd size of the main ruminant activities in the Irish agriculture sector are the highest overall activities (Table 4). Livestock numbers in beef meat activities as well as sheep and goat numbers decrease by around -11%, while dairy cow numbers decrease by -4.27%, both due to not having support that would allow a switch to lower emission technologies (Table 4). Meat and milk supply decreases are slightly lower than the reduction in herd size, showing that even though no subsidies are paid for the implementation of mitigation technologies, efficiency gains in the production systems occur.

Table 4: Change in area, herd size and supply for main activities in Ireland

	Reference		No-Sub		All-in		No-target	
	Hectares/ herd size	Supply	Hectares/ herd size	Supply	Hectares/ herd size	Supply	Hectares/ herd size	Supply
	1000 ha/hds	1000 ha or t	%-difference to Reference					
UAA	4234.51	2025.93	-0.3	-5.83	-0.26	-5.96	0.08	0.23
Cereals	297.24	2527.97	5.02	4.79	7.27	7.91	2.13	2.61
Oilseeds	26.69	102.52	-11.27	-12.12	-17.27	-18.28	-4.05	-4.01
Gras and grazings ext.	1580.36	45850.02	35.14	35.38	40.52	40.79	2.39	2.41
Gras and grazings int.	1625.99	105418.65	-34.15	-34.42	-39.38	-39.69	-2.32	-2.34
Fallow land	8.76		87.14		74.15		-14.44	
Dairy cows	1425.49	8129.61	-4.27	-4.21	-3.24	3.66	1.23	13.26
Beef meat activ.	4876.31	663.78	-10.44	-9.10	-9.05	-7.57	1.50	1.40
Pork meat activ.	3540.48	301.97	0.78	0.78	8.45	8.35	3.40	3.32
Pig breeding	133.64	3603.01	0.70	0.70	4.80	4.80	0.51	0.52
Sheep and Goat meat activities	2045.09	50.44	-11.15	-10.29	-12.25	-10.96	0.72	0.76

Note: Red indicates a decrease and green an increase. Total supply of beef meat activities includes beef from suckler cows, heifers, bulls, dairy cows and calves (carcass weight).
Source: Own compilation.

Herd size and supply changes in the ruminant sectors under the “all-in” scenario clearly indicate, that the dairy sector is strongly capable of adapting to the GHG emission target when receiving subsidies to implement mitigation technology. Even though the herd size decreases by -3.24%, especially the genetical improvement for higher milk yields of dairy cows leads to efficiency gains in the dairy sector and results in an increase in total Irish milk production by 3.66% (Table 4). The beef sector experiences a slightly lower decrease in herd size (-9.05%) under the “all-in scenario” and an even lesser decrease in supply (-7.57%), showing efficiency gains in the production system (Table 4). The efficiency gains from an increased adoption rate of the mitigation technologies appear to be less strong in the beef sector than in the dairy sector. The biggest changes can be seen for the sheep and goat sector where the reductions in herd size and supply are even higher than under the “no-sub” scenario. Experiencing a strong growth in the pig sector in both herd size and supply it seems that the sheep and goat sector is partially substitutes by an increase production of pork.

When paying subsidies for the implementation of mitigation technology but not setting a GHG emission reduction target ("no-target" scenario), animal numbers for all ruminant sector increase (Table 4). For the beef sector as well as the sheep sector, this increase results in an equivalent increase of supply (Table 4). However, when looking at the dairy sector, it occurs, that the subsidies paid are a strong incentive for the dairy farms to implement mitigation technologies which increase efficiency. Next to increasing the herd size by 1.23%, the milk supply increase by 13.26% (Table 4).

As a result of the mandatory reduction of GHG emissions and the implementation of mitigation technologies, a switch from intensive gras-based ruminant production systems towards a more extensive production system becomes apparent. Over all three scenarios the area under intensive usage reduces by the same amount as the area under extensive usage increases (Table 4). Hence, no land-use change is experienced. In order to supply sufficient amount of land under the "no-target" scenario, fallow land is taken back into production leading to a reduction of fallow land of -14.44% (Table 4).

One sector that is highly impacted as it is strongly linked with livestock production is the oilseed production. Oilseed production has as a by-product oil cake which is used as feed for livestock. The reduction in ruminant livestock numbers as well as the switch from intensive to extensive livestock production in all three scenarios, decreases the oilseed production regarding the area under production as well as the total supply (Table 4).

Fertilizer usage as a main input factor of the dairy and beef sector, is strongly impacted by the production changes in the three scenarios. Although the producer price remains stable throughout the different scenarios, the reduction in ruminant herd size and the switch from intensive to extensive grass-based production systems, not only reduces the usage of manure nitrogen but also of mineral nitrogen (Table 5).

Table 5: Changes of Fertilizer usage for fodder activities

	Reference	No-Sub	All-in	No-Target
	N kg/ha	%-difference to Reference		
Mineral nitrogen	76.54	-20.04	-25.71	-4.28
Manure nitrogen	88.48	-10.62	-9.28	1.92

Source: Own compilation.

4.3 Impacts on Irish agricultural trade

Following the production developments, changes in the Irish agricultural trade patterns can be observed for the main agricultural outputs – in particular dairy products and meat (Table 6).

Table 6: Change in Irish imports and exports for main agricultural activities

	Reference		No-Sub		All-in		No-Target	
	Imports	Exports	Imports	Exports	Imports	Exports	Imports	Exports
	1000 t		%-difference to Reference					
Dairy products	93.95	521.92	0.79	2.49	-0.70	7.23	-2.57	8.56
Fresh milk products	483.97	38.34	0.00	0.00	-7.17	0.00	-9.26	0.00
Beef	53.00	618.12	0.00	-9.09	0.00	-7.36	0.00	1.48
Pork meat	90.21	220.31	0.00	1.86	0.00	12.28	0.00	3.99
Sheep & goat meat	4.27	44.30	0.00	-11.62	0.00	-12.38	0.00	0.88

Note: Dairy products include butter, whole &skimmed milk power, cheese, cream, concentrated milk, casein, whey powder.

Source: Own compilation.

For all three scenarios, changes in the import structure of most of the main agricultural activities are either marginal or cannot be observed, as on average 85% of the domestic production is exported (CSO, 2020). Further, the EU has restrictive border measures has in place, which do not allow for a large increase in EU imports especially for dairy products and meat (European Commission, 2020). Changes resulting from the domestic production changes in the different scenarios therefore mainly impact the Irish agricultural export (Table 6).

Exports of beef, sheep and goat meet decrease by -9.09% respectively -11.62% in the “no-sub” scenario (Table 6), following the decrease of domestic production (Table 4). The adoption of several mitigation technologies in the “all-in” scenario leads to efficiency gains in the beef sector which increases the competitive export advantage, leading to a lower decrease of exports than in the “no-sub” scenario (Table 6). In the “no-target” scenario, the increase of exports (Table 6) follows the increase in domestic production (Table 4).

Changes in the dairy sector have to be regarded in a slightly differentiated way, as fresh milk is imported and processed dairy products strongly exported (CSO, 2020). Through the increase in domestic milk production under the “all-in” and “no-target” scenarios, imports of fresh milk products decrease. Exports of dairy products on the other hand increase over all three scenarios (Table 6).

4.4 Impacts on Irish agricultural market prices

Impacts on the Irish agricultural market prices are directly related to how binding the emission mitigation target is in the different scenarios and how decoupled the European market for the affected production activities is from world markets (i.e. by means of import tariffs and tariff rate quotas). In general, crop prices are less affected by the emission mitigation target than animal product prices (Table 7).

Table 7: Changes in Irish producer and consumer prices of main Irish agricultural outputs

	Reference		**No-Sub**		**All-in**		**No-Target**	
	Producer	Consumer	Producer	Consumer	Producer	Consumer	Producer	Consumer
	€/t		%-difference to Reference					
Cereals	158.40	4091.30	4.13	0.20	5.62	0.27	-0.07	-0.01
Oilseeds	204.24	3826.09	4.54	-0.01	4.33	-0.06	-1.63	-0.05
Cow milk/ Dairy	418.14	1533.31	8.83	3.57	3.97	4.04	-12.78	-2.00
Beef	4336.04	9993.41	21.19	9.67	24.96	11.30	-1.56	-0.71
Pork meat	1873.93	8586.22	9.13	1.99	10.09	2.19	-3.57	-0.78
Sheep & goat meat	4661.23	9639.86	9.65	4.92	12.02	6.07	-0.68	-0.36
All primary outputs	74.21	3501.20	15.99	0.95	21.11	1.08	-0.69	-0.17

Note: In the dairy sector, the producer price is stated for raw milk and the consumer price for dairy products.
Source: Own compilation.

In the “no-sub” scenario, producer prices for all main primary outputs increase (Table 7) as the mandatory reduction of the GHG emissions leads to a shift of the production function. Producer price changes for cow milk and meat (beef, sheep and goat meat) are thereby higher than the changes in supply due to the restrictive border measures the EU has in place, which do not allow for a large increase in EU imports (European Commission, 2020).

When subsidies are paid as in the "all-in" scenario, the producer price for cow milk increases are lower than in the "no-sub" scenario (Table 7), as a consequence of the induced production increase through implemented mitigation technology (Table 4). For beef, sheep and goat meat producer prices increase further (Table 7), resulting from an increase in the producer's cost structure, subsidies being paid for 80% of the additional costs and an increase in the comparative advantage regarding exports (Table 6).

In the "no-target" scenario, producer prices decrease due to the increase in Irish production. Especially the dairy and meat sectors experience a strong drop in producer prices (Table 7).

Since price mark-ups do not change, Irish consumer prices mirror the development of the producer prices over all scenarios even though at a lower magnitude. For the "no-sub" and "all-in" scenario, this results in a slight reduction of the consumer surplus in Ireland. Prices for beef experience thereby the largest price variation (Table 7)

4.5 Impacts on Irish farmers' income

As a result of the above discussed changes in the Irish agricultural markets, initiated through setting a GHG emission reduction target and further paying subsidies to encourage the voluntary implementation of mitigation technologies, the Irish farmers' total income over all primary activities increases in the "no-sub" by 29.8% and "all-in" scenarios by 38.4% (Table 8).[5]

Table 8: Changes in Irish farmers' income from main agricultural activities

	Reference	No-Sub	All-in	No-Target
	€/ha or head	%-difference to Reference		
Cereals	310.55	18.41	26.44	0.64
Oilseeds	146.42	27.86	28.13	-7.22
Dairy cows	1201.02	25.58	33.58	-0.81
Beef meat activities	284.39	82.05	105.02	11.45
Pork meat activities	-66.31	98.18	116.26	0.34
Sheep & goat meat activities	59.03	10.04	12.15	1.90
All primary activities	414.49	29.83	38.47	-2.06

Note: Red indicates a decrease in Irish farmers' income and green an increase.
Source: Own compilation.

Looking at the livestock activities in more detail, it appears that especially beef farmers would gain from a binding GHG emission target with an increase in income of +82% in the "no-sub" scenario and +105% in the "all-in" scenario. High producer prices (Table 7) as well as subsidies paid overcompensate the production decrease.

Setting no GHG emission target ("no-target" scenario) would on the other hand lead to a reduction of -2% of the overall agricultural income of the farmers (Table 8). This is mainly driven by the changes in production and price of the dairy sector.

5 Discussion and Conclusion

The strong current and projected growth of the Irish agriculture sector up to 2030 will come with a significant increase in agricultural GHG emissions (+12.2% by 2030 compared to 2005) (EPA, 2019b). The United Nations Paris agreement on limiting global warming has increased

[5] It needs to be noted that CAPRI cannot provide any results on how many farms will remain active and as a result will benefit from the potential increases in total agricultural income (i.e. the model does not consider farm level structural change) (Perez Dominguez et al., 2016).

the pressure on governments to reduce or at least slow down the growth of total national GHG emissions (UNFCCC, 2015) and the recently published Irish Climate Action Plan has outlined the leading role that the agriculture sector is required to take for Ireland in order to achieve the Irish GHG emission targets by 2030 (DCCAE, 2019).

To reduce the Irish agricultural GHG emissions significantly by 2030, the agriculture sector would need to increase the adoption of mitigation technologies in order to not decrease domestic production substantially. To assess the possible effects of a mandatory reduction of the agricultural GHG emissions and the implementation of mitigation technologies on the Irish agriculture sector, an EU-wide agricultural GHG emission reduction target of 20% by 2030 relative to 2005 was set. Through a heterogenous distribution among the Member States in the CAPRI simulations this leads to an Irish reduction target of -4% by 2030 relative to 2030.

For the analysis, the agricultural sector model CAPRI was used. Three scenarios developed under the JRC-project EcAMPA2, allowing the endogenous implementation of mitigation technologies were simulated, in order to show the possible impact range that such a policy target could have.

The results show that the Irish agriculture sector can achieve the set mitigation target by strongly adapting livestock production systems. In order to adapt to the set mitigation target, the beef and dairy sector would likely reduce their livestock numbers but also increase efficiency through implementing mitigation measures such as genetic improvements, nitrification inhibitors, anaerobic digestion and fallowing histosols. Granting subsidies to the farmers increases the voluntary adoption of mitigation technologies and hence buffers the impact that a mitigation target will have on the Irish livestock production. In both scenarios, the ruminant production systems become more extensive grass-based resulting in a reduction of fertilizer usage.

Resulting reductions in agricultural revenues are overcompensated through the increase in producer prices for beef and raw milk as well as through subsidies paid. Hence, the impact on the income of Irish farmers is mostly positive in all three scenarios – except for the dairy sector when no mitigation target is set.

Paying subsidies without setting a mitigation target is the least effective solution regarding the reduction of agricultural GHG emissions, as the choice of implementing mitigation technology is purely based on cost-effectiveness and GHG emission reduction is only a side-effect. Production structures, therefore, remain nearly unchanged and production is increased through an expansion of the herd size. Hence, this scenario would have the least impact on agricultural activities but would also achieve the smallest reduction in GHG emissions.

Regarding the action plan and the mitigation target for the agriculture sector pointed out in the Climate Action Plan, it appears that the actions planned correlate highly with the findings in this paper and that the Irish agriculture sector has the potential to take up a leading role in respect to GHG emission reductions. As this emission reduction is partly achieved through a reduction in total production, it needs to be pointed out that a production reduction could lead to carbon leakage effects with production and emissions shifting to other strong ruminant based producing countries.

In order to increase the abatement potential of the agriculture sector and to substantially help bring the nexus between agricultural development and GHG emission targets in Ireland closer together, mitigation subsidies paid to the farmers occur to be reasonable.

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