Global land use impacts from a subsidy on grassland-based ruminant livestock production in the European Union

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1. Introduction

Population growth, rising income and changes in dietary patterns and production technologies have been main drivers of increased global consumption of livestock products during the last decades (OECD/FAO 2018). This trend is expected to continue, with global meat consumption projected to rise by 15% in 2027, relative to the year 2017, and milk production by 22% over the same period (OECD/FAO 2018) with the replacement of conventional pasture-based systems by more indoor and intensified production in main production regions, leading to productivity increases, decreased grazing areas worldwide (40% between 1982 and 2006, as estimated by Bao Le et al. (2014)) and increased protein-rich concentrate use. Soybean, with its high protein content, has become a major feed crop with around 70% of global soybean production used for feed (Brack et al. 2016).

In the European Union (EU), increased demand for compound feed implies higher dependence on imports of protein-rich crops (European Environment Agency 2017). In fact, around 17 million tonnes of crude proteins are imported every year, of which 13 million tonnes are soya-based, representing an EU self-sufficiency rate of only 5%. These imports come mainly from Brazil, Argentina and the USA (European Commission 2018). The European Environment Agency (2017) reports that 8.8 million ha of land in South America were used to meet the EU’s soybean import demand in 2011. Soybean production is associated with the loss of natural ecosystems, either directly or indirectly through subsequent land use substitutions (Fehlenberg et al. 2017). Substitution of traditional feedstock in the EU has also led to unwanted loss of grasslands, e.g. by 12% from 1991 to 2017 in Germany (Umwelt Bundesamt 2018). This has negative impacts in terms of soil quality, carbon sequestration and other ecosystem services, such as biodiversity conservation (van Swaay et al. 2015). In order to alleviate grassland degradation and promote the domestic production of plant protein sources, the Common Agricultural Policy (CAP) has established multiple measures, such as maintenance requirements for permanent pasture or minimum crop diversification obligations (European Commission 2013). The European Parliament (2018) has recently called for additional CAP reforms to boost the role of grassland in enhancing agricultural sustainability and ecosystem services, in order to accelerate the impact of the aforementioned measures (Gocht et al. 2016).

In view of the ongoing CAP Post-2020 discussions for the promotion of grassland as animal feedstock, our objective is to quantify potential market-mediated impacts from a subsidy on grassland-based ruminant livestock production in the EU, in terms of global Land Use Change (LUC) and greenhouse gas

(GHG) emissions. To do so, we use a novel approach that combines the Computable General Equilibrium (CGE) 'GTAP' model with a recently released Multi-Region Input Output (MRIO) database called 'FABIO'. FABIO includes a detailed representation of bio-based products (Bruckner et al. 2018). Therefore, this approach aims at providing insights on global and regional impacts from policy induced shifts to grassland-based livestock systems in the EU. To our knowledge, this is the first study to tackle both direct and indirect effects from policy support on grassland from a global perspective, as compared to existing empirical studies focusing on domestic impacts by employing farm level models (Gocht et al. 2016). In the following section, we briefly review the most commonly used MRIO databases in the literature with some examples of their application.

1.1. Review of multi-region input output (MRIO) databases

In recent years, MRIO analysis has frequently been used to estimate impacts across global supply chains (Wiedmann et al. 2011; Tukker et al. 2013) driven by growing international trade and its role in displacing environmental impacts between regions. According to Boc and Lanz (2013), more than 50% of the internationally traded goods are intermediate inputs. In contrast to CGE models, MRIO typically offers a higher level of detail, in terms of trade information as well as sectoral and regional resolution. This allows for linkages between consumption and production to be tracked across complex and geographically fragmented value chains. Tukker and Dietzenbacher (2013) specifically underline the potential of MRIO analysis to attribute environmental impacts not only to producers, but also to consumers. This helps informing consumers' responsibility for global trade-mediated environmental effects, as an aspect that has been ignored for a long time in environmental policy making. Recent literature includes the variety of efforts in building MRIO databases that describe the global monetary and/or physical flows of goods and services across the economy.

MRIO has the additional advantage of describing trade flows by economic agent (firms, private households, investments and government); while traded goods are usually aggregated in CGE analysis on the borders and bilateral trade information is not differentiated between agents. To do so, the majority of MRIO databases rely on detailed trade information from different sources, mainly UN COMTRADE HS6 data, and use the UN Broad Economic Classification (BEC) concordance in order to allocate imports across intermediate, final and mixed demand. To overcome data challenges, as well as balancing and harmonization issues, the 'proportionality assumption' is frequently made to distinguish between imports at the agent level, i.e. across intermediate and final demand, e.g. in EXIOBASE (Tukker et al. 2013); or in the recent GTAP-based MRIO version (Andrew and Peters 2013). Earlier MRIO databases do not usually implement the BEC concordance and simply rely on the proportionality assumption to split imports by sourcing region and agents. In this publication, we describe and compare some of the most widely used MRIO databases for environmental footprinting, such as EORA, EXIOBASE, WIOD, GTAP-MRIO; including the one we use, i.e. Food and Agriculture Biomass Input-Output (FABIO).

1) The EORA MRIO database (Lenzen et al. 2012; Lenzen et al. 2013) provides complete global coverage of the 190 UN countries, as combined with a high number of sectors -between 26 and 500- and continuous time series for the period 1990-2015. It is extended with different environmental and social satellite accounts, quantifying GHG emissions, water consumption, land use, and 'Human Appropriation of Net Primary Productivity'. However, the EORA is often used in its simplified version (EORA26), with only 26 sectors; in order to represent the global economy in a fully consistent and homogenous way. Examples of using EORA for environmental footprint calculation are found in the studies of Kanemoto et al. (2014) and

(Chen et al. 2018a), who respectively quantify the carbon footprint, and the land and water footprints embodied in international trade.

2) EXIOBASE (Tukker et al. 2013) has a strong focus on the EU. Its latest version EXIOBASE 3 covers the EU28 Member States along with 15 non-EU countries. Compared to other MRIO databases such as EORA, EXIOBASE comprises many more environmental extensions and a higher sectoral resolution -with 129 sectors-, hence providing more details in important sectors such as agriculture, energy and transport (Tukker and Dietzenbacher 2013). Beylot et al. (2019) use EXIOBASE to calculate the environmental impacts of the overall EU consumption. O'Brien et al. (2015) quantify the land footprint of bio-based sectors in the EU.
3) The World Input-Output Databased (WIOD) (Dietzenbacher et al. 2013; Timmer et al. 2015) is characterized by a highly homogenous sectoral classification, especially as compared with EORA (Kander et al. 2015). The latest version, WIOD 2016, disaggregates the economy into 56 sectors, while covering 43 countries over the period 2000-2014. WIOD is not only used in environmental accounting (Arto et al. 2014) but additionally in topics related to trade in value added (Los et al. 2015); same as happens with the other MRIO databases described above.
4) A GTAP-based MRIO table is also available, taking advantage of the potential of the GTAP data to facilitate the construction of a consistent, harmonized, balanced and global MRIO tables (Hertwich and Peters 2009). The latest version, GTAP9 (Aguiar et al. 2016) disaggregates the economy into 57 sectors and 140 regions. In contrast to other MRIO databases such as WIOD, EXIOBASE and EORA, the GTAP-based MRIO does not however provide time series and includes less environmental and social indicators. Thus, it must be linked to external data to be able to quantify carbon, land and water footprints (Steen-Olsen et al. 2012).

Aggregation biases are still largely discussed among MRIO users (Arto et al. 2014). Despite the continuous progress in the construction of MRIO databases, the geographical and sectoral resolution is still insufficient; hence hindering more comprehensive and detailed policy analysis (Steen-Olsen et al. 2014). For instance, in EORA26 all the agricultural activities are aggregated as one sector named 'Agriculture'. Even the disaggregation of the GTAP data, with its 23 agri-food sectors, might be insufficient for addressing market effects from Food vs. Feed vs. Fuel competition since this requires further detail in processed products, e.g. oilseeds and vegetable oils. Improving the resolution of these sectors is thus crucial to inform both regional and global policies for a sustainable transition towards a more bio-based economy. On the one hand, this would provide transparency in global value chains of bio-based products, including land substitution effects; on the other hand, it would allow quantifying the sustainability implications of shifting to biomass feedstock in many sectors, with the associated impacts from induced Land Use Change (LUC) (Chen et al. 2018b; Plevin et al. 2015).

In order to fill this gap, a global MRIO database has recently been developed by Bruckner et al. (2018), under the name of 'Food and Agriculture Biomass Input-Output' or simply FABIO. It covers the 191 countries and about 130 agricultural and food sectors. Thus, FABIO allows for the analysis of biomass flows along geographically fragmented global supply chains. It is based on supply-use tables that combine physical data from the Food and Agriculture Organization (FAO) and monetary data from EXIOBASE 3 (Stadler et al. 2018). To the best of our knowledge, FABIO represents the only MRIO with such level of detail in agri-food commodities, providing time series data over the period 1986-2013. As such, it has already been used to quantify the land? footprint of non-food products in the context of the growing bioeconomy in the EU (Bruckner et al. 2019). In FABIO, data on trade flows are taken from the FAO bilateral trade data (BTD). They match data based on the supply and utilization of agricultural commodities provided by the FAO's commodity balance sheets (CBS) (Figure 1).

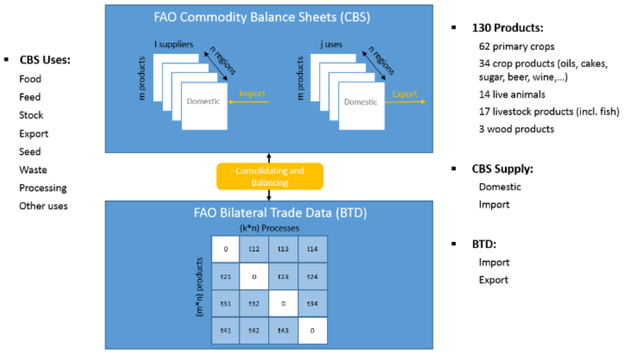

Figure 1. FABIO framework (Bruckner 2018)

2. Materials and Methods

2.1. Model and database

The standard Multi-Region Input Output (MRIO) analysis is based on the Leontief approach (Leontief 1970), which was initially used in country-based assessments by using national IO-tables. The Standard Leontief approach is used to quantify economic and environmental implications of a change in the final demand for a certain product, as described by the following equations (eq.1- 4):

$$X = A\,X+Y \qquad \text{(eq.1)}$$

$$X = (I-A)^{-1}\,Y \qquad \text{(eq.2)}$$

$$F = f\,X \qquad \text{(eq.3)}$$

$$F= f\,(I-A)^{-1}\,Y \qquad \text{(eq.4)}$$

Where X is a vector of output, which represents the sum of intermediate and final demand; A is the matrix of input coefficients; Y is the final demand; I is referred to as the ‘identity matrix’; $(I-A)^{-1}$ is thus the ‘Leontief inverse’ (L); F is the environmental vector, e.g. total resource use; and f is the vector that represents the environmental intensities, e.g. resource use per unit of output. The Leontief inverse (L) is thus the matrix that delivers direct and indirect impacts that arise from economy-wide adjustments due to a change in final demand.

Results from MRIO-based assessments should then reflect the limitations of this Leontief approach, since this assumes that the demand for inputs per unit of output is fixed. This means that any increase in supply generates an increase in demand for intermediate inputs and primary factors in a linear fashion, without resource constraints. The so-called fixed technology approach thus ignores price and substitution effects, even between imported and domestically produced products (Beylot et al. 2019) On the contrary, CGE analysis typically treats imported and domestic goods as imperfect substitutes via a nested Constant Elasticity of Substitution (CES) function, which is in turn based on the Armington assumption. As a result, CGE implements substitution, at least between primary factors in production, and treats primary factor endowment as fixed or (moderately) price responsive. In the latest GTAP-MRIO version, the Armington assumption is adjusted to allow for substitution between domestic and foreign products at an agent level. There have been many attempts is the development of a GTAP-based MRIO model, called GTAP Supply Chain (GTAP-Sc) (Walmsley et al. 2014). GTAP-Sc builds on the GTAP-based MRIO database (Andrew and Peters 2013) that employs the UN Broad Economic

Classification (BEC) concordances to differentiate between traded goods for intermediate use from those devoted to final consumption at the HS6 level, as well as the proportionality assumption to split these trade data across each demand category, i.e. intermediate and final demand.

We propose combining CGE and MRIO methodologies to carry our more comprehensive and detailed assessments of environmental and economic impacts associated to agriculture. We specifically implement the FABIO database (Bruckner et al. 2018) with the standard GTAP model (Hertel 1997). We depart from the GTAP9 database, as extended with the GTAP-AEZ (Lee et al. 2005) and GTAP-Agr (Keeney and Hertel 2005) auxiliary accounts. Non-CO_2 emission (Rose and Lee 2008) and carbon stock data (Gibbs et al. 2014) are also used for the quantification of GHG emission impacts. We then aggregate the original GTAP database into 36 regions while keeping its full sectoral resolution of 57 sectors. Despite the relatively high sectoral detail in agricultural commodities in GTAP9 data, further detail is desirable to better assess inter-industry relations, especially between food and feed sectors; and improve reliability. We use production and consumption information from FABIO to consistently break down the original GTAP "Oilseed", "Vegetable oils", "Other crop" and "Other Food" sectors into different sub-sectors (Table 1), by using the "SAM split" utility in CGEBox (Britz and van der Mensbrugghe 2018). "Vegetable oils" generates a non-diagonal SAM due to crushing of specific oilseeds into cake and oil. Hence, co-products are also introduced, by distinguishing between food and feed uses. .

Table 1: Split of sectors / commodity

Original GTAP sector / commodity	FABIO Sub-sectors
osd – Oilseeds	Olive; Soy bean; Palm oil fruits; Rape and mustard seed Other oilseeds
vol - Vegetable Oils	Olive oil production => olive oil Soybean crushing => Soybean oil, cake Palm oil production => palm oil Rapeseed crushing => Rape seed oil, cake Other oilseed crushing => Other cakes and oils
Ocr- other crops	Legumes; other crops
Odf – other food processing	Feed compounds; Other food processing

For the newly created agri-food sectors, FABIO provides data on intermediate and final demand. For the rest, we adopt the widely used proportionality assumptions (Andrew and Peters 2013) to differentiate among import sources by economic agent. The representation of livestock production technologies is also improved by adding a substitution possibility between land and different feedstuffs. The production structure of the compound feed industry was thus adjusted by introducing an additional nest that differentiates between energy and rich protein crops (Figure 2); assuming a elasticity of 5 for the substitution between feed crops. As a result of these improvements, the presented GTAP-FABIO integrated model is better suited for the quantitative assessment of agri-food policies than the GTAP-Sc model (Walmsley et al. 2014).

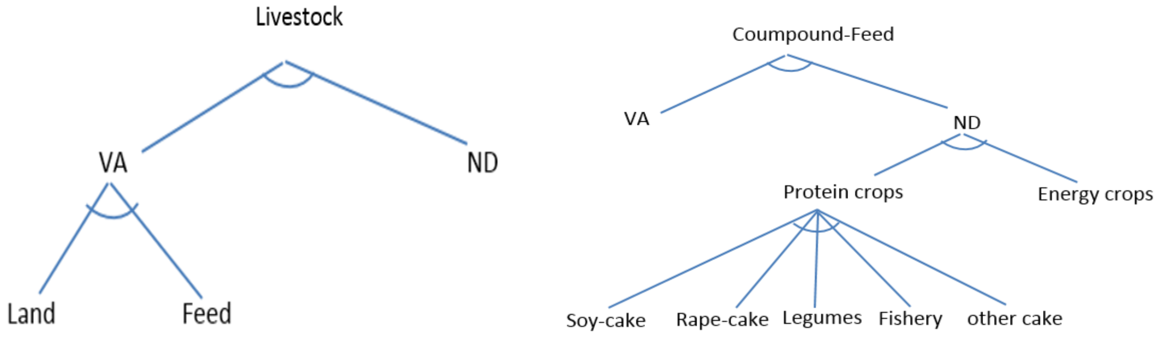

Figure 2. Updated production technologies in GTAP

2.2. Model simulation and scenario design

We employ the GTAP-derived Recursive Dynamic Extended Model (G-RDEM) (Britz and Roson 2018) to better understand the dynamic of the economy-environment interactions in the long run. G-RDEM builds on the standard recursively dynamic GTA-Dyn model (Ianchovichina and McDougall 2012) that extends the static version of the GTAP model (Hertel 1997) to allow for capital accumulation, national capital mobility and perfect capital mobility; only in the long-run, by using the 'disequilibrium approach'. Total Factor Productivity (TFP) is endogenously determined in GTAP-RDEM during the baseline generation while macro-economic drivers (GDP and population growth) are kept exogenous. The TFP shifters and other parameters that drive structural changes are then maintained constant during model simulations for counterfactual analyses; in order to replicate that given projected path of growth, while GDP is set as endogenous. This approach is however highly biased as it does not consider structural changes that may occur in the composition of production and consumption. For example, the GTAP-Dyn assumes uniform productivity shifters and fixed cost shares. Thus, in order to overcome these limitations, G-RDEM introduces the following five features: (1) a non-homothetic demand system that allows one to define long run changes of consumption patterns, (2) endogenous savings rates (3) productivity growth which is differentiated by broader sectors (Agriculture, Manufacturing and Services) (4) debt accumulation from foreign savings and (5) income dependent cost-shares that adjust over time.

G-RDEM is available as a module on the CGEBox (Britz and van der Mensbrugghe 2018) and can be combined with other modules and extensions. In this study, we present an application of the GTAP-RDEM model extended with the GTAP-AEZ land use, plus CO_2 and Non-CO_2 emission modules.

Modelling land supply in long-run analyses has been largely debated among the CGE community (Golub et al. 2009). Despite the fact that competition for land resources between different uses, i.e. pasture, forestry, cropland and land heterogeneity, has been considered in many CGE modelling frameworks, such as the GTAP-AEZ model in which land supply is constrained by a nested constant elasticity of transformation (CET) structure depicting land rent maximization, one major limitation is still impeding plausible CGE-based land use modelling in the long-term. In fact, due to data scarcity e.g. empirically estimated land supply elasticities, these models only consider land which is under economic use. That implies that un-managed land such as natural forests cannot be converted and brought to economic use. The accessibility of unmanaged land that could represent new sources for feedstock production becomes highly relevant, given the ongoing shift to bio-based economy and its land use change as well as its associated environmental implications. That is why, in this study that gives a special focus on land use change (LUC) and GHG emissions from increased support to grassland-based ruminant livestock production in the EU, we adjust the land supply function of the GTAP-AEZ by introducing a possibility of land conversion to an economic use based on estimated land buffer at country level, along with a land supply elasticity equal to 1. For better spatial resolution, we also introduce the EU regions at their sub-national NUTS 2 level. This may allow the tracking of heterogeneity among EU Member States in terms of LUC and associated emission effects.

GTAP-RDEM draws on the Socio-Economic Pathways projections on GDP and population growth to build long-run baselines. Our baseline scenario represents business as usual up to the year 2029 according to GDP and population projections from the IIASA Socio-Economic Pathways 3 (SSP3) (Riahi et al. 2017). The SSP3 storyline is known as 'Regional Rivalry – A Rocky Road' to refer to high challenges to mitigation and adaptation. The baseline scenario represents a situation without any policy intervention and no climate change effects. As such, it provides a counterfactual scenario to assess potential impacts from a simulated policy.

Our external policy shock consists of a shift of subsidy on grassland-based livestock production in the EU, to we examine the medium-term (2011-2029) implications of in accordance with the objective of the study. To do so, we apply a “tax recycling approach”: a budget-neutral increase in subsidies to grassland-based livestock systems in the EU, which is financed by reducing subsidies allocated to cropland. Specifically, we assume that subsidies allocated to grassland are at least two times higher than subsidies on cropland, with an upper bound of 80%. Thus, total subsidies to land in the EU agricultural sector are held fixed at benchmark level. Technically, in order to enforce this condition, we exogenize the total subsidy costs for land in each EU countries and introduce an endogenous correction of the subsidy. That mechanism is also active during the construction of the baseline. The tax recycling approach entails a redistribution of direct payments towards permanent grassland (European Commission 2018; Hecht et al. 2016). In a further step, we will analyse the extent to which such tax reallocation can promote extensive livestock farming and reduce dependence on imported feed; together with the associated environmental consequences.

4. Results

4.1. Market mechanisms

Results are presented as percentage changes from the baseline scenario along the period 2011-2029. In this way, outcomes reflect the net effect from a simultaneous increase in land-based payment to the cattle sector and a decrease in land-based support to cropping activities (Figure 3). As a production factor subsidy, an increased land payment to the ruminant livestock sector results in a decrease in land rents paid by farmers and thus incentivizes the use of land in cattle production, i.e. extensification. The nesting in the production function will, as a first order effect, decrease the amount of crops used for feed in cattle production. A tax (or lower subsidies) on cropland pushes their production costs up and let their output shrink. Consequently, compound feed becomes more expensive and increases the production cost of other livestock sectors such as pig and poultry which will hence tend to shrink. The cattle sector relies as well on other feed resources besides grass, i.e. feed crops. Hence, the overall effect from the shock on cattle production results from the combination of two effects: (1) decreases in costs of production factors due to higher land-based payments and (2) increases in costs of intermediate inputs due to higher crop prices. As for the environmental effects, greenhouse gases (GHG) from ruminant livestock production are expected to increase, especially non-CO_2 emissions. On the contrary, promoting grassland can help to increase soil and biomass carbon stocks, hence decreasing overall emissions from LUC. Effects on average land rents depend as well on the land buffer availability and land transformation costs. Countries with a higher land buffer are expected to experience lower LUC and smaller effects in domestic land markets.

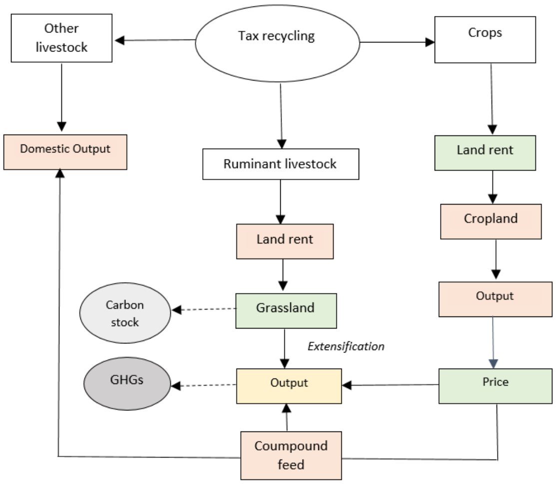

Figure 3. Economic and environmental impacts of increased land-based payments to ruminants at the expense of crop sectors. Green indicates an increase, red a decrease while yellow indicates possible positive/negative changes. Grey circles relate to environmental effects; dark grey indicates increased GHG emissions and light grey decreased soil and biomass carbon sequestration.

The EU livestock sector is highly heterogeneous both in terms of management system and the level of land subsidies. In our analysis, we therefore differentiate between EU Member States based on the following three criteria: (1) the initial payment on grassland, (2) the initial cost share of land and (3) the share of compound feed in total ruminant production cost (Figure 4).

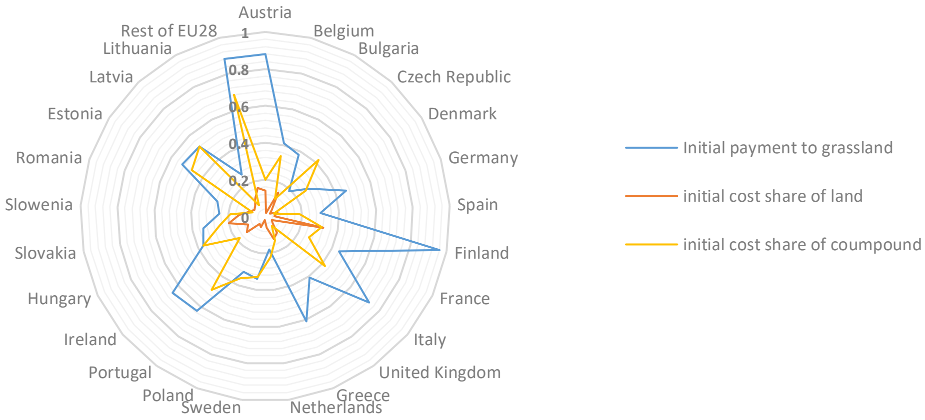

Figure 4. Characterisation of the livestock sector in the EU countries

Figure 4 underlines the high differences in the relative grassland subsidy schemes. Low subsidy rates (below 20%) are found in Netherlands (18%) and Czech Republic (19%). Most of the EU Member States apply subsidy rates in the range from 20% to 50%, namely Belgium, Bulgaria, Denmark, Germany, Spain, France, UK, Sweden, Poland, Hungary, Slovakia, Slovenia, Romania and Lithuania. Finally, high support (more than 50%) is observed in Austria, Italy, Greece, Portugal, Ireland, Estonia, Latvia, and Rest of EU28; while the highest subsidy rate is applied by Finland (96%). In Figure 4, it can be seen that the cost share of land in total costs does not exceed 20% in any EU country; with Finland being the only exception (32%). Land represents only 2% of the cost of cattle production in Belgium. The share is also below 5% in other countries such as Denmark or, France; and it ranges between 5% and 10% in most of the EU Member States. Higher land cost shares are observed in Austria, Czech Republic, UK, Croatia, Hungary, Slovakia, Slovenia, Lithuania, Rest of EU28, and Finland . The cost share of compound feed is in general high in all EU Member States, except for Germany (5%), UK (6%), Croatia, Romania (7%) and Lithuania (7%). It exceeds 30% in Belgium, Czech Republic, Finland, Poland, Portugal Ireland, Slovakia, Estonia, Latvia and rest of EU28. Farmers in countries where initial subsidy rates of land in ruminants are already high, such as in Italy, will have little incentive to convert crop to grassland. Higher expansion rates of grassland are expected in countries with low initial subsidies to grassland and higher land resources are available. As compound feed costs are expected to increase, a high initial cost share of compound feed will counteract the impact of increased land subsidies.

4.2. Market effects

Results show diverse market effects among EU Member States of an increase in the subsidy on grassland (with an upper bound of 80%) at the expense of cropland, see figure 5[1]. In countries where payments are originally high, such as in Italy, Greece and Ireland, the additional subsidy increase is small or even zero such no significant effect on production is observed, such as +1.21% in Ireland, +1.32% in Italy and +2.37% in Greece (in 2029). In countries with rather low initial payments (less than 50%), the substitution of land for feed is more significant, leading to a higher extensification. For instance, in Lithuania, the use of land for cattle production increases by the highest rate among all EU Member States (+27.83%) leading to a significant expansion of ruminant livestock production of 17.24% in 2029. The same is observed for Slovenia, where ruminant production increases by 6.78%. Due to their high initial ruminant production, its output in France, Germany and Spain shows slight increases. Impacts in Austria and Finland are all market mediated as their initial subsidy to the cattle sector exceeds the upper-limit condition of 80% and is kept unchanged.

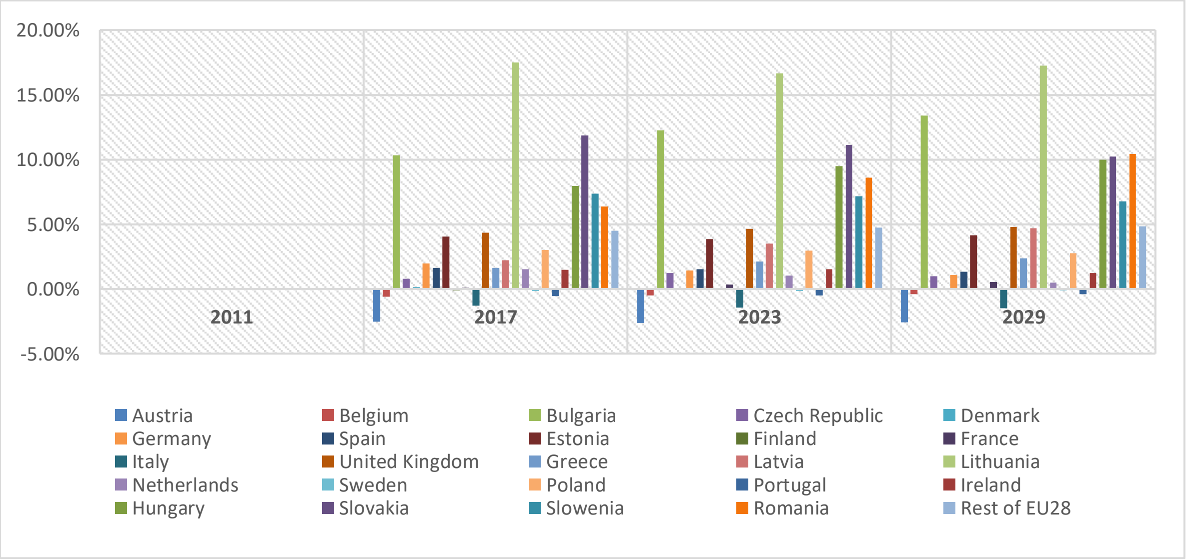

Figure 5. Effects on ruminant livestock production in the EU28 [% change from the year 2011]

In countries where cattle production is highly intensified, compound feed production costs increase due to higher crop prices in combination with the decreasing meat prices; which leads to decreases in cattle production output. For instance, in Belgium, Portugal and Sweden, where compound feed has an important unit cost share of around 34%, 49% and 33%,respectively, cattle production decreases slightly by -0.41%,-0.42% and -0.12% in 2029. In fact, as can be seen in Table 2, reducing cropland-

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[1] Table A1 in the Appendix describes the path of cattle production change over the period 2011-2029

based support to boost extensive cattle production in the EU28 comes at the expense of crop production; hence increasing crop and feed prices. For instance, rapeseed production decreases in many EU countries, e.g. by -13.45% in Netherlands in the year 2029. Legume production shows a significant decrease in the majority of EU countries such as the United Kingdom (-10.77% in 2029), Ireland (-7.65% in 2029) and Bulgaria (-2.04% in 2029). The increase in crop prices in combination with less compound feed demand from the cattle sectors due to extensification reduces the output of the compound feed industry.

Table 2. Effects on the EU28 crop and feed market in 2029 [% change from the year 2011]

	Rape seed		**Legumes**		**Rape seed cake**		**Wheat**	
	Quantity	Price	Quantity	Price	Quantity	Price	Quantity	Price
Austria	0.20	-0.02	0.25	-0.08	0.00	0.04	0.31	-0.03
Belgium	-0.05	0.19	-1.43	0.34	0.16	0.07	0.01	0.09
Bulgaria	-0.42	0.23	-2.04	1.11	0.07	0.06	-0.53	0.23
Czech Republic	1.93	-1.05	6.54	-2.85	1.44	-0.48	3.91	-1.08
Denmark	0.42	0.04	-0.02	0.06	0.10	0.07	0.06	0.02
Germany	0.14	0.06	-0.64	0.26	-0.02	0.07	-0.07	0.05
Spain	0.16	0.04	0.00	0.04	-0.01	0.06	0.40	0.04
Estonia	0.38	0.13	-0.30	0.12	0.17	-0.00	0.04	0.09
Finland	-0.80	0.64	0.30	0.20	-0.21	0.23	-2.99	1.05
France	0.11	0.09	-1.56	0.64	0.10	0.07	-0.39	0.11
Italy	0.32	-0.03	0.12	-0.03	0.09	0.01	0.20	0.00
United Kingdom	-1.41	0.90	-10.77	3.60	-1.37	0.70	-1.51	0.97
Greece			-1.18	0.63	0.37	-0.03	-0.47	0.20
Latvia	0.07	0.15	-1.54	0.47	0.17	0.01	-0.41	0.12
Lithuania	-0.06	0.15	-0.20	0.20	0.27	0.01	-0.36	0.12
Netherlands	-13.45	6.42	1.15	-0.25	-1.03	0.37	0.57	-0.03
Sweden	0.59	-0.09	0.27	-0.14	0.30	0.02	0.41	-0.07
Poland	0.04	0.07	-0.28	0.16	-0.03	0.03	-0.13	0.06
Portugal			-0.94	0.06	0.07	0.00	0.48	0.09
Ireland	0.16	0.22	-7.65	5.96	1.27	0.02	-1.99	1.13
Hungary	-0.68	0.27	-1.10	0.76	-0.54	0.10	-0.48	0.26
Slovakia	-0.52	0.17	-1.62	0.65	-0.42	0.08	-0.85	0.16
Slovenia	-4.16	1.40	-2.37	0.50	-1.35	0.40	-1.43	0.64
Romania	-0.57	0.24	-0.61	0.53	0.12	-0.00	-0.74	0.28
Rest of EU28	-0.75	0.39	-4.98	1.65	0.00	0.14	-0.92	0.46

A redistribution of payment to grassland-based production systems leads to significant price effects on the EU livestock sector, in general. It reduces ruminant production costs, which translates into a decrease in the output price of beef and other ruminants (Figure 6[2]). For example, in Slovakia, the producer price of cattle decreases by around -10.37% in the year 2029. However, in other countries prices are barely affected. This can mainly be explained by the initial subsidy level. For instance, in Italy where payment on grassland is already high in comparison to other EU Member States, increasing subsidies will result in a marginal shift to extensive cattle farming. In addition, the resulting increase in crop prices (Table 2) due to cutting support on cropland implies higher costs in other non-ruminant livestock sectors, such as pig and poultry. For instance, in Slovenia and Romania, prices of other livestock increase by around 1% in both countries (Figure 7).

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[2] Table A2 in the Appendix describes the path of price change in the EU cattle sector over the period 2011-2029

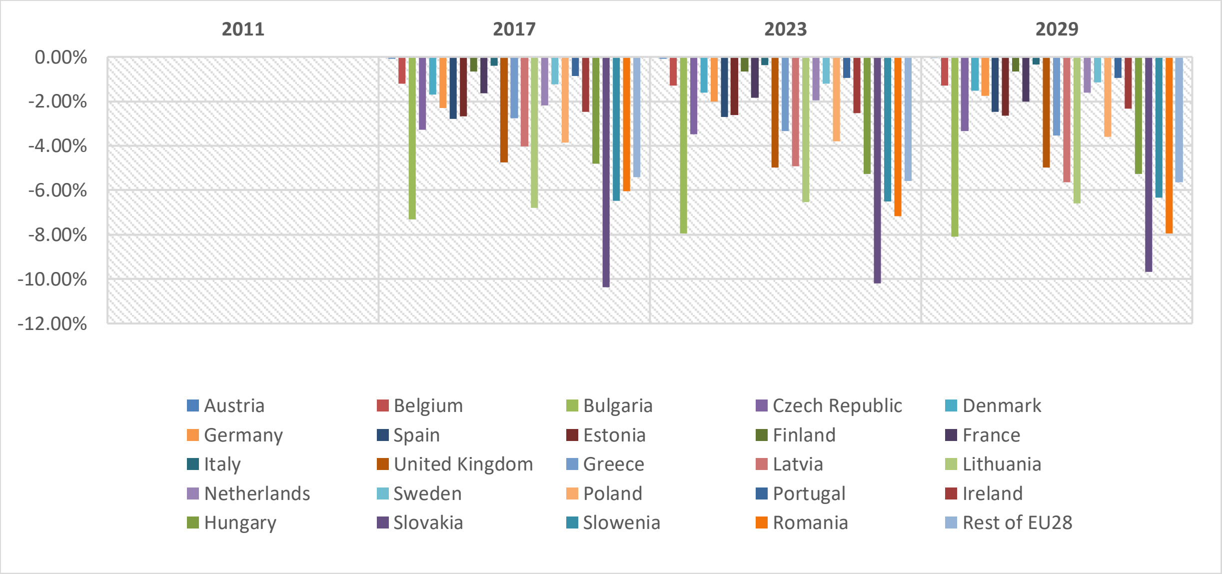


Figure 6. Effects on ruminant livestock prices (net of tax) in the EU28 [% change from the year 2011]

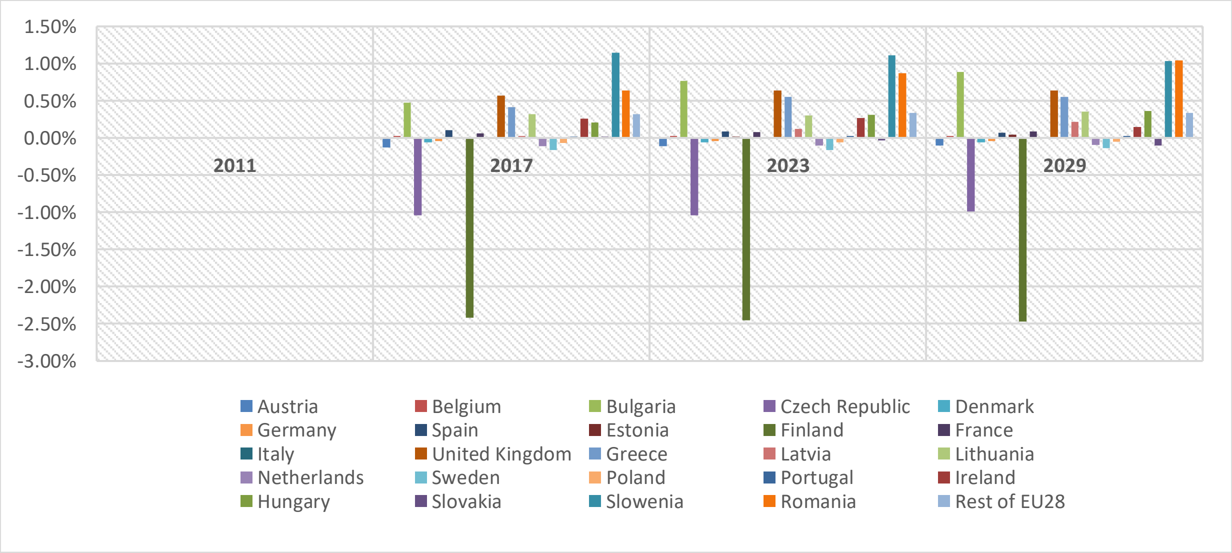


Figure 7. Effects on other livestock prices (net of tax) in the EU28 [% change from the year 2011]

These price effects in livestock sectors are mainly driven by the land market. In fact, with an inelastic land supply and due to the increased competition for the scarce land resources, the reallocation of payment from cropland to grassland has significant effects on land rents. Higher subsidies to cattle let land shift away from other land-based sectors to ruminant livestock where farmers are able to pay higher rental price (Figure 8) while the opposite holds for cropland based sectors (Figure 9). This implies a shift from land from crops to cattle. The magnitude of this effect depends on the availability of land buffer as well as the easiness of shifting land away from crops. For example, in countries with some available land buffer, such as the UK, France and Spain, price effects from land conversion to grassland are dampened. A look at figures 8 and 9 shows also that the largest price are observed in Finland where subsidy rates are not changed and initial subsidies to land are very high. With dropping cattle meat and increasing crop prices, cattle meat production in Finland loses and crops gain competiveness; the net effect is an increase in the land rent.

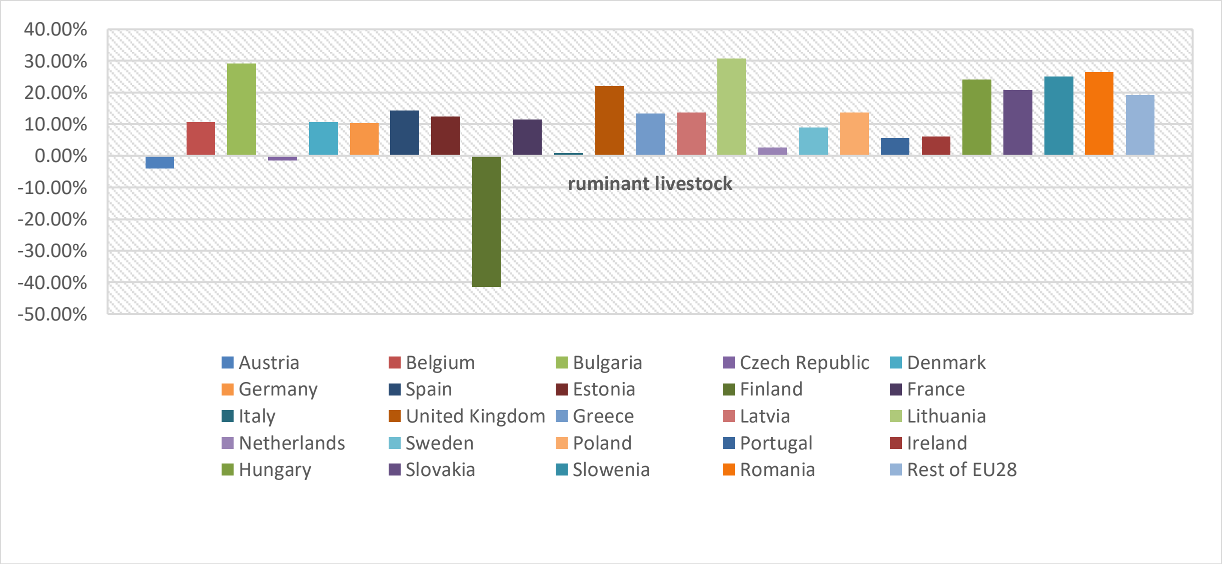


Figure 8. Effects on land rents (net of tax) for ruminant livestock sector in 2029

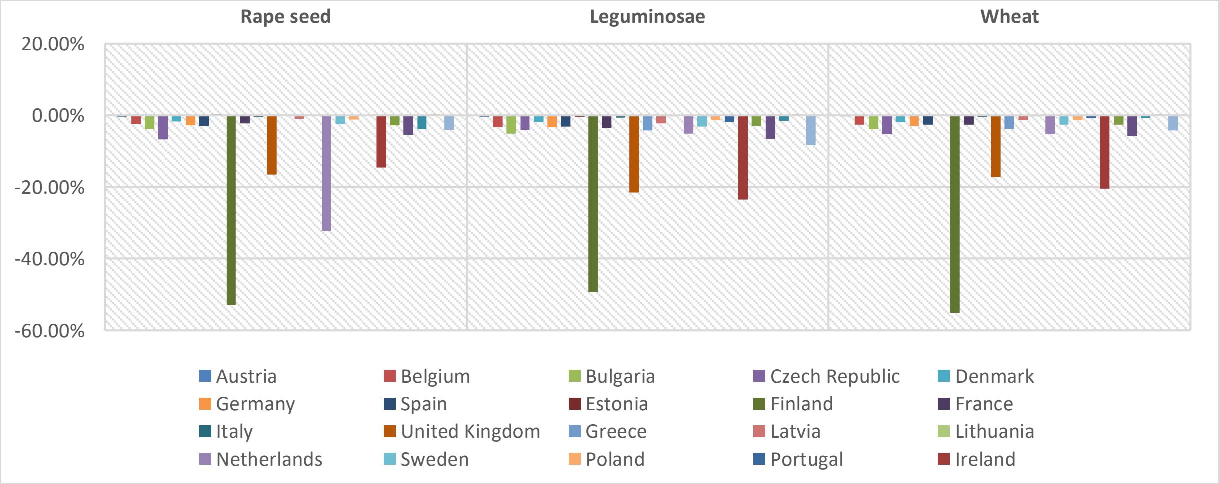


Figure 9. Effects on land rents (net of tax) in other land-based sectors in 2029

At detailed EU level, figure 10 shows that effects on livestock and crop production vary significantly across NUTS2 regions. Increased payment on grassland leads to higher cattle production (Figure 10 a) in most of the EU regions, but essentially in some parts of Spain and Germany (up to +8.05%). However, it decreases slightly (-2.35%) in Austria, Czech Republic, some parts of France and Italy. This expansion of ruminant production comes at the expense of other livestock sectors that decrease essentially in many regions of Spain and the United Kingdom (-6.36%). However, production in other NUTS2 regions is barely affected and raises (up to +2.78%) in Austria, Sweden and some regions of Italy (Figure 10 b). Reducing subsidies on cropland leads to a decrease in the EU crop production. However, some heterogeneity exists when we look at the EU sub-national level. For example, as can be seen in figure 10 c, rapeseed production declines essentially in Spain where its production is originally small. However, in Germany and France, production is barely affected due to the very high initial production of rapeseed in those countries. Wheat production (Figure 10 d) decreases mainly in Spain (-8.18%) and some parts of France (-1.19%).

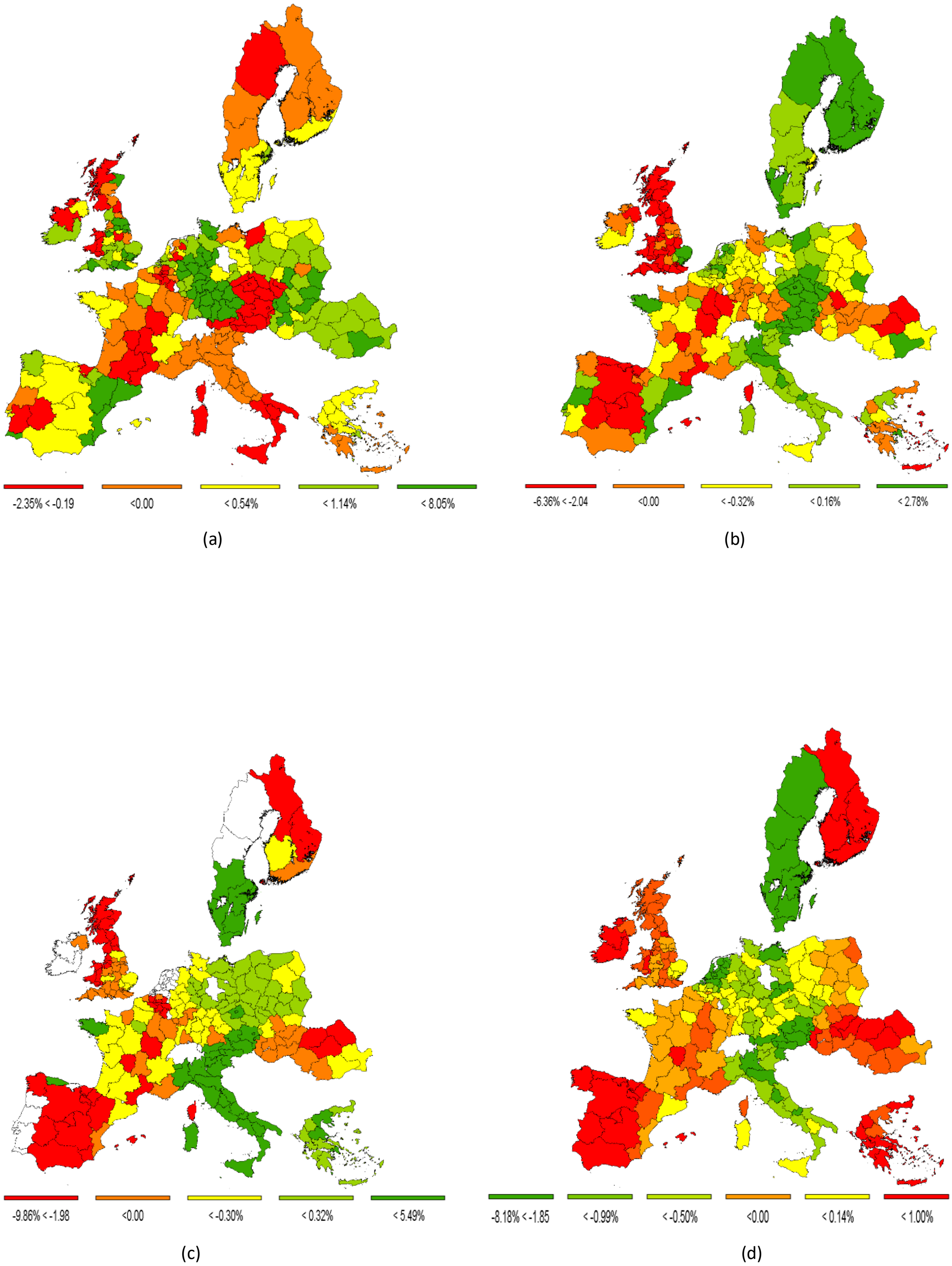
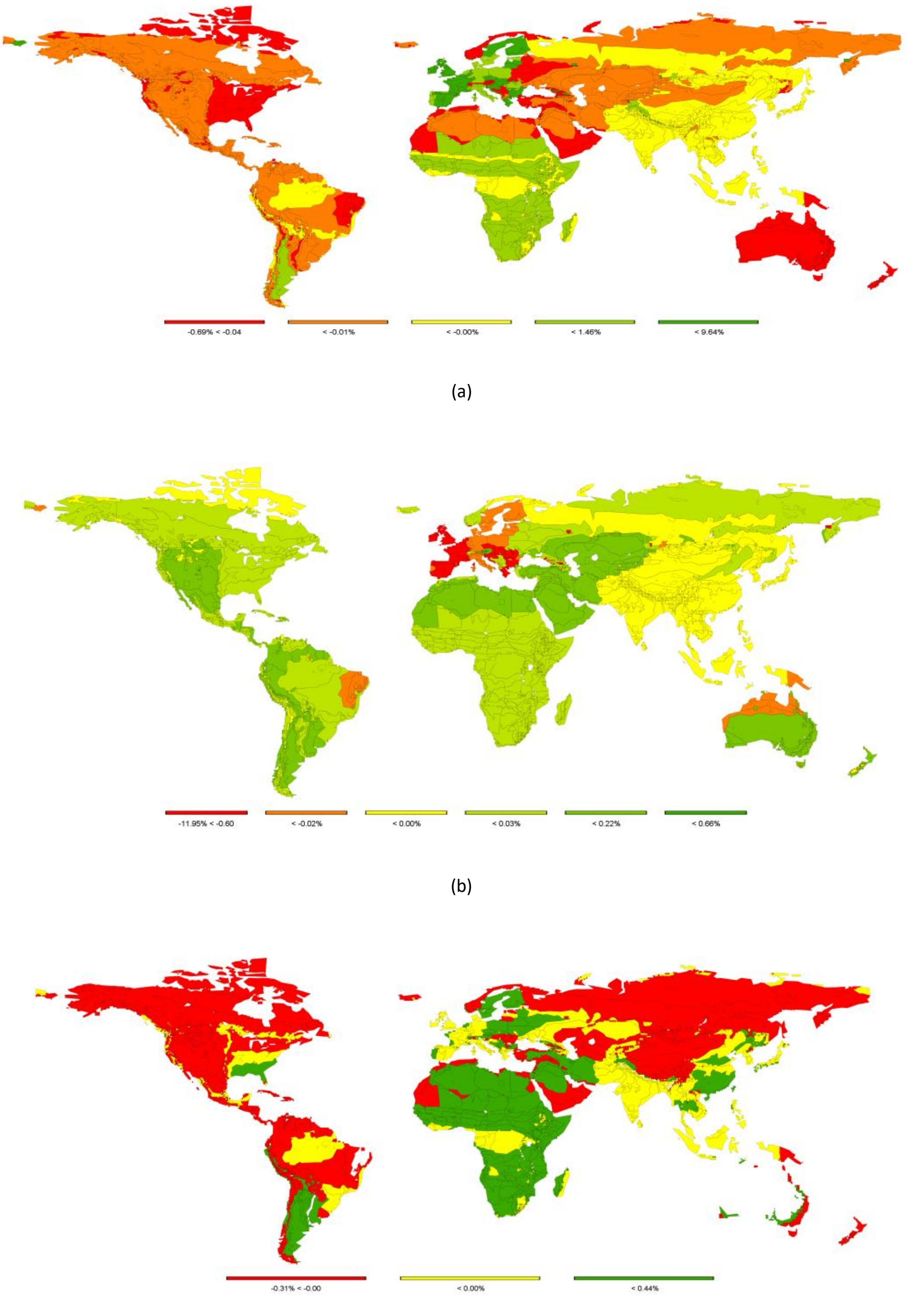


Figure 10. Effects on livestock and crop production in the EU28, at NUTS2 level, in the year 2029 [% change from the year 2011]. (a) Effects on cattle production. (b) Effects on other livestock production. (c) Effects on rapeseed production. (d) Effects on wheat production.

4.3. Global land use change and GHG emissions

The shock also leads to significant land use and cover changes on a global scale (Figure 11). Pastureland expands remarkably in almost all the EU Member States, as expected (Figure 11a). The expansion is greater in countries where large land resources are available, such as France and Spain, where pastureland expands significantly (up to +9.64%). However, in other EU Member States with more limited land resources, such as Netherlands and Denmark, pastureland increases by around 1.5%.



(a)

(b)

(c)

Figure 11. Impacts on land cover change in the year 2029 [% change from the year 2011]. (a) Change in pastureland. (b) Change in cropland. (c) Change in forest cover.

Lower subsidies to cropland in the EU28 lead to significant decreases in cropland area (Figure 11b). However, in Austria, the shock generates insignificant price effects as the initial payment to ruminant livestock sector is already high, due to the tax recycling assumption. Furthermore, since the total land-based tax income is maintained constant, a very small decrease in support to crop-based activities is detected; thus, cropland area increases by around 0.70%, mainly for rapeseed production. At the global level, cropland expands in regions such as North America, Brazil, Argentina and Middle East and North Africa (MENA) region. In fact, the decrease in EU crop production translates into an increased dependence on imported feed crops. As a result, Brazilian soybean exports to Greece, the United Kingdom and Italy rise by 0.20%, 0.15% and 0.34%, respectively. Similarly, legume imports from Argentine rise by 1.75% in Bulgaria, 0.70% in France and by 0.37% in Germany.

Changes in forest cover are negligible across EU Member States. Forestland area decreases slightly (-0.31%) in other outside-EU regions such as Russia and North America while it increases marginally (up to 0.44%) in Argentina and Sub-Saharan Africa (Figure 11 c).

Further implications of land cover changes in terms of GHG emissions are show in Figure 12. It must be noted that LUC emissions from carbon stock changes are not yet included in the discussion. Thus, emissions only arise from intensification of agricultural production due to greater fertilizer application doses. In other words, GHG emissions only arise from changes in land management across land uses. This may lead to underestimating the net GHG emission effects of the policy, since it can translate into enhanced carbon sequestration due to grassland expansion.

In the EU, the highest increases in GHG emissions, as CO_2-eq., are observed for the United Kingdom and Romania, where total GHG emissions rise by 0.5 million tonnes and by around 0.4 million tonnes, respectively. GHG emissions increase by around 0.1 million tonnes in Bulgaria, Poland, Hungary and Lithuania. Minor effects are detected in Czech Republic, Denmark, Spain, Estonia, Finland, Greece, Latvia, Netherlands, Sweden, Ireland, Slovakia, Slovenia and rest of EU28; where emission increases are lower than 0.03 million tonnes of CO_2-eq., where total GHG emissions increase in a few countries, namely Austria, Belgium, Germany, France and Italy, where the overall expansion of ruminant livestock sector is relatively small. Additionally, the decrease in emissions from extensification generates smaller GHG emissions from cattle sector. For example, N_2O emissions from cattle sector in France decrease by around 0.35% while it increases by 3.05% in the United Kingdom.

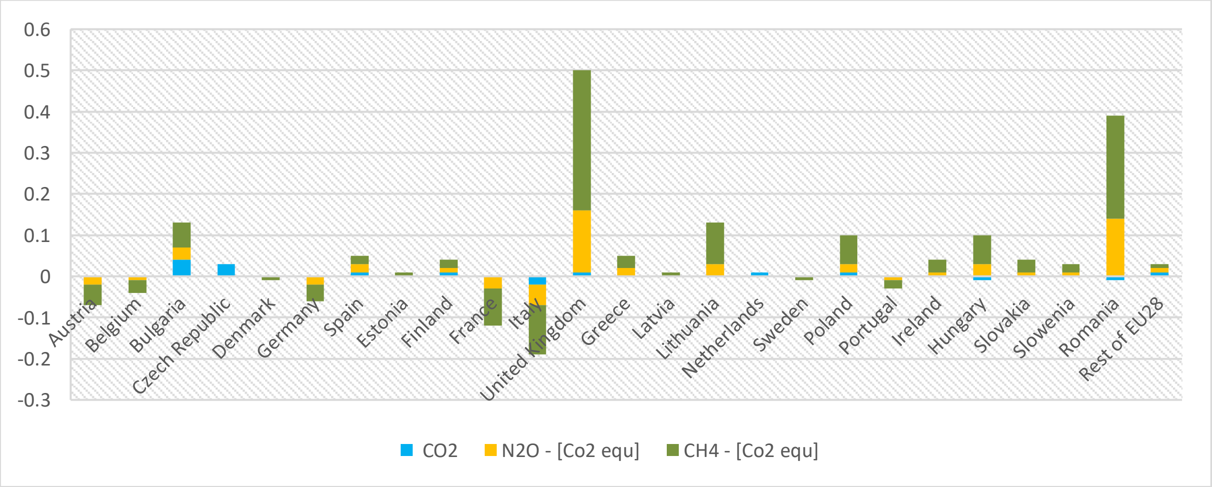


Figure 12. Effects on CO_2 and Non-CO_2 emissions in 2029 (absolute difference from the year 2011 in million tonnes of CO_2-eq, without LUC emissions)

5. Summary and conclusions

This study assesses the global implications of shifting land-based payments from cropland to grassland in the EU28 to promote grassland-based livestock production systems. To do so, we simulate a tax recycling approach which implies a cost neutral increase of subsidies to grassland at the expense of cropland-based subsidies. Given the very high initial support to ruminant sector in Finland, this payment redistribution is not applied in this country. As expected, the policy shock leads to significant effects in agricultural markets across the EU. Cattle production increases in the majority of EU member states, except in Italy where the support to grassland-based ruminant production is initially very high. This increase in cattle production comes at the expense of a decrease in the production of other livestock sectors, such as pig and poultry. Reducing the payment support to cropland leads to an increase in crop prices, especially feed crops, such as rapeseed. Therefore, production cost increase in other livestock sectors; thus, livestock production shrinks in the majority of the EU Member States. As a net effect, imports of feedstuffs from other regions increase.

Promoting grassland-based ruminant sector at the expense of cropland-based activities leads to significant effects in land markets too. Land prices increase in cattle production and decrease in other sectors. Due to the scarcity of land resources, this effect is especially significant in small countries with low land availability; while it is more moderate in countries where land is largely available. In terms of land management, we found that the simulated policy leads to a significant increase in the EU grassland areas. However, this may also trigger some deforestation in other regions outside the EU28, such as Latin America to compensate for the protein crop deficit in the EU market. Complementary strategies are needed to prevent this increased imported protein dependence; while the GHG effects of induced global LUC should be further assessed. With this illustrative example, we present the first application of a novel CGE approach that integrates a very detailed MRIO database in physical units into the GTAP-RDEM dynamic framework, enhancing disaggregation of agri-food sectors and spatial resolution for the EU (at NUTS2 level).

Appendix

Table A.1. Effects on cattle production in the EU28 over the period (2011-2029) [% change from the year 2011]

	2011	2013	2015	2017	2019	2021	2023	2025	2027	2029
Austria	0.00	-2.37	-2.46	-2.55	-2.60	-2.61	-2.62	-2.61	-2.61	-2.56
Belgium	0.00	-0.56	-0.59	-0.60	-0.54	-0.52	-0.50	-0.48	-0.46	-0.41
Bulgaria	0.00	8.56	9.40	10.32	10.98	11.63	12.28	12.91	13.51	13.40
Czech Republic	0.00	0.13	0.48	0.79	0.99	1.16	1.23	1.24	1.21	0.99
Denmark	0.00	0.19	0.16	0.15	0.18	0.10	0.05	0.01	-0.01	0.02
Germany	0.00	2.20	2.08	1.98	1.71	1.57	1.43	1.30	1.16	1.08
Spain	0.00	1.54	1.60	1.64	1.70	1.62	1.54	1.47	1.40	1.32
Estonia	0.00	1.79	2.85	4.03	3.90	3.91	3.85	3.74	3.75	4.14
Finland	0.00	-0.09	-0.10	-0.10	-0.09	-0.09	-0.08	-0.08	-0.07	-0.06
France	0.00	0.03	0.06	0.10	0.22	0.26	0.32	0.38	0.45	0.56
Italy	0.00	-1.16	-1.23	-1.30	-1.36	-1.39	-1.42	-1.45	-1.48	-1.48
United Kingdom	0.00	3.89	4.11	4.33	4.50	4.58	4.66	4.73	4.80	4.77
Greece	0.00	1.40	1.51	1.62	2.01	2.05	2.11	2.20	2.29	2.37
Latvia	0.00	0.79	1.42	2.24	2.55	3.00	3.49	3.98	4.48	4.68
Lithuania	0.00	13.69	15.59	17.52	16.51	16.52	16.65	16.79	16.98	17.24
Netherlands	0.00	1.78	1.66	1.52	1.38	1.20	1.02	0.84	0.67	0.51
Sweden	0.00	-0.16	-0.17	-0.16	-0.17	-0.16	-0.15	-0.14	-0.13	-0.12
Poland	0.00	2.25	2.63	3.02	2.96	2.96	2.96	2.95	2.94	2.78
Portugal	0.00	-0.50	-0.53	-0.55	-0.53	-0.50	-0.48	-0.46	-0.44	-0.42
Ireland	0.00	1.22	1.37	1.49	1.47	1.52	1.52	1.48	1.41	1.21
Hungary	0.00	7.60	7.78	7.96	8.67	9.12	9.47	9.76	9.98	9.97
Slovakia	0.00	11.02	11.46	11.88	11.50	11.33	11.14	10.92	10.69	10.22
Slovenia	0.00	7.24	7.30	7.37	7.30	7.25	7.16	7.06	6.95	6.78
Romania	0.00	4.62	5.42	6.35	7.11	7.89	8.60	9.24	10.11	10.42
Rest of EU28	0.00	4.35	4.43	4.50	4.62	4.67	4.72	4.77	4.81	4.84

Table A.2. Effects on cattle prices (net of tax) in the EU28 over the period (2011-2029) [% change from the year 2011]

	2011	2013	2015	2017	2019	2021	2023	2025	2027	2029
Austria	0.00	-0.07	-0.07	-0.08	-0.07	-0.07	-0.07	-0.06	-0.06	-0.06
Belgium	0.00	-1.12	-1.16	-1.21	-1.27	-1.28	-1.29	-1.30	-1.30	-1.29
Bulgaria	0.00	-6.60	-6.94	-7.32	-7.48	-7.73	-7.94	-8.12	-8.30	-8.09
Czech Republic	0.00	-2.86	-3.07	-3.27	-3.36	-3.44	-3.47	-3.47	-3.47	-3.34
Denmark	0.00	-1.63	-1.66	-1.69	-1.69	-1.65	-1.61	-1.57	-1.54	-1.51
Germany	0.00	-2.36	-2.34	-2.31	-2.17	-2.09	-2.01	-1.93	-1.84	-1.76
Spain	0.00	-2.62	-2.72	-2.79	-2.85	-2.78	-2.71	-2.64	-2.58	-2.48
Estonia	0.00	-1.91	-2.28	-2.68	-2.64	-2.64	-2.61	-2.58	-2.58	-2.65
Finland	0.00	-0.60	-0.63	-0.65	-0.65	-0.65	-0.65	-0.65	-0.65	-0.65
France	0.00	-1.46	-1.54	-1.63	-1.77	-1.81	-1.85	-1.91	-1.97	-2.01
Italy	0.00	-0.38	-0.39	-0.39	-0.40	-0.39	-0.38	-0.37	-0.36	-0.34
United Kingdom	0.00	-4.33	-4.54	-4.75	-4.85	-4.92	-4.97	-5.02	-5.05	-4.97
Greece	0.00	-2.45	-2.60	-2.75	-3.21	-3.27	-3.34	-3.43	-3.51	-3.55
Latvia	0.00	-2.61	-3.26	-4.02	-4.25	-4.57	-4.91	-5.24	-5.58	-5.64
Lithuania	0.00	-5.65	-6.23	-6.80	-6.54	-6.52	-6.53	-6.55	-6.58	-6.59
Netherlands	0.00	-2.23	-2.22	-2.20	-2.14	-2.05	-1.95	-1.84	-1.74	-1.62
Sweden	0.00	-1.14	-1.18	-1.24	-1.22	-1.21	-1.21	-1.21	-1.20	-1.16
Poland	0.00	-3.26	-3.56	-3.86	-3.84	-3.82	-3.81	-3.79	-3.77	-3.61
Portugal	0.00	-0.82	-0.85	-0.87	-0.93	-0.95	-0.96	-0.97	-0.97	-0.94
Ireland	0.00	-2.16	-2.32	-2.46	-2.48	-2.52	-2.53	-2.51	-2.48	-2.34
Hungary	0.00	-4.71	-4.76	-4.81	-5.04	-5.17	-5.26	-5.31	-5.35	-5.26
Slovakia	0.00	-9.51	-9.94	-10.37	-10.27	-10.24	-10.19	-10.10	-10.02	-9.69
Slovenia	0.00	-6.17	-6.32	-6.48	-6.48	-6.52	-6.52	-6.50	-6.47	-6.32
Romania	0.00	-5.07	-5.54	-6.06	-6.46	-6.84	-7.17	-7.45	-7.83	-7.94
Rest of EU28	0.00	-5.23	-5.31	-5.40	-5.48	-5.54	-5.59	-5.63	-5.67	-5.64

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