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Refunding of a climate tax on food consumption in Sweden

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Abstract: Refunding of climate taxes on consumption of food might reduce the resistance towards the introduction of such a tax, which is necessary to achieve climate targets. This paper examines the implication of refunding a tax on consumption of food in Sweden under three refunding schemes; lump sum, in proportion to agricultural area, and payments for ecosystem services on agricultural land (carbon sink enhancement by restoration of drained peatland, biodiversity provision from increased area of grassland, and nutrient regulation by construction of wetlands). The theoretical results showed that economic and environmental conditions can improve compared with the no tax case under all three schemes, but to different farmer categories. The empirical results from a partial agricultural sector model showed that the introduction of a climate tax corresponding to the Swedish tax of 115 Euro per ton CO_2e reduces total emissions by 5% without any refunding of the total tax incomes which amount to 1.391 billion Euro. Refunding with payments for restoration of drained peatlands enhance carbon sink by 5.9 million metric tons of CO_2e and results in net benefit of the tax system as a whole but not for all farmer categories.

Key words; climate tax, food consumption, tax refunding, partial equilibrium analysis, Sweden

JEL codes; Q28, Q25, H23

1. Introduction

Emissions of GHG from agriculture accounts for 22% of total anthropogenic GHG emissions worldwide and 80% of these emissions come from livestock (McMichael, 2007). Suggestions have therefore been made to introduce climate taxes on meat in order to reduce demand and emissions (e.g. UNEP, 2009; Roos and Tjarnemo, 2011; Cederberg et al., 2013; Bajzˇelj et al., 2014; Säll and Gren, 2015). Several studies show that the price elasticity of demand for meat and dairy products is relatively low (Wirsenius et al., 2011; Edjabou and Smed, 2013; Säll and Gren, 2015, Chalmers et al., 2016), which requires considerable increases in the price of meat for a significant reduction in emissions. The introduction of such an environmental tax on consumption of food may also meet resistance from the agricultural sector because of expected loss in profits. The fear of profit losses and resistance towards the environmental tax can be mitigated by earmarking the revenues from the taxes to support farmers (e.g. Kallbekken et al., 2011; Sterner and Coria, 2012). Such systems have been introduced in several countries (e.g. Sweden, Demark, Italy, UK, France, the Netherlands) where emissions of CO_2 and other pollutants have been taxed and refunded by cutting other taxes (labor, capital, VAT) or pay roll charges, promote investment in clean technologies, or compensate polluters paying the environmental tax (Millock, 2004; Sterner and Isaksson, 2006; Aidt, 2010).

Starting in early 1990s there is a large body of theoretical and empirical literature on refunding of environmental taxes (see review in Freire-Gonzáles 2018). A meta-analysis of the empirical studies has pointed out the existence of a double dividend, i.e. improved economic and environmental conditions compared to the no policy case (Freire-Gonzáles, 2018). Other studies have examined the distributional aspects of a green tax reform, and found that the progressivity in the system depends on refunding mechanism (Klenert and Mattauch, 2016). The literature on earmarked refunding to specific groups in society, mainly to polluters paying the tax, is smaller (e.g.Aidt, 2010; Fischer, 2010; Bonilla et al., 2015; Hagem et al., 2015). Aidt (2010) makes a theoretical comparison of three different refunding schemes, income tax cuts, increased governmental spending (lump sum), and tax cuts for polluters, and shows that polluters can promote extra governmental spending in order to foster public support for a refunding scheme. Fisher (2010) finds that an output based refunding system, where taxes are refunded according to the market share of the firm, may increase total emission when there is market power. Hagem et al. (2015) make a theoretical comparison of two refunding schemes; payments in proportion to outputs and to abatement expenditures. Bonilla et al. (2015) evaluate the impact on the development of clean technologies of the refunding of the Swedish tax on NO_x, and found that the refunding boosted investment in abatement of NO_x.

Despite the experiences in practice from emission tax refund systems and the large literature in economics, there is, to the best of our knowledge, no study on the effects of a recycled climate tax on consumption of food. The purpose of this study is to evaluate such a system, which is made for food consumption in Sweden. The refunding schemes are compared with respect to their effects on farmers' profits in Sweden and environmental performance. To this end, a partial equilibrium model of the agricultural sector (CAPRI, Common Agricultural Policy Regionalized Impact model) is used to evaluate and compare economic and environmental impacts of three refunding schemes; lump sum, in proportion to agricultural area and payments for ecosystem services. In our view, in addition to the application to consumption of food, the study makes a contribution by including payments for ecosystem services as a refunding scheme.

The remaining part of the paper is organized as follows. In Section 2 we present a simple theoretical analysis of the economic and environmental outcomes for a profit maximizing farmer under different policy schemes, where no tax and refunding provides the benchmark case. The partial equilibrium model and data retrieval are presented in the next section, and results are presented in Section 4. The paper ends with a discussion and conclusions.

2. A model of climate tax refund systems

We consider the agricultural sector to include $i=1,\ldots,n$ farmers, each of whom produce food, $Q^{i,M}$, and other commercial outputs, $Q^{i,O}$. Simplifications are made by assuming a linear relation between output and land use $A^{i,M}$ and $A^{i,O}$, where $Q^{i,M},=q^{i,M}A^{i,M}$ and $Q^{i,O},=q^{i,O}A^{i,O}$. The farmer is assumed to operate on competitive markets where the outputs are sold at the prices p^M and p^O.. Without a climate tax , the farmer's decision problem is to choose the allocation of $A^{i,M}$ and $A^{i,O}$ which maximize profits given a restriction on the total are of agricultural land, $\overline{A}^i$ which is written as:

$$\max_{A^{i,M},\,A^{i,O}} \quad \pi^i = p^M q^{i,M} A^{i,M} + p^O q^{i,O} A^{i,O} - C^i(Q^{i,M}, Q^{i,O}) \quad s.t. \;\; A^{i,M} + A^{i,O} \le \overline{A}^i \tag{1}$$

where $C^i(Q^{i,M},Q^{i,O})$ is the cost function assumed to be increasing at an increasing rate in its arguments. The solution to eq. (1) gives the familiar condition where the marginal profits of land in the two uses are equal:

$$\left(p^M - \frac{\partial C^i}{\partial Q^{i,M}}\right) q^{i,M} = \lambda^i = \left((p^O - \frac{\partial C^i}{\partial Q^{i,O}}\right) q^{i,O} \tag{2}$$

where λ^i is Lagrange multiplier on the land constraint, or the shadow value of land, which is determined by the marginal profits from the two land uses.

Total consumption of food in Sweden includes the outputs produced in Sweden and imports, which gives $Q^M = \sum_i Q^{i,M} + Q^{IMP,M}$, where Q^M is determined by the demand for the food and the (world market) price p^M. For analytical convenience but without loss of generality, it is assumed that green-house gas (GHG) emissions occur only from Q^M.

2.1 Climate tax without refunding

A climate unit tax, t., is levied on total consumption of food Q^M. The tax is assumed to reflect the cost of carbon generated by a marginal food output (e.g. Gren et al. (2019)). It consists of two parts;

marginal social cost of carbon and carbon emissions by the food output. Without any other positive or negative externalities, the introduction of this tax will generate an efficient outcome where marginal social cost of producing food equals the marginal value. Without any refunding, the profit, $\pi^{i,t}$, is given by:

$$\pi^{i,t} = (p^M - t)q^{i,M} A^{i,M} + p^O q^{i,O} A^{i,O} - C^i(Q^{i,M}, Q^{i,O}) \quad (3)$$

The first-order conditions deliver:

$$\left((p^M - t) - \frac{\partial C^i}{\partial Q^{i,M}} \right) q^{i,M} = \lambda^{i,t} = \left((p^O - \frac{\partial C^i}{\partial Q^O} \right) q^{i,O} \quad (4)$$

Eq. (4) shows that the introduction of the tax on food reallocates land towards other outputs and reduces the shadow value of land, i.e. that $\lambda^{i,t} < \lambda^i$.

2.2 Lump sum and area based refunding

Total tax revenues, *T*, are given by the unit tax times the total consumption of the output, $T = tQ^M$. In the lump sum refunding scheme each farmer receives the same amount of funding corresponding to *T/n*, which gives the profits $\pi^{i,LS}$ as:

$$\pi^{i,LS} = (p^M - t)q^{i,M} A^{i,M} + p^O q^{i,O} A^{i,O} - C^i(Q^{i,M}, Q^{i,O}) + T/n \quad (5)$$

The optimal allocation of $A^{i,M}$ and $A^{i,O}$ is the same as with the tax, which is a well known result of a lump sum payment.

A refunding scheme corresponding to current income support from CAP implies that each farmer receives payment in proportion to the agricultural area, $A^i \frac{T}{\sum_i A^i}$ and the associated profits, $\pi^{i,AB}$, are written as:

$$\pi^{i,AB} = (p^M - t)q^{i,M} A^{i,M} + p^O q^{i,O} M^{i,O} - C^i(Q^{i,M}, Q^{i,O}) + A^i T / \sum_i A^i \quad (6)$$

The first-order conditions are

$$\left((p^M - t) - \frac{\partial C^i}{\partial Q^{i,M}}\right) q^{i,M} = \lambda^{i,AB} - \frac{T}{\sum_i A^i} = \left((p^O - \frac{\partial C^i}{\partial Q^{i,O}}\right) q^{i,O} \tag{7}$$

The marginal value of land is now increased corresponding to the unit area payments, where $\lambda^{i,t} = \lambda^{i,AB} - \frac{T}{\sum_i A^i}$. When $A^i < \overline{A}^i$, this is likely to increase the area of land in agriculture and associated emissions of GHGs (e.g. Baumol and Oates, 1998).

2.3 Payments of ecosystem services

There is a large body of literature on the payments of ecosystem services, which considers a number of different payments systems such as cost and performance based schemes (see Engel 2016 for a survey), In this study, a performance based system is assumed with unit payments for non-marketed ecosystem services, s^E, which are constant and correspond to society's marginal value of the service. Another assumption is that the farmer needs to allocate land for production of ecosystem services, $A^{i,E}$, with the productivity of $q^{i,E}$. The payment to each farmer is then $s^E q^{i,E} A^{i,E}$ where total payments can not exceed the tax revenues, i.e. $\sum_i s^E q^{i,E} A^{i,E} \le T$. By this formulation, we allow for the possibility that the revenue constraint is not binding which occurs when the unit value of Q^E is lower than the average payment, i.e. when $s^E < \frac{T}{\sum_i q^{i,E} A^{i,E}}$. In this case, the combination of the tax and subsidy system implies an efficient outcome since the tax corresponds to the marginal negative externality and the unit payment to the marginal positive externality.

The famer's decision problem is then formulated as:

$$\underset{A^{i,M}, A^{i,O}, A^{i,E}}{Max} \quad \pi^{i,ES} = (p^M - t) q^{i,M} A^{i,M} + p^O q^{i,O} A^{i,O} + s^E q^{i,E} A^{i,E} - C^i(Q^{i,M}, Q^{i,O}, Q^{i,E}) \tag{8}$$

$$s.t. \quad A^{i,M} + A^{i,O} + A^{i,E} \le \overline{A}^i \quad and \quad \sum_i s^E q^{i,E} A^E \le T$$

where $C^i(Q^{i,M}, Q^{i,O}, Q^{i,E})$ is the cost function for provision of all outputs. The first-order conditions are

$$\lambda^{i,ES} = \left((p^M - t) - \frac{\partial C^i}{\partial Q^{i,M}} \right) q^{i,M} = \left((p^O - \frac{\partial C^i}{\partial Q^{i,O}} \right) q^{i,O} = \left(s^E - \frac{\partial C^i}{\partial Q^{i,E}} - \beta s^E \right) q^{i,E} \qquad (9)$$

Given the assumptions of a convex cost function, the farmer will find it profitable to provide ecosystem services for which the profit of a marginal $A^{i,E}$ is higher than the shadow value of land in the benchmark case, i.e. when $\left(s^E - \frac{\partial C^i}{\partial Q^{i,E}} - \beta s^E \right) q^{i,E} > \lambda^i$. This implies that $\lambda^{i,ES} > \lambda^i$. The constraint on the revenues is binding, $\beta > 0$, when the marginal value of Q^E is higher than the maximum unit payment $s^E = \frac{T}{\sum_i q^{i,E} A^{i,E}}$.

2.4 Comparison of the refunding schemes

Based on the simple theoretical analysis we can make two main conclusions (Table 1). One is trivial; profits will always be lower without than with refunding. The other is that positive environmental impacts are highest when payments are provided for ecosystem services.

Table 1: Comparison of farmer's profits and environmental effects under different climate tax and refunding schemes

	No refunding	**Lump sum**	**Area based**	**Ecosystem services (ES)**
Profits	$\pi^{i,t} < \pi^i$	$\pi^{i,LS} > \pi^{i,t}$ $\pi^{i,LS} > or < \pi^i$	$\pi^{i,AB} > \pi^{i,t}$ $\pi^{i,AB} > or < \pi^{i,LS}$ $\pi^{i,AB} > or < \pi^i$	$\pi^{i,ES} > \pi^{i,t}$ $\pi^{i,ES} > or < \pi^{i,AB}$ $\pi^{i,ES} > or < \pi^{i,LS}$ $\pi^{i,ES} > or < \pi^i$
Environmental effects	$GHG^{i,t} < GHG^i$	$GHG^{i,LS} = GHG^{i,t}$	$GHG^{iAB} \geq GHG^{i,LS}$	$GHG^{i,ES} \leq GHG^{i,LS}$ and ES increase

Starting with comparing the lump sum refunding scheme with the no policy case, it is found from Eq. (1) and eq. (5) that

$$\pi^{i,LS} > \pi^i \quad when \;\; T / n > tq^{i,M} A^{i,M} \qquad (10)$$

This may occur when imports of the taxed food, $Q^{i,IMP,M}$, is large and for a farmer with relatively low $q^{i,M} A^{i,M}$.

Similarly, when we compare the area based system with the lump sum scheme and no policy system we obtain (from eqs. (1), (5), and (6)) that

$$\pi^{i,AB} > \pi^{i,LS} \quad when \quad \frac{T}{\sum_i A^i} A^i > T/n \tag{11}$$

$$\pi^{i,AB} > \pi^{i} \quad when \quad \frac{T}{\sum_i A^i} A^i > tq^{i,M} A^{i,M} \tag{12}$$

Finally a comparison of the ecosystem payment system with the other schemes gives

$$\pi^{i,ES} > \pi^{i,AB} \quad when \quad \left(s^E - \frac{\partial C^i}{\partial Q^{i,E}} \right) q^{i,E} A^{i,E} > A^i \frac{T}{\sum_i \bar{A}^i} \tag{13}$$

$$\pi^{i,ES} > \pi^{i,LS} \quad when \quad \left(s^E - \frac{\partial C^i}{\partial Q^{i,E}} \right) q^{i,E} A^{i,E} > T/n \tag{14}$$

$$\pi^{i,ES} > \pi^{i} \quad when \quad \left(s^E - \frac{\partial C^i}{\partial Q^{i,E}} \right) q^{i,E} A^{i,E} > tq^{i,M} A^{i,M} \tag{15}$$

A farmer who is relatively effective in producing ecosystem services with high $q^{i,E}$ and/or low $\frac{\partial C^i}{\partial Q^{i,E}}$ would favor a system with payments for ecosystem services over the other systems. The area based system might be preferred to the ecosystem service system for a farmer with relatively large A^i, and the lump system is favored by a farmer with a small A^i.

With respect to environmental effects, there are opportunities for a double dividend, i.e. improved profits and reduced GHG emissions as compared to the no policy case, under all refunding schemes. The analysis shows that it can not be excluded that (some) farmers are better off under a tax/refunding scheme than without any policy at all, which depends on the tax revenues from total consumption. High share of imports allows for refunding of revenues where the taxes are not directly affecting the Swedish farmers.

However, there is a risk of higher GHG emissions under the area based system when marginal value of land increases and results in a larger $A^{i,M}$. On the other hand, refunding to support ecosystem services reduces GHG emissions when some $A^{i,M}$ is allocated to produce ecosystem services. A ‘triple’ dividend may then be obtained where profits increase, GHG emissions decrease and ecosystem services are produced.

3. Description of the partial equilibrium model and data retrieval

The partial equilibrium model CAPRI (Common Agricultural Policy Regionalized Impact model) is used to assess the impacts on CO_2 emissions and farmers’ profits of a climate tax on food products and refunding of tax revenues under the different scenarios analyzed in Section 2. The benefit of using a partial equilibrium model is that we get detailed representation of the agricultural sector and can take land use effects and trade into account. The climate tax per food product is determined by emission of CO_2 equivalents and tax per emission unit. Similarly, the payments for different ecosystem services are determined by the quantity of the service, such as carbon sequestration per unit of agricultural land, and the value per unit of service. Before presenting our calculations of the taxes on different food products and payments for ecosystem services we give a brief presentation of the CAPRI model.

3.1 Brief presentation of CAPRI and derivation of the reference case

The partial equilibrium model CAPRI was first developed within an EU funded project[1] in 1997-1999 with the objective to develop a model for analysing impacts of the Common European Agricultural Policy (CAP). In particular, the model was designed to study specific policies such as the sugar reforms, dairy quota abolition and the direct payments. It has since been further developed

[1]For more information http://www.ilr.uni-bonn.de/agpo/rsrch/capri/caprifp4_e.htm

and is now used extensively for forward looking policy impact assessment in European agriculture. CAPRI delivers results on prices and quantities, feed and fertilizer use, human consumption and demand, trade of agricultural commodities, policy costs, agricultural income and profits as well as environmental indicators. Himics et al (2018) and Fellman et al 2017 provide examples of recent studies using CAPRI in the area of climate change management.

CAPRI can be described as a system of interlinked models, with two main modules; a detailed supply module for European regions and a global market module for trade in agricultural products. The supply part consists of 276 regional farm models at the NUTS2[2] level in EU-27, Norway, western Balkans and Turkey. Each representative regional farmer is assumed to maximize farm income[3], minus a nonlinear cost term that allows the model to be calibrated/estimated based on observed behaviour (Jansson and Heckelei, 2011). The regional farmer works at given prices and subsidies subject to restrictions on land, policy variables and feed and fertilizer in each region. Land is endogenous and the total available agricultural land can thus vary across scenarios. Agricultural land can be transformed between grassland and arable land based on a transformation cost function that was specified based on simulation experiments with a biophysical land use model (see e.g. Renwick et al., 2013). Agricultural land supply can increase up to a maximum that has been determined for each region based on biophysical data. In simulations, the total land use is also restricted by the requirement to possess "entitlements" for the single farm payments, without which the marginal value of land would be lower. The supply model contains 50 crop and animal activities in each of the regions, producing 51 agricultural commodities covered by the market model, using general inputs, intermediate input and outputs, crop-specific inputs and feed and fertilizer inputs (Britz and Witzke, 2014).

The market model is a multi-commodity model representing bilateral world trade among 40 trade blocs including the EU. Each trade bloc entails a detailed representation of trade policies and instruments such as tariffs, export subsidies and bilateral trade agreements. Commodities from

[2] The NUTS classification (Nomenclature of territorial units for statistics) is a hierarchical system for dividing up the economic territory of the European Union. The classification is established by regulation EC 1059/2003

[3] Income is defined as the Gross Value Added (GVA) at producer prices plus premiums

different blocs are considered imperfect substitutes in the market (the Armington assumption). Each trade bloc consists of one or several countries or country aggregates, with behavioural equations for human consumption, processing industries and agricultural supply. All goods produced inside the same trade bloc are considered perfect substitutes, i.e. there is one market pool per bloc. Differences in quality/preferences are considered constant and simulated by fixed price differences between individual countries and the market pool. The EU consists of two blocs called "EU-west" and "EU-east". Sweden is part of the EU-west bloc together with the other 14 countries that became EU-members up to 1995 (Figure 1). Equilibrium ensures cleared markets for agricultural products and young animals. The supply modules and the market model are interlinked and solved iteratively. Prices are fixed from the perspective of the farmer and supplied exogenously from the market module (Britz and Witzke, 2014).

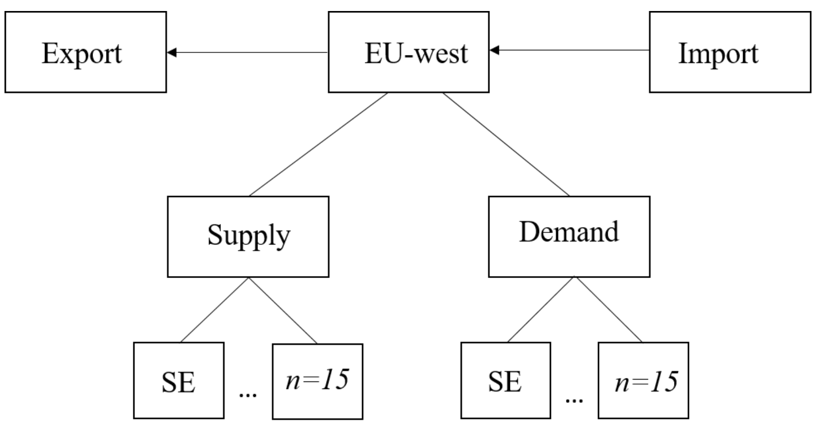

Figure 1: Overview of one CAPRI trade bloc (EU-west) and connection to country level supply and demand (Demand includes human consumption, feed use and processing on the country level and *n* is the numbers of countries in the EU-west trade block and SE exemplifying Sweden)

The standard CAPRI market structure, with one pool market for each trading bloc, which includes all imports and demand, implies that we do not model the origin of the human consumption on national level. This means that, for instance, all Swedish (SE) beef production is sold to the EU-west pool, and all Swedish beef consumption is obtained from that pool, regardless of where it was originally produced. If beef consumption in Sweden is taxed and reduced, demand decreases in the EU-west pool and lower prices for all suppliers to that pool. The price impact is the same for all suppliers to the pool.

In practice, Swedish beef has a larger market share in Sweden than in other EU countries because Swedish consumers, similar to consumers in other countries, tend to prefer the locally produced beef to imports. Therefore, the hypothetical tax on consumption may, *ceteris paribus*, have a larger impact on Swedish producers than on producers in other countries because most of the tons that are taxed are produced in Sweden. In order to account to this, we computed ad-hoc changes in the price mark-ups between the pool price and the producer prices in all countries which generates differentiated price impacts on suppliers depending on their market shares in Sweden. To this end, we assumed that a change in consumption in Sweden would affect all producers in the EU in proportion to their share of the Swedish market. That is, if the share of Swedish beef in the Swedish market is 50%, and there is a reduction in demand of 100 tons, then the reduction in demand for Swedish beef should be 50 tons whereas all other sources together reduce their supply to Sweden by the remaining 50 tons. In order to obtain matching decreases in supply, a price wedge between the EU pool and Swedish suppliers was added, computed by multiplying the slope of a linear approximation of the supply curve for Swedish suppliers by the expected reduction in volume (and similar for non-Swedish suppliers, which becomes insignificantly little). The slope of the linear supply curves for various origins were found by performing a simulation experiment with the model.

A reference case for Sweden gives us a benchmark for our counterfactual analysis where the impact of a climate tax on food products and refunding schemes are measured as deviation from this reference case. The reference case is obtained from the CAPRI baseline, which is a projection of the European agriculture and food sector to 2030 under a set of macro-economic assumptions and current policies. This gives the “business-as-usual” (BAU) development of the Swedish agricultural market. Policies in place are the CAP, including the “greening” requirements and payments, Basic Payment Scheme (BPS) to farmers, Voluntary Coupled Support (used for bovine cattle in Sweden) as well as the Rural Development Program (RDP) within the second pillar of CAP, where we model the Swedish agri-environmental schemes and support to areas with natural constraints. The model also contains the Nordic Aid to dairy in Northern Sweden. The baseline is assumed to be a comparative static equilibrium.

Meat, dairy and vegetable food products constitute the tax bases in the calculations (see Table A1 for a full list of the products included). Products used as inputs are excluded to avoid double accounting. The baseline levels of consumption, import shares, consumer prices and own price elasticities of these products in the reference case, BAU, are displayed in **Error! Reference source not found.**.

Table 2. Projected consumption, import share, consumer prices and own price elasticity of demand for food commodities in Sweden in 2030 for BAU.

Product	Consumption (1000t)	Import share of market use[d]	Consumer Price (Euro/t)	Own price elasticity
Soft wheat	489.18	0.04	4830.62	-0.29
Other cereals[a]	193.50	0.89	4588.78	-0.44
Potatoes	824.22	0.75	1538.66	-0.46
Other vegetables[b]	608.47	0.37	1008.38	-0.48
Beef	275.15	0.48	11397.93	-0.51
Pork meat	383.45	0.54	9262.75	-0.50
Sheep and goat meat	19.07	0.69	12271.41	-0.61
Poultry meat	242.55	0.46	5014.67	-0.65
Eggs	137.62	0.19	6020.54	-0.23
Butter	30.74	0.28	6012.76	-0.15
Skimmed milk powder	36.00	0.01	4002.39	-0.37
Cheese	180.49	0.57	7854.34	-0.35
Fresh milk products[c]	1201.61	0.15	1245.12	-0.35
Cream	159.72	0.22	6109.47	-0.36
Concentrated milk	6.36	0.60	3803.47	-0.53
Whole milk powder	48.38	0.04	5460.69	-0.37
Rape seed oil	40.70	0.64	5782.13	-1.60
Sugar	298.32	0.59	16963.85	-0.15
Total	5176.53			

[a] Includes triticale but not soft wheat, durum wheat, rye and meslin, barley, oats or grain maize; [b]Includes all vegetables excluding tomatoes. [c]Fresh milk products include drinking milk and yoghurt but not cream. [d]Market use includes feed use, human consumption, industrial input, seed, processing and losses.

Recall from Section 2 that a relatively large import share can generate net increases in profits for Swedish farmers. The import shares presented in Table 2 show the share of total imports which includes human consumption and inputs into production. For most products, the largest share is used for human consumption, but, for example, the largest part of Other cereals is used for animal feed. Similar to several studies estimating price elasticities of food (e.g. Säll and Gren, 2015), the own-price elasticities in CAPRI, based on USDA (2003), are low for all included products. Relatively low price elasticities imply high tax revenues because of the small decrease in demand.

Regarding Swedish farmers' net incomes and land use in the reference case, calculations are made for farmers in different NUTS2 regions. Total profits, number of holders and areas of land differ in these regions which implies that the profit per representative farmer differ (Table 3).

Table 3: Number of registered farms, area of pasture and arable land, and net incomes from agricultural production in different Swedish NUTS2 regions.

Region	Number of holders[a]	Pasture[b]. 1000 ha	Arable[c] land. 1000 ha	Agr. land. ha/farm	Net income, 1000 Euro	Net income. Euro/farm
Stockholm	1939	24	97	62	29401	15164
Östra mellansverige	12027	67	635	58	241711	20196
Sydsverige	9512	32	581	64	280490	29709
Norra mellansverige	7120	48	168	30	113510	15957
Mellersta Norrland	3400	57	62	35	56645	16765
Övre Norrland	3568	33	67	28	77646	21805
Småland med öarna	9955	97	278	38	325106	32885
Västsverige	15356	65	627	45	255023	16629
Sweden total	62877	423	2515	47	1379531	22043

[a]Swedish Board of Agriculture (2016); [b]Extensive and intensive grazing from the reference scenario in CAPRI. [c]From CAPRI reference scenario

The total profit amounts to approximately 1.4 billion Euro. The highest average profits are obtained by farmers in the south of Sweden and the lowest in the northern regions.

3.2 Calculations of GHG emissions and tax on food products

GHG emissions and tax per tonne food product are calculated based on emission coefficients for each product and the consumption quantities displayed in Table 3. In order to avoid double taxation of inputs subject to existing carbon tax we consider only emissions from production of the food products which includes emissions of methane and N_2O from agricultural processes (e.g. Gren et al., 2019). This excludes e.g. CO_2 from fossil fuels and other energy use, transportation, land use change, and emissions associated with the industrial production of inputs. GHG emissions are converted into carbon dioxide equivalents, using Global warming potential (GWP_{100})[4].

The CAPRI model includes two types of coefficients for GHG emissions from agriculture: "standard" emission coefficients computed on from the supply side and coefficients computed from the demand side. The standard coefficients show emissions for products at the place of production, whereas the demand side coefficients include emissions associated with the production of tradable intermediate inputs. The main difference is that standard coefficients emissions of tradable feeding stuffs, such as cereals or protein crops, are derived at the place of origin, whereas the demand side computation adds them to the emission of the animals where the products are fed (ultimately adding them to the marketable output such as meat) and subtracts them from the region of origin. We use the demand side coefficients as basis for calculating the tax since it is levied on consumption. These coefficients are used for the Swedish and imported food products, which is a simplification since they would differ for different origins of production. However, for Sweden, most of the imports come from other EU-countries and coefficients within EU varies to a lesser extent.

[4] IPCC 2007: Global warming potentials (based on Fourth AR 2007, Ch2.10.2 "Direct Global Warming Potentials" Table 2.14 p.212) Source: IPCC, 2007. Climate change 2007: Synthesis report. Contribution of working groups I, II and III to the fourth assessment report of the Intergovernmental Panel on Climate Change. Core Writing Team, Pachauri, R.K.and Reisinger, A. (eds.). IPCC, Geneva, Switzerland

The calculation of the demand side coefficients in CAPRI is based on the standard supply side coefficients, adjusted by taking trade data and input/output relations into account. The standard coefficients are computed in different ways inside the EU and in the global trade model. Inside the EU, they are computed bottom up from the production activities using the physical mass flows of the model in combination with coefficients from the IPCC. For regions outside of the EU, for which there exist no detailed agricultural supply model, we estimate the emission coefficients based on the public emission inventories of FAOSTAT combined with agricultural production data and Bayesian priors. The emission coefficients are presented in Table 4.

With respect to the damage costs per unit GHG emissions, there is a large body of literature calculating so-called social cost of carbon (see Tol 2018 for a review). In principle, there are four different approaches. One is to calculate the shadow cost of reaching GHG targets in a cost-effectiveness framework (see Tol 2013 for a review), another is to calculate damages in monetary terms from a marginal change in GHG emissions (e.g. Tol, 2005; Marten et al., 2015), the third is to calculate optimal marginal damage when considering costs of mitigation measures (e.g. Nordhaus, 2007; Hassler et al., 2016). The fourth approach, which is used in this study, is to perceive existing carbon taxes as a revealed preference of the marginal damage. Another argument for using the existing carbon tax in Sweden is that all sources of GHG should meet the same tax for cost-effective GHG emission reductions. The Swedish tax amounts to approximately 115 Euro/tonne CO_2-e in 2016 current prices (e.g. Martinsson and Fridahl, 2018). The introduction of this tax implies price increases of the included meat and dairy products which vary between 0.11% and 17.40% (Table 4).

Table 4: GHG emission coefficient for consumption, total emissions from consumption in the reference case and climate tax per tonne food consumption and the percentage change in price from the tax in 2030. Prices in 2030.

Product	Kg CO_2e emission/ Kg consumption	Tonnes of CO_2e emission from consumption	Climate tax Euro/t consumption	% increase in price
Soft wheat	0.09	44.30	12.81	0.26
Other cereals	0.11	20.36	14.88	0.32
Potatoes	0.02	14.84	2.55	0.17
Other vegetables	0.02	12.34	2.87	0.28
Beef	16.96	4665.30	2398.42	17.40
Pork meat	2.54	973.75	359.21	3.73
Sheep and goat meat	17.97	342.77	2542.55	17.17
Poultry meat	1.28	311.01	181.38	3.49
Eggs	0.84	115.33	118.54	1.93
Butter	4.73	145.27	668.46	10.00
Skimmed milk powder	3.79	136.26	535.41	11.83
Cheese	5.85	1056.39	827.91	9.53
Fresh milk products	1.10	1322.23	155.65	11.12
Cream	4.75	758.22	671.51	9.92
Concentrated milk	2.97	18.87	419.78	9.94
Whole milk powder	5.04	243.67	712.45	11.57
Rape seed oil	0.42	16.94	58.89	1.01
Sugar	0.13	39.94	18.94	0.11
Total		10237.80		

Consumption of beef accounts for 45% of total emissions, and the high emission coefficients generate relatively large increase in the consumer price from the introduction of the tax. Fresh milk and cheese correspond to approximately ¼ of total emissions, but the respective relative price increases are lower than those on beef.

3.3. Payments for ecosystem services: biodiversity, carbon sequestration, and nutrient regulation

In principle, the payment per unit ecosystem service should correspond to the marginal value of the service, such as the value of a marginal unit of biodiversity. The choice of ecosystem services to be funded in this study is guided by possibilities and limitation set by CAPRI and available data necessary for calculating the unit payment. Ideally, there are quantified functional relations between land use of provision of an ecosystem service, and data on the value per unit of the ecosystem services. The farmers would then be paid for the quantity of provided services and choose the optimal land use management as shown in Section 2. Such a system corresponds to payments of marketed outputs such as wheat and potatoes. However, necessary scientific knowledge and data are not available, and we therefore attach unit values and quantities to area of land use for all included services; biodiversity by natural grassland, carbon sequestration from restoration of drained peat land, and nutrient regulation from construction of wetlands.

Starting with payments for biodiversity provision by natural grass land, there is a large body of literature on the estimation of the value of biodiversity (see Atkinson et al., 2012 for a review) provided by different ecosystems in different parts of the world. Most studies estimate the value by stated preferences in hypothetical markets where they provide a willingness to pay or willingness to accept a certain change in the provision of biodiversity. In principle, we could transfer estimated measure of value per ha from these studies, but there is no study on the biodiversity value of grassland in the boreal zones. Similar to the choice of social cost of carbon, we therefore apply the revealed preference approach where the relation in actual payments for biodiversity on grassland among the NUTS2 regions reflect the authorities' perceived relative values. However, actual payments are limited by budget constraints, and it is here simply assumed that the actual valuation is twice as high as the actual payments. As shown in Table 4, these payments vary between Euro169/ha (Sydsverige) and 521/ha (Övre Norrland).

Regarding the value of carbon sequestration of restoring drained peatland on agricultural land, there is no information on carbon releases from drained peatlands in different NUTS2 regions.

Instead there are measurements of average leaching from grassland and arable land on drained peatland in Sweden (Swedish Board of Agriculture, 2014). The reported leaching per unit of arable land is 30.3 tonnes CO_2e/ha and that of grassland is 11.4 tonnes CO_2e/ha. The restoration of the peat lands would not eliminate all leaching because of the methane release, which amounts to 4.4 and 0.3 tonnes CO_2e/ha on arable land and grassland, respectively (Swedish Board of Agriculture, 2014). The value per unit leaching reduction is assumed to correspond to the actual tax of Euro 115/ tonne CO_{2e}, which gives a payment of 2978 Euro/ha and 1277 Euro/ha for peat land restoration on arable land and grassland, respectively. These payments would cover the private economics costs of rewetting agriculture on drained peat lands, which range between 41 Euro/ton CO_2e and 46 Euro/CO_2e (Markensten et al., 2018, Table 3)

Finally, the payments for constructing wetlands to regulate nutrient loads are calculated as the quantity of nutrient retention in the wetlands times the unit value of each nutrient. It is assumed that the wetlands are located downstream close to the coastal zones, and the abatement by wetlands is then dependent on the upstream nutrient load from agriculture and sources discharging nutrient into the coastal waters. These loads are, in turn, determined by different types of production technologies and policies. The nutrient load entering the wetlands depends on the transformation of the nutrients during the transport from the sources to the wetland, the so-called nutrient retention. Both loads from emission sources and nutrient retention vary among the regions, and there is only one study calculating nutrient abatement by wetland, which accounts for management practices at emission sources and nutrient retention (Gren et al., 2015), which is used in this study (Table A2).

The unit value of nutrient abatement is obtained from Gren et al. (2018) and is calculated as the shadow cost of reaching the nutrient emissions targets set by the Baltic Sea Action Plan by Helcom (2013), which correspond to 13% and 42% reduction in the total loads of nitrogen and phosphorus, respectively. The shadow costs in a cost effective solution amount to 4 Euro/kg N and 362 Euro/kg P and show the increases in minimum costs of reducing the emission target by 1 kg of the respective nutrient. Using these values and the wetland abatement reported in Table A2, the value of nutrient regulation per ha wetland construction varies between 414 Euro/ha and 2879 Euro/ha (Table 4). These values of wetlands for nutrient regulations are partly revealed by actual support to cover the costs of wetland construction for biodiversity provision and pollutant regulation of waters (e.g. Swedish Board of Agriculture, 2018). The payments amount to maximum 22000 Euro/ha for investment and to 440 Euro/ha and year for management costs (e.g. Swedish Board of Agriculture, 2018), which at a discount rate of 5% corresponds to approximately 1540 Euro/ha and year. The additional payments suggested here could thus rise the current support considerably.

Table 5: Payments for different ecosystem services, Euro/ha and year in 2016 prices

Region	Biodiversity on grassland[a]	Restored drained peatland[b]; Arable	Grassland	Wetland for nutrient regulation[c]
Stockholm	184	2978	1277	1670
Östra mellansverige	221	2978	1277	1670
Sydsverige	169	2978	1277	2879
Norra mellansverige	255	2978	1277	414
Mellersta Norrland	353	2978	1277	414
Övre Norrland	521	2978	1277	266
Småland med öarna	197	2978	1277	1670
Västsverige	196	2978	1277	2360

[a] Table A2; [b]reduced leaching per ha in Table A2 multiplied by the value of 115 Euro/ton CO_2 reduction; [c] nutrient regulations N and P per ha in Table A2 multiplied by the values 4 Euro and 362 Euro per kg nitrogen and phosphorus reduction, respectively.

In the reference scenario, the gross revenue amounts to 3192 Euro/ha in average for Sweden (Table A3). The payments for restoration of peatland are then in the same order of magnitude as the gross revenues and exceed the gross revenues in three NUTS2 regions; Stockholm, Norra mellansverige, and Mellersta Norrland. The payments in real terms are constant over the period until 2030 with an assumed inflation rate of 1.9%.

Total payments are limited by the areas of land eligible for payments. For example, payments for biodiversity on grassland is limited by the area available for grassland, and payments for restoration of peat lands can be made only for agriculture on drained peat lands. Data on areas of drained peat land is obtained from Phakakangas et al. (2016), and it is assumed that the actual grassland area in 2016 (Statistics Sweden, 2017) constitutes the maximum payment area for biodiversity. With respect to wetland for nutrient regulation, they need to be constructed downstream in a catchment in order to reduce nutrient loads to the sea. There is no data on the availability of such land, and we therefore follow Gren and Säll (2015) and simply assume that 1% of arable land is suitable for wetland construction.

Table 6: Maximum areas for payments, 1000 ha

Region	Grassland for biodversity[a]	Restored drained peat land[b] ; Arable	Grassland	Wetland for nutrient reg.[c]
Stockholm	10.5	10.05	1.89	0.97
Östra mellansverige	91.60	68.15	10.16	6.35
Sydsverige	67.10	20.35	9.46	5.81
Norra mellansverige	24.00	5.78	3.85	1.68
Mellersta Norrland	14.50	1.43	1.65	0.62
Övre Norrland	4.70	6.33	2.30	0.67
Småland med öarna	160.80	37.30	10.87	2.78
Västsverige	78.80	28.50	7.63	6.27
Total	452.00	177.98	47.78	25.15

[a]Statistics Sweden (2017) Table 3.1; [b]Pahkakangas et al. 2016 Table 4A; [c]1% of arable land from CAPRI

To evaluate eventual conflicting uses of tax revenues we calculate total revenue requirement under assumptions of full payment. It is then assumed that the payments listed in Table 4 for providing biodiversity, restoring peat lands and constructing wetlands are made for the maximum areas displayed in Table 5. The total payment for biodiversity, carbon sequestration enhancement and nutrient regulations would then amount to 94 million Euro, 591 million Euro, and 49 million Euro, respectively in 2016 prices. This gives a total amount of 734 million Euro. It can also be noted that restoration of all drained peatlands would increase carbon sinks by 5.9 million tonnes of CO_2e which corresponds to approximately 60% of the calculated emissions from the agricultural sector.

4. Impacts of the climate tax and refunding schemes

Given the structure of the CAPRI model and all assumptions concerning the determination of the climate tax on food products and payments for ecosystem services, we calculate the impacts of different refunding systems on farmers' economic performance and environment, mainly emissions of CO_2e. Since the total tax revenues available for refunding are determined by the impacts of the tax on the consumption of food, we present these effects.

4.1 Impacts on demand, supply and emissions of food products

The introduction of the climate tax on different food products as reported in Table 4 will decrease the demand for the different food items as shown in Table 7.

Table 7: Swedish consumption, production, imports and emissions from consumption in 2030 with a climate tax. Total values and percentage difference to baseline.

Products	Consumption;		Production in Sweden;		Imports;		GHG emission[a]; t CO_2e	
	1000t	%Δ	1000t	%Δ	1000t	%Δ		%Δ
Soft wheat	488.77	-0.08	1945.45	-0.04	69.43	0.00	44.27	-0.08
Other cereals	193.5	0.00	196.82	-0.77	1010.41	-2.82	20.36	0.00
Potatoes	829.21	0.61	345.79	0.48	851.71	0.48	14.93	0.61
Other vegetables	611.76	0.54	414.92	0.32	244.61	0.92	12.41	0.54
Beef	252.99	-8.05	131.02	-19.25	140.34	6.89	4289.57	-8.05
Pork meat	389.17	1.49	216.34	0.39	211.35	2.37	988.27	1.49
Sheep and goat meat	17.66	-7.39	5.24	-14.38	12.58	-4.04	317.43	-7.39
Poultry meat	248.72	2.54	145.75	1.07	115.48	4.19	318.92	2.54
Eggs	137.7	0.06	150.40	0.19	27.43	0.00	115.40	0.06
Butter	30.45	-0.94	36.92	1.37	8.84	0.00	143.90	-0.94
Skimmed milk powder	34.97	-2.86	42.61	15.35	0.47	0.00	132.36	-2.86
Cheese	176.49	-2.22	78.01	-16.89	114.88	11.56	1032.97	-2.22
Fresh milk products	1167.6	-2.83	1131.93	1.99	125.85	-30.87	1284.80	-2.83
Cream	156.13	-2.25	119.89	-3.18	36.19	0.81	741.18	-2.25
Concentrated milk	6.23	-2.04	2.58	-0.39	3.69	-3.15	18.49	-2.04
Whole milk powder	47.08	-2.69	54.92	-3.58	1.83	0.00	237.13	-2.69
Rape seed oil	40.42	-0.69	252.77	0.01	398.70	-0.17	16.83	-0.69
Sugar	298.92	0.20	386.76	-0.03	184.42	0.00	40.02	0.20
Total	5127.77	-0.92	5658.12	-0.39	3558.21	-1.38	9769.23	-4.58

[a] Percent change per product the same as for percent change in consumption

Recall from section 3.1 that demand includes human consumption, feed and processing, which is why imports of *other cereals* is negative although there is no change in consumption. *Other cereals* and *soft wheat* are used for animal feed and when the tax is implemented, there is a reduction in the number of animals which reduces the demand for feed. Sweden is a net importer of other cereals, which is why the import decrease as demand for feed decreases. For soft wheat, the case is reversed and there is an increase in export. The largest decrease in production comes from beef and sheep and goat meat, which are also the products with the largest decrease in emissions from consumption. Production of cheese in Sweden also decreases, but consumption only decreases by 2 percent, while imports increase. Therefore, there is only a small decrease in emissions from consumption. Because of the substitution effects among the food products, consumption of e.g. pork and poultry increase since they are substitutes for beef.

When assessing impacts on home produced and imported food products, it is assumed that the market shares are unchanged compared with the baseline. This explains the relatively higher impact on production of some food products in Sweden compared with imports. This will, in turn, affect the net incomes for farmers with animals.

In total, CO_2e emissions from the included food products are reduced by approximately 5%. The main part, 80%, of this reduction is attributed to the reduction in consumption of beef. These effects are smaller compared with Säll and Gren (2015) who found that a tax on consumption of meat and dairy products corresponding to the Swedish carbon dioxide tax reduces CO_2e emissions from agriculture by 12%. Their study uses higher emission coefficients, which can explain the difference.

4.2 Effects of different refunding schemes

Total tax revenues amount to 1391 million Euro[5], which is in the same order of magnitude as the net income of all farmers in the reference case. However, it is quite likely that the transfer as such will incur transaction costs and it is therefore simply assumed that 80% of 1391 million Euro, is transferred. In the following, we calculate impacts on farmers' net incomes in different regions and environmental effects for seven different scenarios, which are defined in Table 8. All calculations are made for simulations until year 2030 and are compared with the reference case for Sweden.

[5] In 2030 current prices

Table 8. Definition of different refunding schemes of a climate tax on consumption

Scenario	Scenario description
No refunding	
Lump sum	Tax revenues are refunded with equal amount per holder
BPS	The tax revenue is refunded as area based payments (BPS)
Biodiversity	The tax revenue is refunded as farmer support for ES measures to preserve biodiversity
Restored peatland	The tax revenue is refunded as farmer support for ES measures to capture GHG emissions
Wetland	Payments for nutrient regulation of coastal wetlands
Ecosystems	Payments to all three ecosystem services

The total number of farmers amounts to 62877 (Table 3), which gives a transfer of 17.52 thousand Euro per farmer under the lump sum scheme. Total agricultural area is 2938 thousand ha (Table 3) which gives a refunding of 379 Euro/ha for an unchanged total agricultural area. The effects on baseline net income (Table 3) from the introduction of the tax without any refunding and with the lump sum and area based are presented in Table 9.

Table 9: Percent change in baseline profits under different refunding schemes

Region	No refunding	Lump sum	Area based	Peatland	Wetland	Biodiv	Ecosystems

Stockholm	-12.39	115.12	152.60	131.12	-2.99	-2.68	150.00
Östra mellansverige	-18.34	85.02	89.56	98.03	-14.01	-8.01	112.36
Sydsverige	-11.91	57.67	68.27	21.86	-3.54	-3.63	37.72
Norra mellansverige	-19.36	93.06	57.83	6.34	-17.62	-13.43	13.51
Mellersta Norrland	-20.04	84.46	71.28	-5.61	-18.88	-13.45	2.70
Övre Norrland	-18.56	66.47	35.21	18.03	-17.55	-16.98	20.62
Småland med Öarna	-27.01	47.66	15.91	23.09	-25.54	-12.71	38.30
Västsverige	-27.68	101.30	69.87	20.82	-19.04	-19.07	37.69
Sweden total	-20.84	73.84	59.16	35.01	-15.99	-11.33	48.93
Payments in % of total tax revenue		80	82	55	5	9	69

Without any refunding, total net income is reduced with 288 million Euro, or 20.84 per cent. However, the allocation is uneven where the reductions in percent are high in regions with relatively much beef production. Approximately half of the total loss occurs in two regions, Småland and Öarna and Västsverige. However, the income per holder is highest in Småland and Öarna, while it is relatively low in Västsverige (see Table 3).

Refunding of approximately 80 percent of the tax revenues would more than compensate the farmers, which is shown by the considerable increases in net incomes under the lump sum and area based system. As expected, the increase in net income under a lump sum system is relatively high in regions with low average income per farm (Stockholm, Västsverige). The area based system raises income relatively much in Stockholm and Östra Mellansverige.

Total decrease in income is also more than compensated under a system with payments for restoring drained peat lands, but not for farmers in all regions. Regions with abundance of drained peatlands face net gains (e.g. Stockholm and Östra Mellansverige) while a northern region (Mellersta Norrland) faces net losses. Unlike peatlands, all regions make net losses with payments for either wetlands or grassland which are low and correspond to 5% and 9% of total revenues, respectively. On the other hand, income in all regions increase when payments are made for all included ecosystem services.´

With respect to environmental effects, the decrease in consumption generates a decrease in CO_2e emissions by 5%. However, as a result of the refunding, farmers change production and land use, which are examined in this section. Environmental effects from production in Sweden are much determined by the changes in land use compared with the reference case, which are displayed for all refunding schemes but the lump sum payments in Figure 2 . *Percentage change in Utilized Agricultural Area under different refunding schemes*

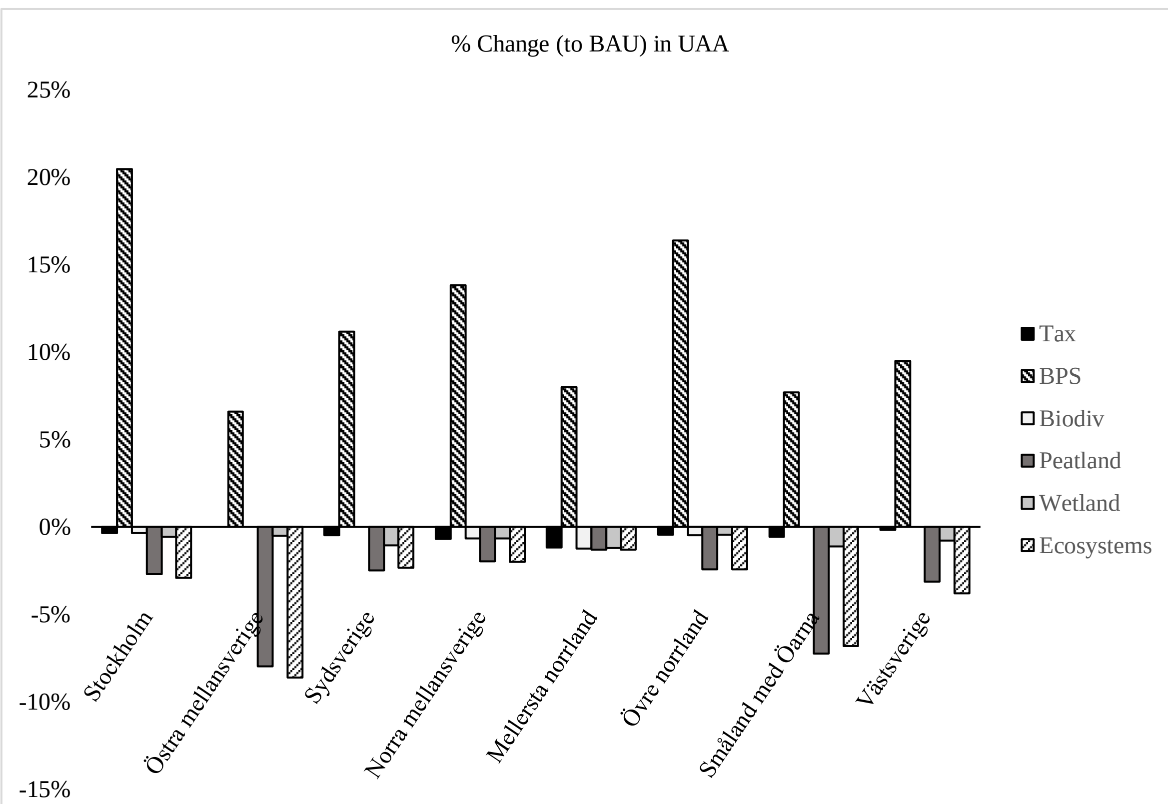

Figure 2 . Percentage change in Utilized Agricultural Area under different refunding schemes

Without any refunding, there is a small decrease in Utilized Agricultural Area (UAA)in all regions, which corresponds to a total reduction of 0.32%. The largest impacts occur under the area based system, where the UAA increases by 9.87% in the entire Sweden, but by 21% in the Stockholm region. The impact on emissions of CO_2e is determined by changes in production and allocation of change between grassland and arable land (Figure 3). The composition of arable and grassland changes in the BPS, Wetland and Ecosystems scenarios where there are shifts from arable land to grassland. In the biodiversity scenario, grassland increases by 5 % in total and most in Sydsverige with 30 % increase in grassland.

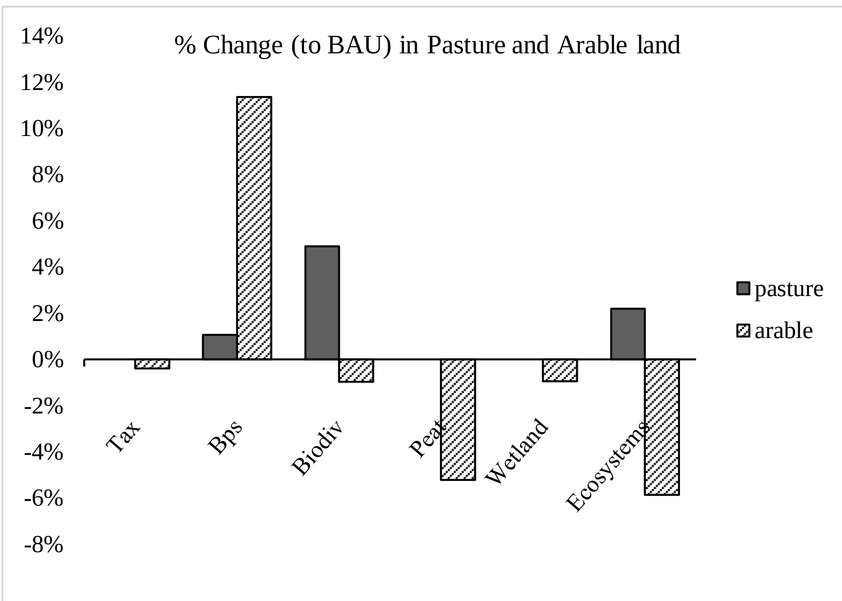

Figure 3: Changes in grass and arable land under different refunding schemes

Both pasture and arable land increase under the area based system, and, as expected, grassland increases under the Biodiversity and Ecosystem scenarios. Despite the increase of both land uses under the area based system, total emission of CO_2e decreases because of the decline in cattle holdings but the decrease is smaller than for the other refunding schemes (Figure 4).

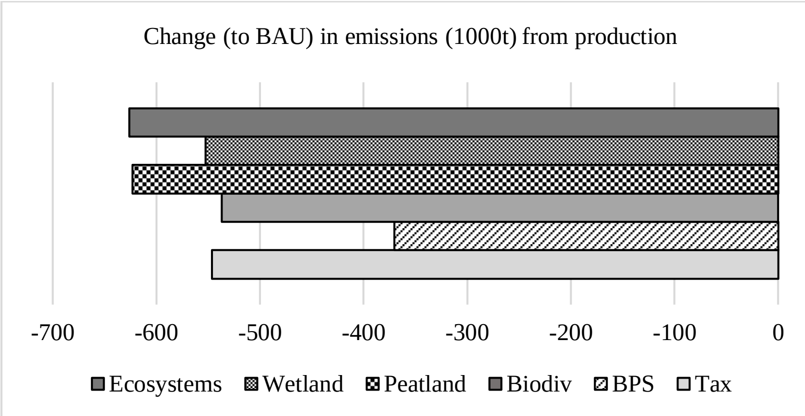

Figure 4 Changes in production based CO_2e emissions in Sweden under different tax refunding schemes.

In addition to the decrease in CO_2e emissions from production, targeted environmental effects are obtained. The reduction in arable land when funding restoration of peatlands implies a carbon sink enhancement which amounts to 5.9 millions metric tons of CO_2e. This corresponds to 60% of the calculated emissions from the included food products and to 9.4% of total CO_2e emissions in Sweden in 2016 and 2017 (Statistics Sweden, 2019). This carbon sink enhancement is in the same order of magnitude under the Ecosystem scenario since all drained peatlands are restored also in this case.

The nitrogen and phosphorus reductions obtained by conversion of arable land into wetlands amount to 5.9 kton N and 0.07 kton P, which correspond to 4.5% and 1.9% of N and P emissions from Sweden into the Baltic Sea, respectively (Gren et al., 2018). When we compare the country targets on reduction requirements set by the Helcom (2013), wetland construction accounts for 64% and 13% of the reduction requirement of N and P, respectively (Gren et al., 2018). The nutrient surplus at the farm level is also affected where nitrogen surplus decreases by 2% without any refunding but can increase with the same percentage under the area based system.

Improved biodiversity from increased area of grassland is obtained under three refunding systems, BPS, Biodiversity, and Ecosystems, but to different degrees. The funding of grassland results in an increase in this area by 5.17%, which is limited by the maximum area available as displayed in Table 6. The increase is reduced by one half under the Ecosystem scheme, and is lowest under the BPS system where it amounts to 1%. However, the increase in grassland area under all systems mitigates the decline by 20% since 2004 (Swedish Board of Agriculture, 2019).

5. Summary and conclusions

The main purpose of this study has been to assess impacts on farmers' net incomes and environment of a climate tax on consumption of food in Sweden under different schemes for refunding the tax revenues. To this end, an agricultural sector model of the EU was used to assess the implications of the tax on demand and production of the food products. The climate tax was determined by the Swedish CO_2 tax, which amounts to Euro 0.115/kg CO_2 emission, and the content of CO_2e in the food products. The highest tax as measured by increases in the consumer price prior to the tax was obtained for beef, for which the price increased by 17%. Seven different refunding schemes were evaluated; no refunding, lump sum per farmer, area based, restoration of drained peat lands for carbon sink enhancement, construction of wetlands for nutrient abatement, increase in grassland for biodiversity improvement, payments for all three ecosystem services. We compared results with a baseline scenario without and tax policy for agricultural production and trade in 2030. Payments for the different ecosystem services were derived from revealed preferences based on actual decisions on the carbon tax, nutrient and biodiversity targets. The calculations indicated annual payments for the ecosystem services up to 2978 Euro/ha, which is in the same order of magnitude as the average gross revenue from agricultural land in Sweden.

The imposition of the designed climate tax resulted in a net decrease in emissions from consumption by approximately 5%. The farmers' income decreased by 288 million Euro, or 20.84% of the reference income, but ranged between the NUTS2 regions from 12% to 28%. The total tax revenues amounted to 1377 million Euro, and a refunding of 80% resulted in net increases in incomes in all regions under the lump sum, area based systems, and payments for all ecosystem services. The payments for peatland raised total income, but not for all regions because of the uneven allocations to regions with relatively large areas of drained peatlands. Payments for wetlands and grassland resulted in net losses for all regions because of the relatively low payments.

With respect to environmental performance, the tax on consumption reduced emissions of CO_2e from consumption by 5% in the scenario without any refunding, which is the same in all scenarios under the assumption of unchanged emission coefficient. It is likely however, that emission coefficients change as production and inputs change, which in turn would change the calculated effect on total emission. Emissions of CO_2e from production decreased under all refunding schemes, but to different degrees where it ranged between approximately 4% (area based system) and 8% (peatland restoration and payments for all ecosystem services). However, the payments for restoration of peatlands increased carbon sink enhancement corresponding to 9.4% of total emissions in Sweden. A main conclusion from this study is thus that the effect of the climate tax on emissions of CO_2e from consumption is relatively low, but the funding for restoration of peatlands would show a considerable decrease in emissions. With respect to other environmental effects, payment for construction of wetlands would also be important where the abatement accounts for 60% and 13% of the international commitment of reductions in loads of nitrogen and phosphorus, respectively, to the Baltic Sea. Payments for grassland raised this area by at the most 5%.

The results rest on a number of different assumptions related to the availability of data and construction of the CAPRI model. Costs of land use change in addition to opportunity cost of land are not included, which is likely to overestimate the incomes from all systems with payments for ecosystem services. Availability of data limits the choice of possible refunding objects. Alternatives to the included schemes are subsidies of food which are regarded as environmentally friendly or food promoting public health, which would partly compensate for consumers' welfare losses from the tax. As demonstrated by Säll (2018), the welfare loss of an environmental tax on meat, calculated as compensating variation, can correspond to 1% of the average household income. The introduction of such schemes would require information on the unit subsidies for the food products based on the quantified and monetarized effect of the products, which do not exist. It can also be argued that the best alternative for society would be to use the revenues to decrease taxes on other tax bases, in particular, income from labor. The marginal cost of the tax system in terms of dead weight losses differ among tax bases, but can be approximately 40% of a marginal cut in the savings income tax (Sörensen, 2010).

The static approach of the CAPRI model excludes the possibilities of investment in new technologies. This might be of particular importance under the lump sum and area based payment schemes where farmers in all regions make net gains which can be used for investment. Another aspect is that an effective CO_2e tax on consumption reduces the tax base when consumption of carbon intensive food products decrease, which reduces future tax revenues and refunding. Other aspects not considered in the assessment is that there might be institutional and legal restrictions on the output based systems for payments of ecosystem services applied in this study. Restriction and regulations from EU that would not allow for payments above the provision costs. It might also be politically infeasible with refunding system where farmers make (high) net gains.

Appendix: Tables A1-A3

Table A1: Emission coefficients, tons of emission from consumption, tax rate and percentage price for all products.

Product	Kg Co2eq emission/ kg consumption	Tons of emission	Climate tax Euro/t	% increase in price
Soft wheat	0.09	44.30	12.81	0.26
Durum wheat	0.00	0.00	12.81	0.26
Rye and meslin	0.08	9.52	11.96	0.25
Barley	0.08	0.72	11.07	0.24
Oats	0.09	3.30	13.00	0.29
Grain maize	0.10	2.55	14.58	0.32
Other cereals	0.11	20.36	14.88	0.32
Pulses	0.06	0.92	8.51	0.15
Potatoes	0.02	14.84	2.55	0.17
Tomatoes	0.00	0.83	0.40	0.01
Other vegetables	0.02	12.34	2.87	0.28
Apples pears and peaches	0.00	0.73	0.40	0.01
Other fruits	0.02	4.25	3.49	0.18
Beef	16.96	4665.30	2398.42	17.40
Pork meat	2.54	973.75	359.21	3.73
Sheep and goat meat	17.97	342.77	2542.55	17.17
Poultry meat	1.28	311.01	181.38	3.49
Eggs	0.84	115.33	118.54	1.93
Butter	4.73	145.27	668.46	10.00
Skimmed milk powder	3.79	136.26	535.41	11.83
Cheese	5.85	1056.39	827.91	9.53
Fresh milk products	1.10	1322.23	155.65	11.12
Cream	4.75	758.22	671.51	9.92
Concentrated milk	2.97	18.87	419.78	9.94
Whole milk powder	5.04	243.67	712.45	11.57
Casein	10.67	0.43	1508.96	12.63
Whey powder	1.37	1.31	194.34	12.07
Rape seed oil	0.42	16.94	58.89	1.01
Sunflower seed oil	0.38	9.25	53.97	0.94
Sugar	0.13	39.94	18.94	0.11
Total		10250.69		

Table A2: Registered areas and Actual payments for biodiversity on grassland, nutrient abatement by wetlands, and reductions in CO_2e leaching from restoration of peatland.

Region	Biodiversity on grassland[a]; Registered area	1000 SEK	Nutrient abatement by wetland[b]; Kg N/ha	KgP/ha	Peatland restoration, tonnes CO_2e/ha[c]; Arable land	grassland
Stockholm	9794	16431	150.50	2.95	25.9	11.1
Östra mellansverige	89300	179232	150.50	2.95	25.9	11.1
Sydsverige	70592	108225	365.50	3.92	25.9	11.1
Norra mellansverige	14189	32968	47.00	0.63	25.9	11.1
Mellersta Norrland	5019	16124	47.00	0.63	25.9	11.1
Övre Norrland	4095	19415	18.50	0.53	25.9	11.1
Småland med öarna	158265	282941	150.50	2.95	25.9	11.1
Västsverige	69410	123656	343.50	2.73	25.9	11.1

[a]Swedish Statistics (2017); [b] Gren et al. 2008; [c]Swedish Board of Agriculture (2014)

Table A3 Agricultural revenue and income of Utilized Agricultural Area (UAA) in each NUTS2 region. For the Reference case in 2030.

Region	Revenue (Euro/ha or head)	Income (Euro/ha or head)	Total income (1000 Euro)
Stockholm	1661.10	242.32	29400.69
Östra mellansverige	2586.60	344.48	241711.28
Sydsverige	3623.33	457.92	280489.74
Norra mellansverige	2612.23	524.61	113509.87
Mellersta Norrland	2328.23	478.06	56645.33
Övre Norrland	3308.99	774.37	77646.08
Småland med Öarna	4907.54	867.11	325105.55
Vätsverige	3073.22	368.61	255022.83
Total			1379531.36

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