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# Refunding of a climate tax on food consumption in Sweden

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ABSTRACT

This paper examines the implications of imposing a climate tax on food consumption in Sweden combined with refunding of the tax revenues to farmers for selected agricultural activities enhancing ecosystem services: restoration of drained peatland (carbon sequestration), maintenance of grassland (biodiversity), and construction of wetlands (nutrient regulation). A partial equilibrium model of the agricultural sector is used to assess economic and environmental effects. The results show that the introduction of a climate tax corresponding to the existing Swedish $CO_2$ tax of 115 euros per tonne carbon dioxide equivalent reduces total emissions from food consumption by 4.4% without any refunding of tax revenues. Refunding with payments for all ecosystems enhances the carbon sink by an amount equivalent to 57% of $CO_2$e emissions from food consumption, and results in net benefits in the tax refund system for the agricultural sector as a whole, but is regressive where farmers in regions with relatively high incomes receive proportionally much of the net benefits.

## 1. Introduction

Estimated emissions of carbon dioxide equivalents, $CO_2$eq, from current food system range between 19% and 29% worldwide (Vermuelen et al., 2012). Most of the emissions originate from animal products, which can correspond to 18% of global anthropogenic $CO_2$eq emissions (e.g, McMichael et al., 2007; Gerber et al., 2013; Clune et al., 2017). Suggestions have therefore been made to introduce climate taxes on meat consumption in order to reduce demand and emissions (e.g. Nellman et al., 2009; Cederberg et al., 2013; Bajzělj et al., 2014; Säll and Green, 2015). Arguments for a tax on consumption instead of firms' pollutants, which would be the first best according to economic theory, are the concern for the competitiveness of the sectors paying the tax and the risk of carbon leakage (e.g. Van Doorslaer et al., 2015). However, several studies have shown that the price elasticity of demand for meat and dairy products with relatively large $CO_2$eq emissions is low (e.g. Wirsenius et al., 2011; Edjabou and Smed, 2013; Säll and Gren, 2015; Chalmers et al., 2016; Jansson and Säll, 2018). Considerable increases in the price of meat are then required if a significant reduction in emissions is to be achieved. Such a tax will create negative welfare effects for consumers, the magnitude of which depends on responses to the tax and consumption shares of $CO_2$eq intensive food products (e.g. Säll, 2018).

The negative effects on consumers and eventual regressive income distributional effects (i.e. proportionally large welfare decreases from the tax for low income households) are likely to influence the consumers' acceptance of a climate tax and thereby the introduction of this policy as a means of reducing $CO_2$eq emissions (e.g. Kallbecken and Saelen, 2011). This might add to the existing public resistance towards environmental taxes in general (e.g. Bachus et al., 2019). Another group in society, the producers of agricultural outputs, will also face negative effects of the tax through decreases and reallocation of demand for different food products. A common result in the large literature in political economy of environmental regulations, which can be traced to Buchanan and Tullock (1975), is that firms meeting higher costs due to an environmental tax form powerful groups and lobby against its introduction, which the authorities have difficulties to resist (e.g. Damania et al., 2003; Cai and Li, 2020). An exception to this rule is that firms obtaining competitive or other advantages can lobby in favour of environmental regulations (e.g. Grey, 2018; Cai and Li, 2020).

However, Grimsrud et al. (2019) showed in a study of consumers in Norway that consumers' acceptance of a tax on red meet and their willingness to pay the tax increases when the tax revenues are refunded and earmarked for development of environmentally friendly technologies. A combined tax and refunding scheme where firms paying the tax are compensated for the increased cost is also likely to increase the acceptance among firms (e.g. Fredriksson and Sterner, 2005; Sterner and Höglund-Isaksson, 2006; Aidt, 2010). Such tax-refunding schemes have been introduced in several countries, such as the air pollution charges in

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Sweden, France, Norway, and the USA, and water and road charges in e. g., China and Columbia which are tied with abatement requirements (Wheeler et al., 2000; Millock et al., 2004; Hagem et al., 2020).

A climate tax on food consumption combined with earmarked refunding of tax revenues to environmentally friendly technologies in agriculture may thus promote acceptance among both consumers and producers and improve the political feasibility of the tax. However, acceptance among the farmers might be reduced if it turns out that the tax-refund system is regressive where the costs of the system is high for the less wealthy farmers (e.g. Kallebekken and Saelen, 2011; Bachus et al., 2019). Therefore, the main purpose of this study is to calculate effects on $CO_2$eq emissions, farmers' net income and distribution of costs of a tax-refunding scheme in Sweden. To this end, a partial equilibrium model of the agricultural sector CAPRI (Common Agricultural Policy Regionalized Impact) is used, which simulates consumers' and farmers' simultaneous responses to the tax and the refunding scheme. The CAPRI model was chosen because it is freely available, with a detailed representation of production and demand for agricultural commodities in Sweden, as well as in the rest of the EU.

To the best of the authors' knowledge, there is no empirical study on the effects of an environmental tax on food consumption combined with refunding of tax revenues to farmers. Several studies have examined the effects of an environmental tax on producers, which is refunded to the same group of producers in different ways. Most of this literature is theoretical and examines impacts of earmarking the revenues from the taxes to support firms based on their outputs or pollutant abatement cost (e.g. Gersbach and Requate, 2004; Bernard et al., 2007; Aidt, 2010; Fischer, 2011; Hagem et al., 2020). There are few empirical studies on environmental taxes with earmarked refunding of the tax revenues (Millock and Nauges, 2006; Sterner and Höglund-Isaksson, 2006; Bonilla et al., 2015; Brown et al., 2018). Millock and Nauge (2006) found in an ex-post evaluation of the French system with taxes on air pollution that the subsidy on abatement increased overall emissions through the lowering of abatement cost. Results from evaluations of the Swedish refundable tax on nitrogen oxides by Sterner and Höglund-Isaksson (2006) and Bonilla et al. (2015) showed that the refunding boosted investment in the abatement of nitrogen oxides. Brown et al. (2018) examined the potential of a $CO_2$ tax combined with an output subsidy when the market for electricity in Alberta, Canada is imperfect. Their results showed that subsidies differentiated with respect to emission intensity can have a relatively high impact on reducing the emissions in the sector.

In our view, the main contribution of this study is the empirical analyses of effects on $CO_2$eq emissions and farmers' incomes of a climate tax on food consumption combined with refunding to promote environmental and climate friendly agricultural production in Sweden. One key finding is that a climate tax on food consumption has a minor effect on $CO_2$eq emissions, but a refunding of the tax revenues for restoring drained peatlands can reduce emissions considerably and raise income for the farmers. The remainder of the paper is organised as follows. In Section 2 we define the design of the tax and refunding scheme, the Swedish policy context in which it is introduced, and policy scenarios. The partial equilibrium model CAPRI is described in the next section, and results are presented in Section 4. The paper ends with a discussion of the results, policy implications and conclusions.

## 2. Policy design, context and scenarios

In the present study, the climate tax on each commodity is based on the $CO_2$eq emissions embodied in it, which is assumed to reflect the cost of carbon generated by a marginal increase in a food good (e.g. Gren et al., 2019). In a similar vein, payments for ecosystem services are determined by the unit value of the service and the supply. This tax refund system is introduced in a landscape of existing policies for the agricultural sector in Sweden.

### 2.1. Calculation of the climate tax and payments for ecosystem services

The tax consists of two parts: $CO_2$eq emission by the food good and the marginal social cost of $CO_2$eq emissions. Regarding calculations of $CO_2$eq emissions, we only considered emissions from production of the food commodity, which, in line with the UNFCCC guidelines, includes emissions of methane and nitrous oxides from agricultural processes (e. g. Gren et al., 2019). This excludes, for example, $CO_2$ from fossil fuels in energy production and transport, and emissions associated with the industrial production of inputs. Many of these emissions are taxed in Sweden, and their inclusion in emissions from food, which is common in several studies estimating impacts of a climate tax on food, would imply double taxation. The choice of food commodities and data on emission coefficients is based on the partial equilibrium model CAPRI, presented in Section 3, which includes 33 food items and the emission coefficients range between zero (certain fruits) and 17.97 (sheep and goat meat) kg $CO_2$eq/kg food (Table S1 in Supplementary material). Because of lack of data, the calculated coefficients, which are based on food production in Sweden, are the same for the Swedish and imported food products. This is a simplification since they would differ for different origins of production.

There is a large body of literature estimating the damage costs of marginal $CO_2$eq emissions (see van den Bijgaart et al., 2016 for a review). In principle, there are four different approaches. One is to calculate the shadow cost of reaching $CO_2$eq 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 greenhouse gas (GHG) emissions (e.g. Tol, 2005; Marten et al., 2015). A third alternative is to calculate optimal marginal damage when considering costs of mitigation measures (e.g. Nordhaus, 2007; Hassler et al., 2016). The fourth approach, which was 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 $CO_2$eq should have the same tax level for cost-effective $CO_2$eq emission reductions. The Swedish tax is applied on emissions from all sectors with tax exempts for firms participating in the EU emission trading system (see Ministry of Finance (2020) for a description). The tax amounted to approximately 115 euros/tonne $CO_2$eq at 2019 prices (e.g. Martinsson and Fridahl, 2018). The introduction of this tax generates price increases for the included products, varying between zero for certain fruits without emissions and 2 euro/kg for beef, sheep and goat meat (Table S1 in Supplementary material).

With respect to which environmental improvements to subsidize, measures combatting climate change are obvious candidates. In practice, revenues from carbon taxes are refunded for such measures in many countries (Carl and Fedor, 2016). This study will consider one such measure, restoration of drained peatland, which has been shown to have a high potential in reducing leaching of $CO_2$eq from soils (e.g. Pahkakangas et al., 2016). It is well-known that the agricultural sector is a source of water pollution and biodiversity degradation, and we therefore include measures improving water quality and biodiversity. The payment for biodiversity may mitigate eventual negative effects of the climate tax on grazing animals needed for preserving biodiversity on grasslands. In principle, the payment per unit of ecosystem service should correspond to the marginal value of the service, such as the value of a marginal unit of biodiversity.

Ideally, there are (i) quantified functional relationships between land use and the provision of an ecosystem service, and (ii) data on the value per unit of the ecosystem services. Sweden is an elongated land, and the provision of the ecosystem services differs among regions, which is also the case for other land uses. The payment and adjustment by the farmers will then differ depending on the productivity of land. Therefore, the country is divided into eight different NUTS2[1] regions, which differ with respect to climate and soil conditions. For each of these regions, quantities and unit values are calculated for three types of services: carbon sequestration from restoration of drained peatland, nutrient regulation from the construction of wetlands, and biodiversity by natural grassland.

According to the Swedish Board of Agriculture (2014), the gross leaching of $CO_2$eq from agriculture on drained peatland amounts to 30.3 tonnes $CO_2$eq/ha and year for arable land and 11.4 tonnes $CO_2$eq/ha for grassland. However, the restoration of peatlands would not eliminate all leaching because of the methane release, which amounts to 4.4 and 0.3 tonnes $CO_2$eq/ha on arable land and grassland respectively, resulting in reduced leaching of 25.9 and 11.1 tonnes $CO_2$eq/ha on arable land and grassland respectively. The value per unit leaching reduction was assumed to correspond to the actual Swedish tax of 115 euros/tonne $CO_2$eq, which gives a payment of 2,978 euros/ha and 1,277 euros/ha for peatland restoration on arable land and grassland, respectively.

Payments for the construction of wetlands to regulate nutrient loads are calculated as the quantity of nutrient retention in the wetlands multiplied by the unit value of each nutrient reduction. Nutrient loads from emission sources and nutrient retention vary between the regions. There is only one study calculating nutrient abatement by wetland, which accounts for management practices at emission sources and nutrient retention (Gren and Säll, 2015), and which is used in the present study (Table S3 in Supplementary material). The unit value of nutrient abatement was obtained from Gren et al. (2018) and is calculated as the shadow cost of achieving the nutrient emissions targets set by the international agreement in the Baltic Sea Action Plan (Helcom, 2013), which envisages reductions by 13% and 42% in the total loads of nitrogen and phosphorus, respectively. The shadow costs in a cost-effective solution amount to 4 euros/kg nitrogen (N) and 362 euros/kg phosphorus (P) at 2019 prices, which 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 S3, the payment for nutrient regulation per ha wetland construction varies between 414 euros/ha and 2,879 euros/ha (Table S2).

Regarding payments for biodiversity provision by natural grassland, there is a large body of literature on the estimation of the value of biodiversity provided by different ecosystems in different parts of the world (see Atkinson et al., 2012 for a review). 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 have transferred the estimated measure of value per ha from these studies, but there has been no study of the biodiversity value of grassland in the boreal zones. As with the choice of social cost of carbon, we therefore applied the revealed preference approach where the actual payments for biodiversity on grassland in the NUTS2 regions are assumed to reflect the authorities' perceived values. However, actual payments are limited by budget constraints, and it was simply assumed here that the actual valuation is twice as high as the actual payments. In Section 5, sensitivity analysis is made with respect to the level of this and the payments for peatlands and wetlands. As shown in Table S2, these payments vary between 169 euros/ha (Sydsverige) and 521 euros/ha (Övre Norrland).

### 2.2. Policy context and scenarios

The suggested tax-refund system is not implemented in a policy vacuum. On the contrary, Sweden is, as a member of the EU, subject to the Common Agricultural Policy (CAP) the overall purpose of which is to ensure viable food production, sustainable use of natural resources and balanced development among the countries in the rural areas (European Commission, 2020). The CAP regulations are divided into two main classes, Pillar 1 and Pillar 2. Pillar 1 accounts for approximately 75% of the total CAP budget with direct payments to the farmers, which are based on the number of hectares farmed. In order to receive the basic payment, the farmers have to comply with cross-compliance conditions which involve protection of water quality and quantity, soil and carbon stock, and landscape features. In addition, the greening payments are directed towards maintaining permanent grassland, crop diversification, and ecological farming. The basic payment and the greening payments are mandatory for the EU member states. Pillar 2 is more flexible for the member states and can be used for rural development and environmental improvements beyond a base line required by the regulations. In Sweden, these payments are used to subsidize land for wetland construction, biodiversity improvement, water management, soil management, bioenergy, and livestock management to reduce $CO_2$eq emissions (European Commission, 2019).

With respect to the chosen refunding of environmental improvements, it can be argued that the best alternative for society would be to use the revenues to decrease taxes on other tax bases, such as labour or capital, depending on their marginal costs of taxation (e.g. Goulder, 1995; Freire-Gonzáles, 2018). The partial equilibrium model used in this study does not allow for the evaluation of such refunding. Instead, we calculate impacts on farmers' net income and discuss environmental effects of an area-based and lump-sum refunding. An area-based refunding comes relatively close to the output-based system used in the literature where output is a measurement of the size of a firm (e.g. Fischer, 2011; Hagem et al., 2020). In this case, each farmer receives funding as a proportion of the agricultural area, which is similar to the current basic payment from CAP. The lump-sum refunding option is often suggested in the literature since, in theory, it does not create any social costs in terms of dead weight losses from the subsidy (e.g. Goulder, 1995). In the present study, such a refunding scheme gives all farmers equal payments.

In sum, the present study includes seven different policy scenarios (Table 1), the outcomes of which are compared with the reference scenario where the CAP polices under Pillar 1 and 2 are in place.

For each of these scenarios, we calculate emissions of $CO_2$eq, and income for farmers in the different NUTS2 regions. The distributional effects on farmers' incomes are calculated by the Suits index (Suits, 1977), which is used in the literature to examine progressivity or regressivity in environmental tax/subsidy programs (e.g. Eliasson et al., 2018; Tirkaso and Gren, 2020). The index relates the accumulated proportion of the costs of the tax payments (or subsidy receipts) to the accumulated proportion of income in different groups (see e.g. Anderson et al., 2003 for a description on how to calculate the index). As such, it shows if poor groups pay proportionally much of the total tax bill (or receives proportionally much of total subsidy payments).

**Table 1**
Benchmark and policy scenarios.

| Scenario | Description |
|---|---|
| Benchmark | No climate tax and refunding, CAP policies are in place |
| Tax | Climate tax without refunding |
| Refunding schemes: | |
| Peatland | Refunding for carbon sequestration by restoration of drained peatlands |
| Wetland | Refunding for nutrient cleaning by wetland construction |
| Grassland | Refunding for biodiversity provision by grassland preservation |
| All ecosystems | Simultaneous refunding of all three land uses |
| Lump-sum | Refunding with equal payment per farmer |
| Area-based | Refunding with equal payments per ha farm land |

[1] 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 was established by regulation EC 1059/2003.

## 3. The partial equilibrium model and the benchmark

The simultaneous introduction of the climate tax and the policy scenarios examined in this paper generates responses by the consumers to the climate tax on food goods, which will change relative prices of these goods, create adjustments by the farmers to these changes and to the payments in the different policy scenarios. The numerical solution of the final effects of these adjustments requires a partial equilibrium model of demand, supply and trade in food goods for Sweden. To this end, we use the only available open access model, the CAPRI (Common Agricultural Policy Regional Impact) model, which was constructed in 1990′s to analyse effects of different agricultural policies at the EU level. The model evaluates effects of a policy by comparing outcomes in a reference or benchmark scenario with a policy scenario, such as introduction of a climate tax, and is thus well suited for the purpose of this study.

The CAPRI model includes two main modules; a global market model and a supply model. Demand for the different food goods in each country is based on econometric estimates of a demand system with assumption of utility maximizing households, which has a long tradition in economics (e.g. Deaton and Muellbauer, 1980). The demand system contains own and cross price elasticities for the different consumption goods, and the own price elasticities for Sweden are presented in Table S1 in the Supplementary material. Calculation of the supply of the goods is based on the concept of a representative farmer operating in each region who is assumed to maximise farm income[2] minus a nonlinear cost term that allows the model to be calibrated/estimated based on observed behaviour (Jansson and Heckelei, 2011). The regional farmer acts on competitive markets with given prices and subsidies subject to restrictions on land, existing policy variables, and feed and fertiliser constraints in each region.

With respect to market equilibrium, the global market model is divided into 40 trade blocs where the equilibrium prices are determined. The demand from consumers in Sweden and supply from Swedish farmers enter the "EU-west" bloc together with the other 14 countries that had become EU-members by 1995. The other trade bloc in the EU "EU-east" includes the other EU countries. In addition to the CAP policies, each country in the trade bloc entails a detailed representation of trade policies and instruments such as tariffs, export subsidies, and bilateral trade agreements with countries outside EU. All goods produced within the same trade bloc are considered perfect substitutes, i.e. there is one market pool per bloc. For a further description of the CAPRI model we refer to Britz and Witzke (2014).

In order to calculate the benchmark scenario and impacts of the different policy scenarios displayed in Table 1 for Sweden three adjustments are necessary in the CAPRI model. One is the consideration of difference in demand between a good produced in Sweden and imported. In the CAPRI model there is no difference, which implies that the national origin of the consumption is not modelled. For example, all Swedish beef production is sold to the EU-west pool, and all Swedish beef consumption is sourced from that pool, regardless of where it was originally produced. If beef consumption in Sweden is taxed and reduced, demand in the EU-west pool is reduced, which implies lower prices for all suppliers to that pool. This price effect is likely to be small since the share of the Swedish demand of total demand for food commodities at the EU-west pool is relatively low.

In reality, however, Swedish beef has a much higher market share in Sweden than in other EU countries because Swedish consumers, similar to consumers in other countries, tend to prefer local products to imports. A climate tax on consumption might then, *ceteris paribus*, have a greater impact on Swedish producers than on producers in other countries. In order to approximate this effect, we introduced imperfect substitution in consumption between domestic production and imported goods. There is a large body of literature estimating this so-called Armington elasticity, which is infinite when consumers make no difference between domestic and foreign good and positive otherwise. Results from a meta-analysis by Bajzik et al. (2019) indicate that the mean value is approximately 1 or 3 depending on adjustments for uncertainty in the estimates. In the present study we use the value of 2, which is also close to the assumption used in the Swedish general equilibrium model developed by Swedish National Institute of Economic Research (2019). Similarly, on the production side, the aggregate production is composed of products destined for the home market and for export to the pool market. The constant elasticity of transformation between production for domestic consumption and exports is assumed to be the same as the Armington elasticity. For more details on the correction of trade between Sweden and the EU-west pool, we refer to Supplementary material.

The second adjustment of the CAPRI model is the introduction of a budget constraint under the refunding policies where the total payments can not exceed the tax revenues. The third adjustment limits the areas of land eligible for payments. Restored peatland can only be undertaken on drained agricultural land (Pahkakangas et al., 2016). Wetlands need to be constructed downstream in order to provide nutrient regulation. There are no data on the availability of such land for the NUTS2 regions, and we therefore assumed that the estimate by Gren and Tirkaso (2020) of 1% of arable land for entire Sweden is suitable for wetland construction in each region. It was assumed that the registered grassland area in 2016 (Statistics Sweden, 2017) constituted the maximum payment area for biodiversity (see Table S2 in Supplementary material for maximum available areas in the different regions).

Given all assumptions of the CAPRI model and the Swedish component, the reference scenario with respect to consumption, supply and equilibrium prices is derived under the assumption that current agricultural policies (CAP 2014–2020) are fully implemented as decided, and then maintained up to 2030. Trends in yields, demand and land use are based on the EU Agricultural Outlook 2017–2030 (European Commission, 2017). Calculated total emissions of $CO_2$eq from food consumption in the reference scenario amounts to 10.30 million tonnes (Table S5 in Supplementary material). This corresponds to approximately 20% of total territorial $CO_2$eq emissions in Sweden in 2018 (SEPA, 2020). Consumption of beef accounts for almost one half of total emissions from food. The calculated emissions from food imports correspond to approximately 40% of all emissions (Tables S1 and S5 in Supplementary material). This relatively high share of emissions from imports highlights possibilities for net gains for farmers under tax refunding schemes.

Swedish farmers' net incomes and land use in the reference scenario differ considerably between the NUTS2 regions (Table 2).

Total net income amounts to approximately 1.4 billion euros. The highest average profits are obtained by farmers in the south of Sweden (Sydsverige, Småland med öarna) and the lowest in the north (Norra Mellansverige, Mellersta Norrland, Övre Norrland). It can also be noted that the average farm size is relatively small in the northern regions, and relatively large in Stockholm and Sydsverige.

## 4. Impacts of the climate tax and refunding schemes

The introduction of the climate tax will decrease the demand for beef and other food items with relatively large price increases but also increase demand for commodities that are substitutes to these food products. Common to most commodities is that, in equilibrium, the main part of the tax is transferred to the consumers because of the low price elasticities in absolute terms. For example, 85% of the climate tax on beef, which amounts to 1950 euros/tonnes, is transferred to the consumers in terms of an increase in the consumer price of beef by 18% (Table S4 in Supplementary material).

The net decrease in total emissions of $CO_2$eq is relatively small, 0.45

[2] Income is defined as the gross value added (GVA) at producer prices plus premiums.

**Table 2**
Number of registered farms, area of pasture and arable land, agricultural land per farm, and net incomes from agricultural production in different Swedish NUTS2 regions in the benchmark scenario.

| Region | No. of holders[a] | Agr. land 1000 ha: | | Land, ha/farm | Net income, mill euros |
|---|---|---|---|---|---|
| | | pasture[b] | arararable[c] | | |
| Stockholm | 1939 | 24 | 97 | 62 | 30.05 |
| Östra mellansverig | 12,027 | 67 | 635 | 58 | 251.64 |
| Sydsverige | 9512 | 32 | 581 | 64 | 292.76 |
| Norra mellansverige | 7120 | 48 | 168 | 30 | 109.20 |
| Mellersta Norrland | 3400 | 57 | 62 | 35 | 54.54 |
| Övre Norrland | 3568 | 33 | 67 | 28 | 73.00 |
| Småland med öarna | 9955 | 97 | 278 | 38 | 316.76 |
| Västsverige | 15,356 | 65 | 627 | 45 | 272.25 |
| Sweden total | 62,877 | 423 | 2515 | 47 | 1400.19 |

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

million tonnes of $CO_2$eq or 4.4% of the benchmark emission from food consumption (Table S5 in Supplementary material). This effect is lower than the results obtained by Säll and Gren (2015), who found that a tax on consumption of meat and dairy products corresponding to the Swedish carbon dioxide tax reduces $CO_2$eq emissions from consumption of meat and diary products by 9%. This difference in results can be explained by the higher emission coefficients and associated climate taxes used by Säll and Gren (2015). Similar to Säll and Gren (2015), most of the total emission reduction, 80%, is due to the decrease in beef consumption (Fig. 1).

It can also be noted that the emissions from consumption of pork and poultry increase because of the change in relative prices between those meat products and beef.

### 4.1. Farmers' incomes and environmental effects

With respect to impacts of the tax on farmers' net incomes, the greatest decrease in production comes from beef, sheep and goat meat (Table S4 in Supplementary material) and farmers producing these products will face reductions in net incomes in all seven policy scenarios. This implies that farmers producing cereals used for animal feed will face a decrease in demand because of the reduction in the number of animals and decrease in the producer price. Compared with consumer prices, a lower share of the tax is transferred to the producers. For example, the producer price of beef is reduced by approximately 7% or 282 euros/tonnes beef (Table S4 in Supplementary material), which corresponds to 15% of the climate tax of 1950 euros/tonnes beef. The decreases in net incomes are partly compensated for by the increase in demand for pork and poultry. Without any refunding, total net income is reduced by 64 million euros, which corresponds to 4.6% of the benchmark net income (Table 3).

The losses under the six policy scenarios with refunding are lower. Total tax revenues amount to 1.14 billion euros in all scenarios, and the total decrease in net income without refunding can thus be compensated with refunding. However, it is quite likely that the refunding creates transaction costs from distribution of the payments, and it is therefore assumed that 80% of the tax revenues, i.e. 0.91 billion euros, can be distributed. The refunding is also limited by the payments per ha of land for the different environmental improvements and by the available areas. The maximum environmental payment occurs for simultaneous payments for all three land uses and amounts to 0.73 billion euros, but the payments are unevenly distributed among the farmers in the different regions (Table S6 in Supplementary material), The lump-sum payment amounts to 14,441 euro/farm, which gives a higher increase in the reference income in average for Sweden than for payments of environmental improvements. Under the area-based system the payment per ha is endogenous since it creates incentives to increase the agricultural area and amounts to 282 euro/ha.

Payments for peatlands, simultaneous payments for all three environmental improvements, lump-sum and area-based payments more

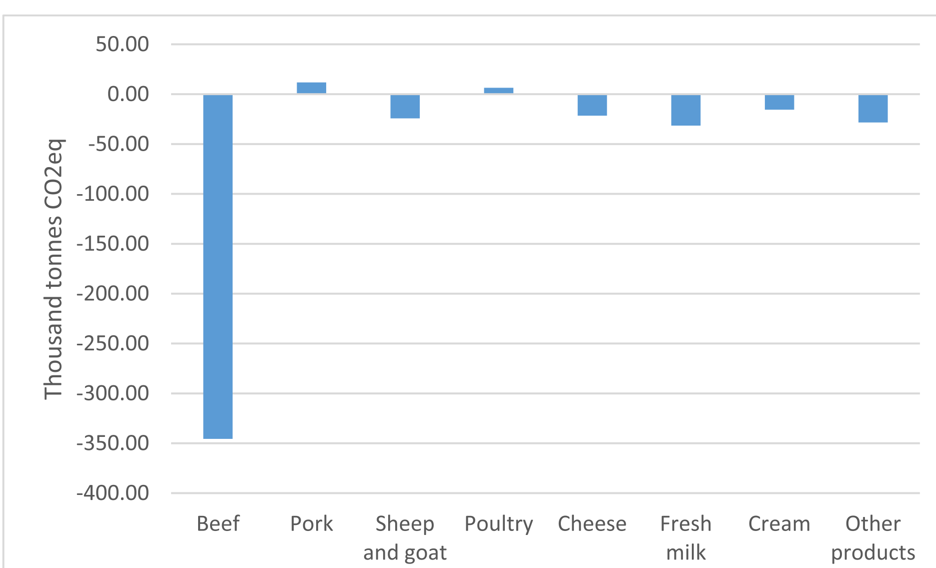


**Fig. 1.** Change in emissions of $CO_2$eq of the climate tax without refunding for different food groups. Source: Table S5 in Supplementary material.

than compensate for the losses in incomes from the introduction of the climate tax, but to different degrees among the regions (Table 3).

Without any refunding, the overall reduction in income corresponds to 4.6% of the total benchmark income. It is unevenly distributed among the regions, with the largest percentage decreases in Västsverige and Småland med öarna. Decreases in total benchmark income and for all regions also occur with refunding for wetlands and grassland since those payments are limited by small eligible areas (Table S2 in Supplementary material). The largest average income increase versus the benchmark, approximately 60%, is obtained with lump-sum payments, the total of which is higher than for payments of all ecosystems. The variation in income effects is large between regions, in particular with payments for all ecosystem services. The largest increase in per cent of benchmark income is obtained by farmers in the Stockholm region under all refunding schemes generating net benefits because of the relatively low benchmark income and abundance of drained peatland.

With respect to environmental effects, the decrease in emissions from consumption of food by 4.4% is obtained under all policy scenarios. The refunding for restoring drained peatlands implies a carbon sink enhancement, which amounts to 5.9 million tonnes of $CO_2$eq. This corresponds to 60% of the calculated emissions from the included food products and to 11.4% of total $CO_2$eq emissions in Sweden in 2018 (SEPA, 2020). The nitrogen and phosphorus reductions obtained by conversion of arable land into wetlands amount to 5.9 ktonne N and 0.07 ktonne 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 for reduction requirements set by Helcom (2013), wetland construction accounts for 64% and 13% of the reduction requirement of N and P respectively for Sweden (Gren et al., 2018). The refunding based on grassland results in a slight increase in the area of grassland, 0.5%. There are no environmental impacts under the lump-sum refunding, as expected from the literature (e.g. Fischer, 2011), but the area of used farmland increases under the area-based system by 10% which implies increased leaching of nitrogen by 2%.

### 4.2. Distributional effects

The regionally differentiated impacts on the reference income of the consumption tax and refunding schemes raise the question whether the losses without refunding and payments are progressive or regressive. Progressivity in the losses implies that relatively rich regions face proportionally much of the losses, and a progressive payment system implies that poor regions receive a proportionally large share of the total increase in income. The Suits index measures the proportionality between income and the net costs or benefits of the tax-refund system. For example, when the proportion of net costs or benefits among farmer in the different regions is the same as the proportions of total income in the benchmark case, the effect is neutral and the index is zero. On the other hand, when relatively poor farmers face proportionally low (high) net costs, the index is positive (negative).

The calculated Suits index of the climate tax without any refunding amounts to 0.15, which indicates that the costs of the tax is progressive. However, the Suits index for the payments schemes shows that they are all regressive, but to different degrees. The lump-sum payment is almost neutral with a Suits index of −0.02, but all environmental payment schemes show a higher regressivity with a Suits index ranging between −0.10 for grassland and −0.31 for wetland construction (Fig. S1 in the Supplementary material). The reason for these regressive effects of refunding for environmental improvements is the location of the areas eligible for environmental payments, which are mainly located in regions in mid and south Sweden with relatively high average incomes in the benchmark. This regressive effect of the payments schemes counteracts the progressivity of the costs of the tax. The combined effect of the tax and refunding is regressive and the Suits index amounts to –0.26, −0.01, and –0.16 for all ecosystems, lump-sum and area-based refunding schemes, respectively.

## 5. Discussion

The results presented in this study rest on a number of different assumptions related to the construction of the partial agricultural sector model in the CAPRI framework, availability of data and parameter values on included variables. The static approach of the CAPRI model excludes the possibilities of investment in new production and environmental technologies with effects on future net incomes and environmental improvements. However, the modelling of farmers' investment decisions under uncertainty on e.g. yield, output and input prices would require quite other modelling approaches such as dynamic and/or stochastic programming at the farm level (e.g. Huber et al., 2017; Spiegel et al., 2020). Another limitation was the focus on income effects on farmers, and exclusion of welfare impacts on the consumers. The consideration of consumers would require data on impacts on different household categories, which is not available in CAPRI. Based on such data for Sweden, Säll (2018) calculated the compensation needed for different households to stay at the same welfare level as without an environmental tax on consumption of meat and diary products, where the tax on beef corresponded to approximately 30% of the price. The results indicated compensation requirements ranging between 0.51% and 0.99% of the household income, being highest for low-income households. This might be regarded as upper limit effects on the households from the climate tax introduced in the present study, which corresponds to a maximum price increase of 18%.

Similar to most numerical partial equilibrium models, the CAPRI model assumes competitive markets. This is likely not to hold in practice for several markets, with high concentrations of a few firms on the supply and retail level in Sweden (e.g. Konkurrensverket, 2005). It is well-known in environmental economics that the optimal environmental tax is in general lower than the marginal social cost of pollution when implemented on distorted markets since the production and, hence, pollution is lower than in competitive markets (e.g. Requate, 2005). The introduction of the $CO_2$eq tax suggested in this study would thus be too high on food markets with imperfect competition, and a

**Table 3**
Change in % to benchmark net income from the climate tax on food consumption with refunding for environmental improvements, lump-sum and area-based.

| Region | No refunding | Refunding for: | | | | | |
|---|---|---|---|---|---|---|---|
| | | Peatland | Wetland | Grassland | All three ecosystems | Lump sum | Area based |
| Stockholm | −2.52 | 113.18 | 3.38 | 2.68 | 118.09 | 90.67 | 103.30 |
| Östra mellansverige | −3.72 | 86.47 | 0.66 | 1.04 | 85.53 | 65.30 | 82.42 |
| Sydsverige | −2.22 | 25.38 | 3.90 | −0.28 | 25.36 | 44.70 | 62.40 |
| Norra mellansverige | −4.30 | 17.95 | −3.58 | 0.22 | 11.29 | 89.86 | 52.14 |
| Mellersta Norrland | −4.87 | 8.51 | −4.29 | 2.76 | 2.63 | 85.16 | 34.87 |
| Övre Norrland | −4.79 | 27.79 | −4.48 | −2.07 | 18.25 | 65.80 | 27.72 |
| Småland med Öarna | −6.52 | 35.85 | −5.02 | −1.65 | 25.98 | 38.86 | 30.05 |
| Västsverige | −5.99 | 32.17 | −0.18 | −2.22 | 26.77 | 75.46 | 72.52 |
| Sweden total | −4.60 | 40.82 | −0.85 | −0.60 | 36.22 | 60.25 | 57.84 |

Sources: Calculations based on reference income in Table 2 and incomes after tax and payments in Table S7 in Supplementary material.

lower tax would result in smaller effects on $CO_2$eq emissions.

The assumption of constant emission coefficients for each consumption good is likely not to hold since the coefficients change as production and inputs change, which would affect the total emission. Farmers could also change the emission intensity by e.g. changed feeding for livestock. The exclusion of these options is likely to overestimate the calculated costs of the climate tax. On the other hand, costs of ecosystem services include only the opportunity cost of land and not the cost of any investment and management of the restoration of drained peatland, which is likely to overestimate the incomes from all systems with payments for ecosystem services.

With respect to chosen parameter values of included crucial variables, the results can be sensitive to the assumed payments for ecosystem services and substitution elasticities between demand and production for domestic and foreign goods. Therefore, sensitivity analyses were made for changes in the basic parameter values in the environmental payments and the consumption and production functions. Regarding environmental payments, the calculated size of the environmental payments rests on simplifying assumptions, in particular for biodiversity provision by grassland. Lower payments can be explained by a combination of lower unit values and production per ha of the ecosystem service. For example, the reduction in emissions of $CO_2$eq from restoring drained peatlands can be lower than the estimates used in this study and the unit value can be below the Swedish $CO_2$ tax. A reduction in payments by one half increases the losses with separate payments for grassland and wetland with more than 100% and reduces the net benefit from payments to peatland and all ecosystem services by approximately one half (Table S8 in Supplementary material). However, despite these effects on income, the payments are still sufficient to provide several targeted ecosystem services. Restoration of peatlands then remains at same level, but the provision of grassland shows a slight decrease. Because of the limitation of areas eligible for environmental payments, an increase in payment to the budget constraint has no environmental effect, but turns the net losses with payments for wetlands and grassland into net incomes, and increases the income with payments to peatland and all three ecosystems with a maximum of 60%.

Lower substitution elasticities in the consumption and production functions imply a higher degree of differentiation between domestic and foreign product for the consumer, and for domestic and foreign sales for the producer. This, in turn, implies larger effects on farmers' income of the climate tax on food consumption in Sweden. In order to quantify the role of substitution elasticity, sensitivity analyses are made where the substitution elasticities deviate by 0.5 from the assumed level of 2. The sensitivity analysis shows a modest effect of a decrease by 0.5 in both elasticities, where the average loss is increased by 11% (Table S9 in Supplementary material). Similarly, higher substitution elasticities imply that more of the climate tax is transferred to the EU market, which gives lower income losses for the Swedish farmers. The loss decreases by 10% when the elasticities increase from 2 to 2.5.

It is difficult to compare our results with other studies because of lack of studies on a food tax-refunding system. On the other hand, there is a large body of literature on impacts of different environmental taxes and subsidies to agriculture (see OECD, 2020 for a review). There are very few studies calculating impacts on farmers' income from consumption taxes on food (Jansson and Säll, 2018; OECD, 2019). Both these studies calculated impacts on farmers' incomes from introduction of $CO_2$eq taxes on animal food consumption, but at different geographical scales. Jansson and Säll (2018) used the CAPRI model to introduce different levels of taxes (60 to 290 euros/tonne $CO_2$eq) on animal food consumption in the EU, and found that emissions reduced by a maximum of 4.9% and the incomes could decrease by up to 11%. OECD (2019) used a global general equilibrium model and calculated effects on the OECD countries of a tax amounting to 100 USD /tonne $CO_2$eq. The results showed that the emission reduced by approximately 3% and value added in the agricultural sector decreased by 8%. The calculated average decrease in emissions by 4.4% and in incomes by 4.6% in the present study is thus in the same order of magnitude as in these studies.

There is a large body of literature on the effects of different environmental payments to farmers (see review in Uthes and Matsdorf, 2013). An aspect pointed out in this literature is the role of transaction costs. Ollikainen et al. (2008) showed that the transaction costs in Finland for agri-environmental policies can vary between 2% and 40% of the payment to the farmer depending on environmental policy. Basic income support combined with environmental cross compliance conditions gives the lowest transaction costs while the environmental payments in general are associated with high transaction costs. The assumption made in the present study of 25% administration cost could then be too low for the environmental payments. On the other hand, the result showed that the maximum environmental payments amount to 0.73 billion euros and the tax revenues to 1.1 billion euros. The transaction costs could thus be higher than the assumed 25% of the environmental payment and still generate the same environmental effects.

## 6. Policy implications

Despite the limitations of the numerical model underlying the comparison of outcomes under the different policy scenarios, the study points out three main policy implications; design of a food consumption tax, $CO_2$eq tax on imported food, and design of payments for ecosystem services.

Several studies calculating effects of climate taxes on food goods have attributed emission coefficients to the goods in a life cycle analysis (LCA) perspective (e.g. Edjabou and Smed, 2013; Säll and Gren, 2015; Chalmers et al., 2016; Janson and Säll, 2018). The LCA calculates emission coefficient per unit food item from the 'cradle to the grave', which includes emissions at all production and processing steps of the good, such as use of fertilizers and transports. However, this implies double taxation of emissions that are subject to carbon pricing, such as the fertilizer industry in the EU emission trading system and national carbon taxes on transport emissions. The inclusion of emissions at all steps in the value added chain then generates too high taxes on goods, the magnitude of which depends on the share of emissions from taxed fossil fuels. Gren et al. (2019) showed that an LCA tax on beef produced in Sweden is 16% higher than when only non-priced carbon emission is included. However, it can be eight times higher for tomatoes because of a large share of emissions from taxed emissions on transports. An advantage of the tax suggested in this study compared with the LCA taxes is that it includes only non-taxed emissions of $CO_2$eq.

Current world trade agreements and EU treaties could be an impediment to the introduction of a national $CO_2$eq tax on food consumption, which would be particularly relevant for meat because of the high emission coefficients. However, as argued by Bärh (2015) and Arvidsson (2016), an EU country has the discretion to introduce national environmental taxes and associated adjustment of import prices. Ideally, the tax should reflect the non-taxed emissions in the countries of origin. The tax could then differ considerably between countries depending on food production technology and national environmental taxes. For example, the tax on Swedish consumption of tomatoes from the Netherlands could be twice as high as a tax on tomatoes produced in Sweden (Gren et al., 2019). The assumption made in this study of harmonized environmental taxes on each food item irrespective of country of origin thus implies non-optimal taxes but could be an advantage by its simplification of trade.

The point of departure in this study was an output-based system for payment of the included ecosystem services. This implies that payments are made for the value of the provision of the services, and farmers then make net profits when the provision costs are lower than the payment. In Sweden, a cost-based system is often used where payments for e.g. land managed for biodiversity protection are based on the management cost of the land and not the provision of biodiversity (Swedish Board of Agriculture, 2018). The net benefits, in particular of restoration of peatlands, would be lower with such a cost-based system. The sensitivity analysis made in this paper showed that even if payments for restoring drained peatlands were reduced by one-half, it is still profitable for the farmers to restore the same area and, hence, provide a considerable quantity of carbon sequestration. This can be a result of relatively low cost estimates of land conversion used in this study. It also points out the need for a careful design of payments in an output-based system.

## 7. Conclusions

The main purpose of this study was to assess the impacts on farmers' net incomes and on the environment of a climate tax on consumption of food in Sweden where tax revenues were refunded for three types of environmental improvements (carbon sequestration by restoring drained peatlands, biodiversity from grassland, and nutrient cleaning by wetlands), lump-sum and area-based. The climate tax was determined by the Swedish $CO_2$ tax and payments for the different ecosystem services were derived from revealed preferences based on actual decisions on the Swedish carbon tax, nutrient targets, and the biodiversity targets.

Similar to several other studies on a climate tax on food consumption, a main conclusion in this study is that, despite a relatively high tax on $CO_2$eq, the emission reduction from reduced consumption is modest and corresponds to approximately 4.4% of the $CO_2$eq emissions from consumption without the tax. It was also shown that the main part of the tax is transferred to the consumer in terms of increases in prices for most goods. Because of the relatively large tax revenues and large payments for, in particular, restoration of drained peatland, the average net income for farmers in all regions is higher with the tax-refund system than without any tax at all. This is also the case for lump-sum and area-based refunding. With respect to environmental effects, emissions of $CO_2$eq from food consumption decrease by 4.4% in all policy scenarios. Furthermore, the restored peatland increases carbon sequestration corresponding to approximately 57% of the $CO_2$eq emissions from food consumption in Sweden.

The materialization of the environmental improvements and income increases from the combined system requires implementation of a payment scheme for carbon sequestration by drained peatlands that is not yet in place in Sweden. The construction of an efficient payment scheme must meet the challenges associated with difficulties to measure and monitor carbon sequestration, which has been made in different ways in other countries (see review in Gren and Aklilu, 2016). There might also be institutional and legal restrictions on the output-based systems for payments of ecosystem services applied in this study, where restrictions and regulations in Sweden may not allow for payments above provision costs.

It was shown that the payment for the ecosystem services is in general regressive where regions with relatively high average incomes receive a large proportion of the total income increase. This counteracted the progressivity of the losses in incomes of agricultural production from the consumption tax where high-income regions faced a large share of the total losses, which may create political opposition against the introduction of the system. Although refunding for the purpose of environmental improvements may increase the acceptance of a climate tax on food consumption it may well be politically difficult to introduce a refunding system where farmers in relatively rich regions make large net gains.

## CRediT authorship contribution statement

**Ing-Marie Gren:** Conceptualization, Formal analysis, Methodology, Funding acquisition. **Lisa Höglind:** Methodology, Validation, Resources, Data curation, Visualization. **Torbjörn Jansson:** Methodology, Validation, Resources, Data curation, Visualization.

## Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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## Appendix A. Supplementary material

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