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WORKING PAPER

Towards a Food System Transition in Germany: A Scenario Analysis of VAT Reform and Peatland Restoration

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A Scenario Analysis of VAT Reform and Peatland Restoration

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Abbreviations and Acronyms

BMEL	Bundesministerium für Ernährung und Landwirtschaft / Federal Ministry of Food and Agriculture Germany
BMU	Bundesministerium für Umwelt, Naturschutz, nukleare Sicherheit und Verbraucherschutz / Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection Germany
ca	circa
CAP	Common Agricultural Policy
CGE	Computable general equilibrium
CO_2	Carbon dioxide
CPI	Consumer Price Index
CV	Compensating variation
ERS	Economic Research Service, US Department of Agriculture
EU	European Union
EV	Equivalent variation
EVS	Einkommens- und Verbrauchsstichprobe / Income and expenditure survey for Germany
FSEC	Food System Economics Commission
GDP	Gross domestic product
GHG	Greenhouse gas
GMC	Greifswald Moor Centrum
GTAP	Global Trade Analysis Project
GWP	Global warming potential
ha	Hectar
IFPRI	International Food Policy Research Institute
IMF	International Monetary Fund
kha	Kilo hectar (1000 ha)
LES	Linear expenditure system
LMI	Low- and Middle-Income countries
LULUC	Land Use, Land Use Change and Forestry
mio	Million
NPPS	National Peatland Protection Strategy

PIK	Potsdam-Institut für Klimafolgenforschung / Potsdam Institute for Climate Impact Research
SSP	Shared Socioeconomic Pathway
tCO_2e	Ton of carbon dioxide equivalent
UAA	Utilised agricultural area
UBA	Umweltbundesamt / German Environment Agency
USDA	US Department of Agriculture
VAT	Value-added tax
WBAE	Wissenschaftlicher Beirat Agrarpolitik, Ernährung und gesundheitlicher Verbraucherschutz / Scientific Advisory Board on Agricultural Policy, Food and Consumer Health Protection
WBW	Wissenschaftlicher Beirat Waldpolitik / Scientific Advisory Board on Forest Policy
ZKL	Zukunftskommission Landwirtschaft / Commission on the Future of Agriculture

1. Introduction

This study provides a forward-looking quantitative analysis of selected policy interventions that can contribute to promoting a transition towards a healthy, inclusive and nature positive food and land use system in Germany. The focus of the analysis is on two sets of policy measures that figure prominently in the pertinent current discourse about the future of agriculture and the food system in Germany - namely **(i)** an indirect tax reform aimed at inducing a gradual shift in household food consumption patterns towards healthier and more environmentally sustainable choices, and **(ii)** a policy reform aimed at reducing the large volume of greenhouse gas (GHG) emissions from agricultural production on drained peatland in Germany.

With respect to **(i)**, Germany's Scientific Advisory Board on Agricultural Policy, Food and Consumer Health Protection (WBAE, 2020; WBAE/WBW, 2016) as well as the Commission on the Future of Agriculture appointed by the German federal government (ZKL, 2021) have recommended to raise the value-added tax (VAT) rates on meat and dairy products, to reduce the VAT rates on fruits and vegetables, and to impose a new excise tax on sugar use.

From a human health perspective, the proposed reform would raise the consumer prices of animal source foods and sugar-sweetened products relative to the consumer prices of plant-based food, and would thus induce substitution effects broadly in line with the dietary recommendations of the EAT-Lancet Commission (Willetts et al, 2019). The EAT-Lancet healthy reference diet is based on an extensive review of the scientific literature on dietary patterns, and health outcomes and consists of a diversity of plant-based foods, low amounts of animal source foods, unsaturated rather than saturated fats, and small amounts of refined grains, highly processed foods, and added sugars (ibid., 448).

From an environmental perspective, a tax-reform-induced substitution of animal source food by plant-based foods is in particular associated with a reduction in agricultural GHG emissions, as emissions per calorie and per unit of protein are generally far larger for the former than for the latter (Clark and Tilman, 2017).

However, from an inclusion perspective the price effects of the tax reform are expected to have on balance a regressive impact – i.e., the additional net tax burden in proportion to income will be higher for low-income households than for high-income households - because low-income households spend a higher share of their income on food products subject to rising prices under the tax reform than high-income households. In view of this adverse distributional impact, WBAE (2020) and ZKL (2021) as well as the Climate Neutrality Foundation (Grethe et al, 2021) recommend to combine the tax reform with compensation payments to lower-income households.

In line with these proposals, the tax reform scenario analysis of the present study thus considers a policy bundle[1] consisting of a VAT rate increase for meat and dairy products, a new excise tax on sugar use in intermediate and final consumption, a VAT rate reduction for fruits and vegetables (including root, tubers, pulses and nuts), and a revenue-neutral lump-sum cash transfer scheme designed to compensate lower-income households for the net real income loss due to the induced changes in consumer prices.

With respect to (**ii**), drained peatlands used for agricultural production are a major source of land-use-related GHG emissions in Germany, and thus the mitigation potential of an ambitious peatland rewetting programme is potentially large. The country's total peatland area amounts to 1.8 million hectares (ha) and 92 percent of this area has been drained. When peatland is drained for agriculture, forestry, peat extraction or human settlement, the organic matter stored in peat soils comes into contact with oxygen and the resulting decomposition process leads to significant CO_2 and N_2O emissions for decades to centuries (Leifeld and Menichetti, 2018; Günther et al, 2018).

Annual greenhouse gas (GHG) emissions from drained peatland amounted to 53 million tCO_2e in 2020, that is 7.5 percent of Germany's total 2020 GHG emissions (UBA, 2022; BMU, 2021). 77 percent of the drained peatland area is used for agricultural production, which accounts for over 80 percent of the GHG emissions from Germany's drained peatlands. While agricultural peatland represents only 7.7 percent of Germany's total utilized

[1] The need for the bundling of different policy measures towards a food system transition in the presence of potential trade-offs between health, environmental and inclusion goals is emphasized by Gaupp et al (2021) and Leip et al (2022). The recognition that the achievement of multiple policy targets generally requires the combination of multiple policy instruments is a basic insight of the theory of economic policy in the tradition of Jan Tinbergen (1952). As noted by Willenbockel (2015: 170), a corollary of this insight is that an exclusive focus on the identification of win-win or triple-win measures unduly narrows the space of potential policy options.

agricultural area in 2020, it contributes a disproportionate 40 percent of Germany’s total GHG emissions from agriculture and agricultural land use (Grethe et al, 2021; Hirschelmann et al, 2020).

Under the amended Climate Change Act 2021, the German government is committed to reduce GHG emissions by 65 percent relative to 1990 level by 2030 and to reach climate neutrality by 2045. The National Peatland Projection Strategy (NPPS) (BMU, 2021) - adopted in 2022 after protracted political debate about potential adverse economic impacts - recognizes that without a reduction in peatland emissions, these climate change mitigation targets will not be achievable. The target set out in the NPPS is to reach an initial reduction in annual peatland emissions of 5 million tCO_2e by 2030. While some contributors to the discourse on peatland restoration in Germany criticise the NPPS target for its lack of ambition (e.g. GMC, 2021; Grethe et al, 2021), others point to high implementation costs and raise questions concerning the achievability of the target (e.g. Hofer and Köbbing, 2021).

Against this backdrop, the present study considers an NPPS implementation scenario in which 7 percent of agricultural peatland is rewetted by 2030 as well as two more ambitious scenarios in which respectively 37 and 55 percent of agricultural peatland is rewetted by the end of the decade. The specification of the scenarios draws upon recommendations by the Climate Neutrality Foundation (Grethe et al, 2021) and WBAE /WBW (2016). All scenarios assume the implementation of a payment scheme to incentivize a voluntary switch from agricultural production on drained peatland to the harvesting of carbon credits on rewetted peatland.

The main analytical tool for the policy scenario analysis is a dynamic five-region computable general equilibrium (CGE) model of the German economy and its trade relations with the rest of the European Union, Other High-Income Countries, Africa, and Other Low/Middle-Income Countries. The model distinguishes 20 production sectors and corresponding commodity groups including seven agricultural and six food processing sub-sectors. To enable an analysis of distributional impacts on different household income groups with and without compensatory measures, and thus to assess the simulated transition pathways from an inclusivity perspective, the CGE model is linked with a dynamic household microsimulation model for Germany that uses data from the latest Income and Expenditure Survey. The time horizon of the analysis is 2023-2030.

Section 2 provides a concise non-technical description of the CGE model and outlines the dynamic baseline calibration process. Section 3 explains the specification of the simulation scenarios. Section 4 presents and discusses the simulation results. Section 5 recapitulates and draws conclusions.

2. Analytical Framework

2.1. The GLOBE Model

The main analytical tool for the policy scenario analysis is a dynamic five-region computable general equilibrium (CGE) model of the German economy and its trade relations with the rest of the European Union, Other High-Income Countries, Africa, and Other Low/Middle-Income Countries. The model distinguishes 20 production sectors and corresponding commodity groups including seven agricultural and six food processing sub-sectors (Table A-1).

The main features of the dynamic GLOBE model are outlined in the Appendix and a detailed technical exposition is provided in Willenbockel et al (2018).[2] For the present study, the stylized treatment of sales taxes in GLOBE has been modified to incorporate the VAT rebates on intermediate input and investment purchases in Germany. This modification draws upon the approach of Chang and Chang (2022).

The model is initially calibrated to the GTAP10 database (Aguiar et al, 2019). This data set provides a detailed and internally consistent representation of the global economy-wide structure of production, demand, and international trade at a regionally and sectorally disaggregated level for the benchmark year 2014.

2.2. The Dynamic Household Microsimulation Model

To enable an analysis of distributional impacts on different household income groups with and without compensatory measures, and thus to assess the simulated transition pathways from an inclusivity perspective in line with the food system development paths approach proposed by Gaupp et al (2021), the CGE model is linked with a purpose-built dynamic household microsimulation model for Germany that is calibrated to data from the latest available Income and Expenditure Survey (EVS) for 2018 (Statistisches Bundesamt, 2020,2021). The EVS data distinguish eight household groups according to net income (Table 2.1). On the expenditure side, the EVS data are aggregated into five food commodity

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[2] Recent applications of GLOBE for medium- and long-run food system scenario analysis include inter alia Komarek et al (2021), Wiebe et al (2021), Sulser et al (2021) and Mason-D'Croz et al (2019),

groups and a composite non-food consumption commodity such that they can be mapped to the corresponding commodity groups of the CGE model (Table 2.2). On the income side, the EVS data provide information on labour income, capital income, transfer income and direct tax payments. A detailed exposition of the microsimulation model is provided in the Appendix.

Table 2.1: Household Groups for Distributional Impact Analysis

Code	Net Income Bracket 2018	Average Net Income 2018	Extrapolated No. of Households 2018	Persons per Household
	Euro / month	*Euro / month*	*in 1000s*	
H1	<900	726	2,006	1.0
H2	900-1300	1,099	3,413	1.1
H3	1300-1500	1,400	1,816	1.3
H4	1500-2000	1,750	4,803	1.4
H5	2000-2600	2,290	5,475	1.6
H6	2600-3600	3,073	7,250	1.9
H7	3600-5000	4,252	6,895	2.4
H8	> 5000	7,607	9,024	2.9
Total		**3,661**	**40,682**	**2.0**

Source: Statistisches Bundesamt (2020)

Table 2.2: Commodity Composition of Consumption Expenditure by Household Group 2018

	Average	H1	H2	H3	H4	H5	H6	H7	H8
					Monthly Expenditure *(Euro)*				
Meat Products	*49*	20	23	26	32	39	50	59	76
Dairy Products	*42*	19	22	26	29	35	41	49	63
Fruit, Vegetables	*61*	31	33	38	43	54	60	70	92
Sugar Products	*19*	8	10	11	13	15	18	23	28
Other Food	*150*	77	84	94	107	125	151	179	221
Non-Food	*2625*	756	1004	1205	1479	1870	2426	3181	4741
					Monthly Per Capita Expenditure *(Euro per household member)*				
Meat Products	*25*	20	21	20	23	24	26	25	26
Dairy Products	*21*	19	20	20	21	22	22	20	22
Fruit, Vegetables	*31*	31	30	29	31	34	32	29	32
Sugar Products	*10*	8	9	8	9	9	9	10	10
Other Food	*75*	77	76	72	76	78	79	75	76
Non-Food	*1313*	756	912	927	1056	1168	1277	1325	1635
					Expenditure Share *(%)*				
Meat Products	*1.7*	2.2	2.0	1.9	1.9	1.8	1.8	1.7	1.5

Dairy Products	*1.4*	2.1	1.9	1.9	1.7	1.6	1.5	1.4	1.2
Fruit, Vegetables	*2.1*	3.4	2.8	2.7	2.5	2.5	2.2	2.0	1.8
Sugar Products	*0.6*	0.9	0.9	0.8	0.8	0.7	0.7	0.6	0.5
Other Food	*5.1*	8.5	7.1	6.7	6.3	5.8	5.5	5.0	4.2
Non-Food	*89.1*	83.0	85.4	86.1	86.8	87.5	88.3	89.3	90.8
Food Share (%)	*10.9*	17.0	14.6	13.9	13.2	12.5	11.7	10.7	9.2

Source: Statistisches Bundesamt (2021) and author's calculations.

3. Specification of Scenarios

3.1. Baseline Scenario

As the benchmark year for the GTAP10 database is 2014, while the time horizon for the policy scenario analysis is 2023-2030, the model is first used to generate a new updated benchmark equilibrium for 2022 which reflects observed / estimated population growth, labour force growth and economic growth over the period 2014-2022. In a next step, a dynamic baseline scenario up to 2030 is constructed which serves as the reference for comparison with the food system transition scenarios. The baseline development uses SSP2 assumptions for population, labour force and GDP growth (Dellink et al, 2017) and incorporates a stylized representation of the CAP reform 2023-27 based on the German CAP Strategy Plan (BMEL, 2022) and European Commission (2022). Technically, in the construction of the dynamic baseline, the aggregate real GDP growth paths for all model regions are exogenized and the production function efficiency parameters governing the growth rates of labour-augmenting technical progress are endogenized. To replicate observed trends in German food consumption since 2014 such as the gradual drop in per-capita meat and dairy product consumption, the marginal expenditure parameters of the household demand function are adjusted gradually over time.[3] Further information on the details of the baseline calibration are provided in the Appendix.

3.2. Scenario Set A: Tax Policy Reform Scenarios

[3] See Valin et al (2014) for further reference to this common practice in economic model-based long-run food system analysis. See also Cirera and Masset (2010).

This set of scenarios considers a policy bundle aimed at incentivizing a gradual shift in household food consumption patterns in Germany towards the dietary recommendation of the EAT-Lancet Commission (Willetts et al, 2019). The policy bundle includes changes of the indirect tax rates on meat and dairy products, fruits and vegetables, and sugar along with compensation payments for low-income households adversely affected by the resulting price effects. The specification of the policy bundle draws on recommendations by WBAE (2021), the ZKL (2021) and Grethe et al (2021).

Specifically, from 2023 onwards in Germany

- the VAT rate on meat products rises by 12 percentage points from 7 to 19 percent
- the VAT rate on dairy products rises by 12 percentage points from 7 to 19 percent
- the VAT rate on fruits and vegetables drops by 7 percentage points from 7 to 0 percent[4]
- an excise tax on intermediate and final consumption of refined sugar at an ad-valorem-equivalent rate of 10 percent is imposed.

The tax reform is first simulated in the absence of compensatory transfers to the household sector (**Scenario A.1).** This scenario serves both to determine the net additional fiscal space in the form of additional net tax revenue available for compensatory lump-sum payments to the household sector opened by the policy reform and to estimate the size order of the lump-sum transfers that would be required to fully compensate lower-income households for welfare losses arising under this scenario.

In **Scenario A.2** these compensation payments are added to the policy bundle. Specifically,

- an amount equivalent to 100 percent of the additional net government revenue raised by the tax reform is recycled to the household sector in form of a budget-neutral lump-sum transfer to compensate lower-income households for the welfare losses associated with the reform-induced price changes while keeping government

[4] The reduction to a zero rate is permissible under the new EU Council Directive 2022/542 of 5 April 2022. Under previous EU tax harmonization regulations, a drop of the reduced VAT rate below 5% was not permitted – see e.g. WBAE (2020: 557). The author is grateful to Benjamin Bodirsky (PIK) for drawing attention to this rule change.

spending on the baseline path in real terms. In the linked microsimulation analysis, the transfer sum is allocated to households in reverse order of income bracket until the additional fiscal space is fully exhausted.

3.3. Scenario Set B: Agricultural Peatland Restoration Scenarios

This set of scenarios considers a policy bundle aimed at reducing agricultural GHG emissions by incentivizing the restoration of drained peatland in Germany currently used for agricultural production. The scenario specifications take inter alia account of Germany's National Peatland Protection Strategy (BMU, 2021), the respective recommendations by the Stiftung Klimaneutralität (Grethe et al, 2021) and WBAE /WBW (2016), and the latest data on organic soil area (~ peatland) use and associated GHG emissions from Germany's 2022 National GHG Inventory Report (BUA, 2022) displayed in Table 3.1 below.

Table 3.1: Peatland Area by Use and GHG Emissions Germany 2020

Use	Area	GHG Emissions	Emission Factor
	k ha	*Mio t CO2e /Year*	*t CO2e/ha*
Cropland	331.2	13.2	39.8
Grassland	951.8	29.3	30.8
Forest Land	278.0	3.1	11.1
Peat Extraction	17.7	0.1	5.6
Other	243.4	5.4	22.4
Total	**1822.1**	**51.2**	
Total Agriculture	***1283.0***	***42.5***	***33.1***

Source: BMU (2022), Tables 345, 263, 362, 394, 409 and author's calculations.
Emissions comprise CO_2, N_2O and CH_4.

Three abatement scenarios in which peatland users are incentivised to reduce these emissions on a voluntary basis are considered. All scenarios assume that the treated areas are fully rewetted by raising the water table permanently to less than 0.1m below ground level to achieve maximum emission impact. In this case, annual emissions drop to 5.5 tCO_2e/ha (Tiemeyer et al, 2020) and consist primarily of methane emissions. Full rewetting entails that these areas become unsuitable for conventional agriculture and conversions to paludicultural[5] uses are not considered in these medium-run scenarios to avoid speculative assumptions about the speed of development of commercial value chains, required new infrastructure investments and so forth.[6]

The National Peatland Protection Strategy (NPPS) and the associated Target Agreement (2021) between the federation and the Länder sets an aim to reduce annual peatland emissions by 5 mio tCO_2e for 2030, but both documents are short on concrete policy detail and silent on prospective funding levels to support this aim. It is assumed that rewetting measures on 30 percent of the forest peatland area (that is the state-owned share of forest peatland according to Nitsch / Schramek, 2020) and the complete phasing-out of peat extraction and use (as envisaged in the Climate Act 2030) contribute respectively annual reductions in emissions of 0.467 mio tCO_2e and 1.0 mio tCO_2e (based on Höfer /Kobbing, 2021) by 2030. These non-agricultural peatland restoration measures will have negligible economy-wide effects and are subsumed in the baseline scenario, while all measures on agricultural peatland are included in the policy scenarios.

This approach allows to consider a targeted agriculture-focused NPPS implementation scenario (B.1: RewetLo) that can be contrasted with more ambitious agricultural peatland rewetting scenarios (B.2: RewetHi and B.3: RewetHi+) that go beyond the NPPS target.

As the emission factor for cropland in Table 3.1 is an average over cropland with varying drainage levels and deeper draining entails higher emissions, the specification of the RewetLo and RewetHi scenarios follows WBAE/WBW (2016) in assuming that rewetting starts on deeply drained cropland with above-average baseline submissions. Specifically, it is assumed that the first 100 kha of fully rewetted cropland reduces emissions by 39.7 tCO_2e/ha, the next 100 kha by 34.8 tCO_2e/ha, and the final 133.1 kha by 29.8 tCO_2e/ha. These rates are set such that the integral under this stepwise linear emission function is consistent

[5] Paludiculture is the productive land use of wet and rewetted peatlands.
[6] Partial rewetting measures that allow some form of conventional agricultural income generation to continue, such as the conversion of deeply drained cropland into medium drained extensive grassland are not considered here, because the empirical evidence suggests that abatement costs per tCO_2e tend to be significantly higher compared to complete rewetting – i.e., the opportunity cost reduction tends to be dominated by the drop in the mitigation effect – see e.g. Schaller (2014), WBAE/WBW (2016: 150), Krimly et al (2016).

with the figures in Table 3.1, given the 5.5 tCO_2e/ha emission factor under complete rewetting.

Thus, **Scenario B.1** (RewetLo) assumes that the remaining abatement effort of 3.5 million tCO_2e required to reach the 5 million tCO_2e NPPS target – given the aforesaid non-agricultural measures subsumed in the baseline scenario - is realized by fully rewetting a suitable fraction of cropland. Under the stated assumptions about 88,000 ha of cropland need to be rewetted by 2030 to reach the NPPS target.

Scenario B.2 (RewetHi) is a substantially more ambitious abatement scenario, in which all drained cropland is rewetted and in addition 15 percent of drained grassland is fully rewetted by 2030 (Table 3.2). Annual emissions from agricultural peatland use drop by 15 million tCO_2e towards 2030 in this scenario (Table 3.3). In terms of mitigation outcomes – though not in the details of the pathway – this scenario is similar to 'scenario C' to 2030 of WBAE/WBW (2016) and to the 'Pathway 1' scenario to 2030 in Tanneberger et al (2021). In both RewetLo and RewetHi, the rewetting process takes place over the period 2023 to 2030 according to a linear expansion path as shown in Table 2.

The specification of **Scenario B.3** (RewetHi+) draws upon the aforementioned model-based spatially explicit simulation analysis by Röder et al (2015), which assumes that peatland use by an agricultural activity in a NUTS3 region of Germany is abandoned in favour of full rewetting once the reward payment received for rewetting exceeds the short-run opportunity cost measured in terms of gross value added foregone. The original analysis of Röder et al (2015) suggests that at a reward level of 5 Euro/ tCO_2e, an area of 261,000 ha (primarily cropland in areas of East-Central Germany with low value added per ha due to unfavourable soil and climatic conditions), while at 10 Euro/ tCO_2e (20 Euro/ tCO_2e) the total rewetted area rises to 405,000 ha (729,000 ha).

The RewetHi+ scenario modifies this abatement cost schedule by adding planning and engineering costs and by scaling up the implied schedule of opportunity costs per to arrive at an updated valuation of foregone income in Euros of 2020 purchasing power and to reflect the conjecture that probably a stronger financial incentive beyond the compensation for lost income is required to induce the level of voluntary participation in rewetting schemes assumed in this scenario. Furthermore, since the rewetted cropland area in Röder et al (2015) exceeds the total available organic soil cropland area according to the more recent BMU (2022) data used in the present study (Table 3.1) by 20,000 ha, the rewetted area figures have been adjusted accordingly. Thus, under the RewetHi+ scenario 709,000 ha are completely rewetted by 2030 (Table 2). Annual emissions from agricultural peatland use drop by 19.1 million tCO_2e towards 2030 in this scenario (Table 3.3)[7].

To assess the minimum compensation payment levels required to induce a voluntary switch from agricultural production to the harvesting of carbon credits, an estimate of the short-run private abatement costs is required. These comprise the opportunity cost of full rewetting in terms of agricultural income foregone plus the annualized planning, construction, maintenance and monitoring costs (net of avoided baseline drainage costs) associated with permanently raising the water tables (e.g. through drain blocking and ditch closing) on the peatlands designated for rewetting.[8] Existing empirical studies for Germany[9] measure the opportunity cost component by the gross margin (foregone revenue including subsidies minus short-run variable cost) or gross value-added at factor cost. For the RewetLo and RewetHi scenarios the annual opportunity cost component is set at a uniform rate of 900 Euro/ha[10]. Following Isermeyer et al (2019: 46-47) and Grethe et al (2021: 72), the average annualized engineering costs are set at 500 Euro/ha (i.e. 10,000 Euro/ha over 20 years). The engineering costs enter the general equilibrium model in the form of additional exogenous government-financed purchases of construction services and other services. It is assumed that these rewetting costs consist of upfront planning and construction costs of 8000 Euro/ha in the first year and recurrent annual maintenance and monitoring costs of 100 Euro/ha for 20 years. The annualized short-run private abatement including engineering costs is thus 1400 Euro/ha, which equates to marginal private abatement costs of 35 Euro/tCO_2e under RewetLo

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[7] Emission figures in for RewetHi+ in Table 3 are based on emission reduction factors (29.9 to 25.0 tCO_2e/ha) backed out from Röder (2015: Supplementary Information Table A.2).
[8] In the following these latter costs are referred to as ‘engineering costs’ for brevity’s sake.
[9] See Bonn et al (2015) for a concise review.
[10] This figure is slightly above the range for the private opportunity cost of rewetting suggested by Grethe et al (2021: 72).

and 40 to 50 Euro/tCO_2e under RewetHi (Table 4). These figures are within the mid-range of existing abatement cost estimates for fully rewetted agricultural peatland in Germany.

In the RewetHi+ scenario, the upscaled opportunity costs derived from Röder et al (2015) rise from 308 Euro/ha for the first 261 ha to 529 Euro/ha for the next 142 ha and to 1030 Euro/ha for the last 306 ha of rewetted peatland, and thus the marginal private abatement costs including annualized engineering costs rise from 808 Euro/ha to 1029 Euro/ha and 1530 Euro/ha respectively. The corresponding marginal abatement costs per tCO_2e are shown in Table 3.4. It is assumed that reward payments at the initial low rate are offered from 2023 to 2025 and then rise to higher levels in 2026 and 2028.[11]

Table 3.2: Agricultural Peatland Transformation Pathway by Scenario

	2023	2024	2025	2026	2027	2028	2029	2030
Rewetted Peatland Area				**B.1: RewetLo**				
Cropland (kha)	11.0	22.0	33.0	44.1	55.1	66.1	77.1	88.1
Grassland (kha)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total (kha)	**11.0**	**22.0**	**33.0**	**44.1**	**55.1**	**66.1**	**77.1**	**88.1**
Rewetted Peatland Area				**B.2: RewetHi**				
Cropland (kha)	41.4	82.8	124.2	165.6	207.0	248.4	289.8	331.2
Grassland (kha)	17.8	35.7	53.5	71.4	89.2	107.1	124.9	142.8
Total (kha)	**59.2**	**118.5**	**177.7**	**237.0**	**296.2**	**355.5**	**414.7**	**474.0**
Rewetted Peatland Area				**B.3: RewetHi+**				
Cropland (kha)	86.3	172.7	259	331.2	331.2	331.2	331.2	331.2
Grassland (kha)	0.7	1.3	2.0	16.8	72.0	174.0	276.0	378.0
Total (kha)	**87.0**	**174.0**	**261.0**	**348.0**	**403.2**	**505.2**	**607.2**	**709.2**

[11] Practical barriers to a more fine-tuned sequencing of rewetting measures in order of abatement costs arise inter alia due to the dispersed ownership of suitable connected areas and the related need to negotiate agreement among multiple stakeholders.

Table 3.3: Direct Greenhouse Gas Emission Reduction by Scenario

	2023	2024	2025	2026	2027	2028	2029	2030
Direct GHG Reduction				**B.1: RewetLo**				
Cropland (million tCO2e)	-0.4	-0.9	-1.3	-1.8	-2.2	-2.6	-3.1	-3.5
Grassland (million tCO2e)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total (million tCO2e)	**-0.4**	**-0.9**	**-1.3**	**-1.8**	**-2.2**	**-2.6**	**-3.1**	**-3.5**
Direct GHG Reduction				**B.2: RewetHi**				
Cropland (million tCO2e)	-1.6	-3.3	-4.8	-6.3	-7.7	-8.9	-10.1	-11.4
Grassland (million tCO2e)	-0.5	-0.9	-1.4	-1.8	-2.3	-2.7	-3.2	-3.6
Total (million tCO2e)	**-2.1**	**-4.2**	**-6.2**	**-8.1**	**-9.9**	**-11.6**	**-13.3**	**-15.0**
Direct GHG Reduction				**B.3: RewetHi+**				
Cropland (million tCO2e)	-2.6	-5.2	-7.7	-9.6	-9.6	-9.6	-9.6	-9.6
Grassland (million tCO2e)	0.0	0.0	-0.1	-0.4	-1.9	-4.4	-7.0	-9.5
Total (million tCO2e)	**-2.6**	**-5.2**	**-7.8**	**-10.0**	**-11.5**	**-14.0**	**-16.6**	**-19.1**

Table 3.4: Private Abatement Costs by Scenario

		2023	2024	2025	2026	2027	2028	2029	2030
					B.1: RewetLo				
Marginal short-run cost	*Euro/tCO2e*	35.2	35.2	35.2	35.2	35.2	35.2	35.2	35.2
Funding requirement	*Million Euro*	98.0	107.9	117.8	127.8	137.7	147.6	157.5	167.4
					B.2: RewetHi				
Marginal short-run cost	*Euro/tCO2e*	39.6	39.6	42.0	43.9	44.7	49.2	49.2	49.2
Funding requirement	*Million Euro*	528.4	582.8	637.2	691.7	746.1	800.5	854.9	909.4
					B.3: RewetHi+				
Marginal short-run cost	*Euro/tCO2e*	27.0	27.0	27.0	40.1	40.1	61.2	61.2	61.2
Funding requirement	*Million Euro*	728.7	761.4	794.1	846.2	626.8	1112.2	1223.2	1334.2

Funding requirement in year t equals upfront engineering cost for additional area rewetted *in* t plus recurrent annual payments (maintenance / monitoring costs and compensation for foregone agricultural income) for the area rewetted *up to* t.

In the CGE model the reductions in the availability of agricultural land in the peatland restoration scenarios are implemented as exogenous shifts of the German aggregate land supply function. Land supply is specified as an iso-elastic function of the real returns to land to allow for endogenous increases in the utilization of mineral soil land in response to the rice effects triggered by peatland restoration. As the peatland restoration is assumed to take place on land with below-average productivity in terms of baseline value added per ha, the size of the annual land supply functions shifts are specified by transforming the UAA reductions into equivalent changes in units of average-productivity land. The compensation payments for foregone agricultural income enter the model as recurrent additional annual transfer payments from the government to the private household sector. As noted in section 2.3, the upfront and recurrent engineering costs enter in the form of additional exogenous government-financed purchases of construction services and other services. The net increase in government expenditure in the peatland restoration scenarios is by assumption financed through a marginal increase in the household income tax rate. Technically, the time paths of government savings and real government expenditure (other than the government payments related to peatland restoration) are kept frozen at baseline levels, and the income tax adapts endogenously to satisfy the government budget constraint. An alternative government sector closure under which the additional government expenditure is debt-financed has been considered as part of the sensitivity analysis.

3.3. Scenario Set C: Joint Implementation of Scenario A.2 and B.2 Policy Bundles.

Scenario C considers the simultaneous implementation of the tax reform policy bundle with compensatory income transfers (scenario A.2) and the RewetHi peatland restoration incentivation scheme (scenario B.2). This scenario serves to check for potential synergies and trade-offs arising from a joint introduction of the policy reforms considered in each scenario.

4. Results of the Simulation Analysis

4.1. Tax Reform Scenarios – CGE Simulation Results

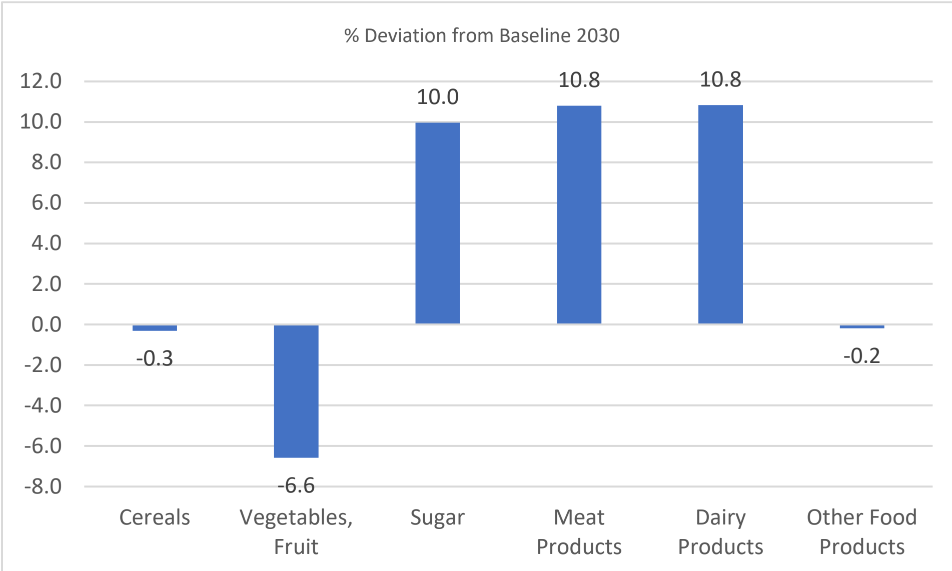
The simultaneous implementation of the tax rate changes under scenario A.1 and A.2 directly raise the consumer prices of meat, dairy and sugar products and reduce the consumer prices of fruits and vegetables in Germany for both domestically produced and imported varieties (Figure 4.1). The resulting impacts on household food consumption quantities by commodity group are displayed in Figure 4.2 for the years 2023 and 2030. The percentage deviations from the baseline become gradually smaller (in absolute terms) for meat products, dairy products and sugar and larger for fruits and vegetables over time, since the pure income effects of the tax-induced price changes become smaller as the expenditure shares for food commodities in total household spending shrink with rising per-capita income along the baseline path.

The size orders of the simulated consumption responses are in line with the empirical evidence from econometric studies of consumer behaviour for Germany and other high-income regions which generally find own-price elasticities of demand for food commodities well below unity (in terms of absolute value) for Germany and other high-income countries (Appendix Table A-2), and a gradual drop in these elasticities with rising per-capita income.

The consumption responses for meat and dairy products are comparable to the results of previous studies that consider the same VAT rate rise for animal-sourced food to the full rate of 19 percent in Germany: The partial-analytic back-of-the envelope calculations presented in WBAE / WBW (2016: Table 4.1) suggest consumption reductions for meat products by 4.1 percent and for dairy products by 2.1 percent, based on own-price elasticities reported by Effertz and Adams (2015).[12] Banse and Sturm (2019) simulate the same policy scenario with a global CGE model calibrated to the GTAP9 database and report consumption responses on the order of -6 percent for both meat and dairy products.

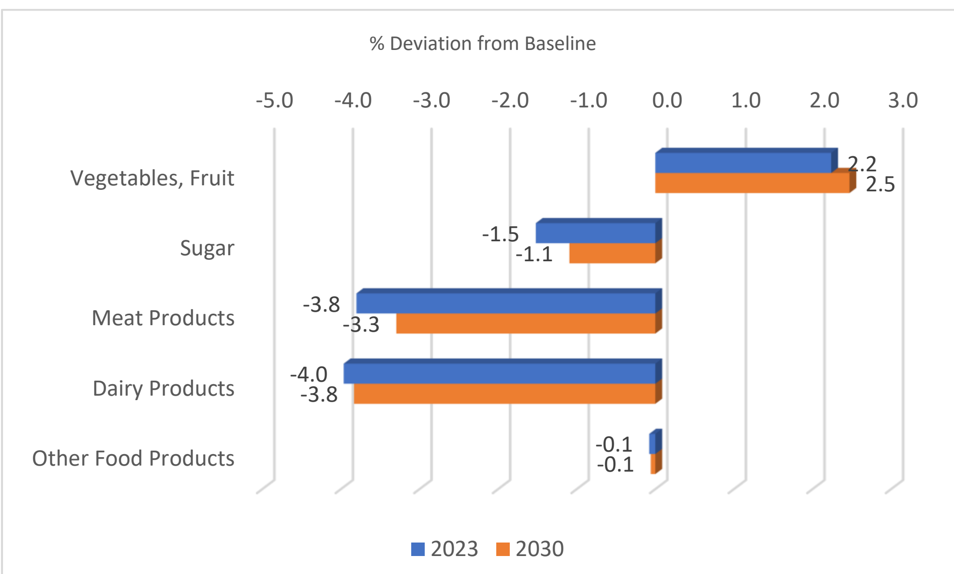
[12] See Appendix Table A-2 below. WBAE / WBW (2016: Table 4.1) also considers an extreme high-elasticity scenario with own-price elasticities for meat and dairy products around -1 based on estimates by Thiele (2008) using data for 2003. Unsurprisingly, in this case the back-of the-envelope calculation yields consumption responses on the order of – 11 percent.

Figure 4.1: Impact on Consumer Prices 2030 in Germany – Tax Reform Scenario A.2



Note: Prices are measured relative to the consumer price index. The figure shows changes in composite price indices over domestic and imported commodities.

Figure 4.2: Impact on Household Food Consumption Quantities 2030 in Germany – Tax Reform Scenario A.2

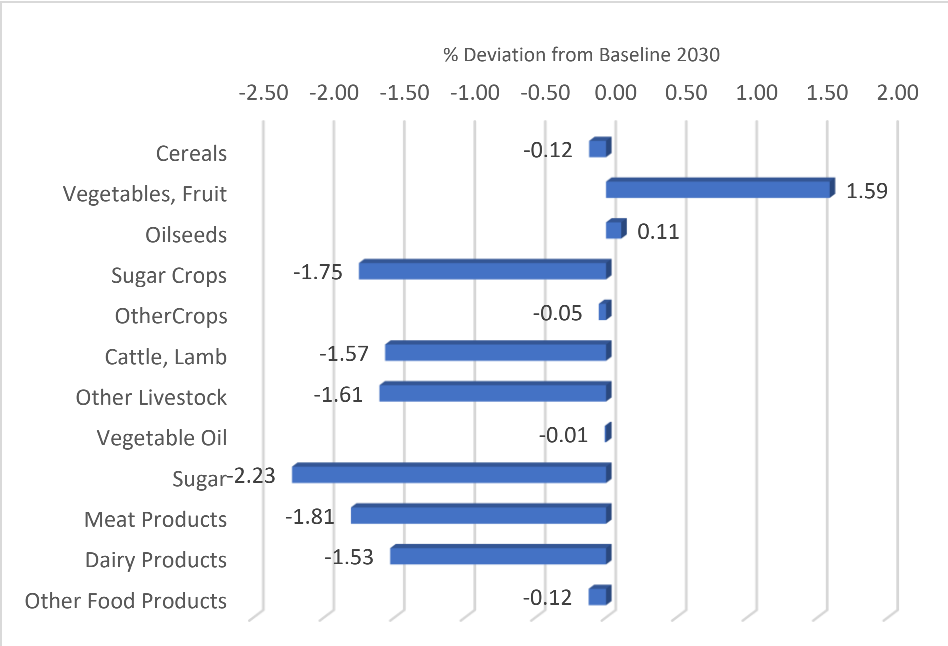


The resulting effects on agricultural output and production of processed food in Germany at the end of the simulation horizon are displayed in Figure 4.3, while Figure 4.4 shows the effects on German food imports by commodity group. The domestic meat processing sector shrinks by 1.8 percent and agricultural livestock production by 1.6 percent relative to the baseline. The associated reductions in feedstock demand entail a noticeable backward linkage effect on the domestic production and imports of Cereals, Other Crops, and Other Food Products. The output of Germany's sugar processing sector drops by 2.3 percent and as a result domestic sugar crop production drops by 1.8 percent, whereas domestic production of fruits and vegetables rises by 1.6 percent relative to the baseline projection. The percentage changes in import quantities (Figure 4.4) are generally of the same order of magnitude as the domestic production effects.[13]

The changes in agricultural production entail a moderate net reduction in agricultural land use in Germany by 67 to 88 kha (Table 4.1), as the area reductions for livestock including feed crop production and sugar crop production together dominate the rise in land area devoted to fruit and vegetable production. However, a full assessment of the land use implications of the tax reform needs to take account of induced land use change in other countries due to the international trade effects of the reform. As Germany's food imports are predominantly of EU origin, the effects on regions outside the Single European Market area suggested by the simulation analysis turn out to be negligibly small – hence Table 4.1 focuses on EU impacts.

[13] The exception is the effect on imports of refined sugar: Unlike VAT, the excise tax on intermediate input use of sugar is not rebated and thus raises production costs – and hence the supply price – in sugar-using industries including the sugar refining sector itself. As the use of sugar in the sugar refining sector is high (the cost share of intermediate processed sugar in Germany's sugar processing industry is around 10 percent according to the GTAP10 database), the user price of sugar of domestic origin rises *relative to* the user price of imported sugar (as foreign sugar producers do not face a new tax on their input use) and thus induces a substitution effect in favour of imported sugar. This substitution effect is sufficiently strong to raise sugar imports despite the fact that the new excise tax is imposed on both domestically produced and imported sugar.

Figure 4.3: Impact on Domestic Food Production Quantities 2030 in Germany – Tax Reform Scenario A.2



The results indicate that the land-saving effects arising due to lower imports of animal-sourced foods and feedstocks by Germany from the RoEU are slightly dominated by the increase in land use associated with the rise in imports of fruits and vegetables. The rise of German sugar imports (Figure 4.4) plays no significant role for the explanation of the net UAA expansion in the RoEU, because the baseline share of agricultural land area used for sugar crop production in the RoEU is tiny in comparison to land use for livestock agriculture and for fruit / vegetable production, and the baseline volume of sugar exports from the RoEU to Germany is also very small in relation to fruit and vegetable exports from the RoEU to Germany.

Figure 4.4: Impact on Food Import Volumes 2030 of Germany – Tax Reform Scenario

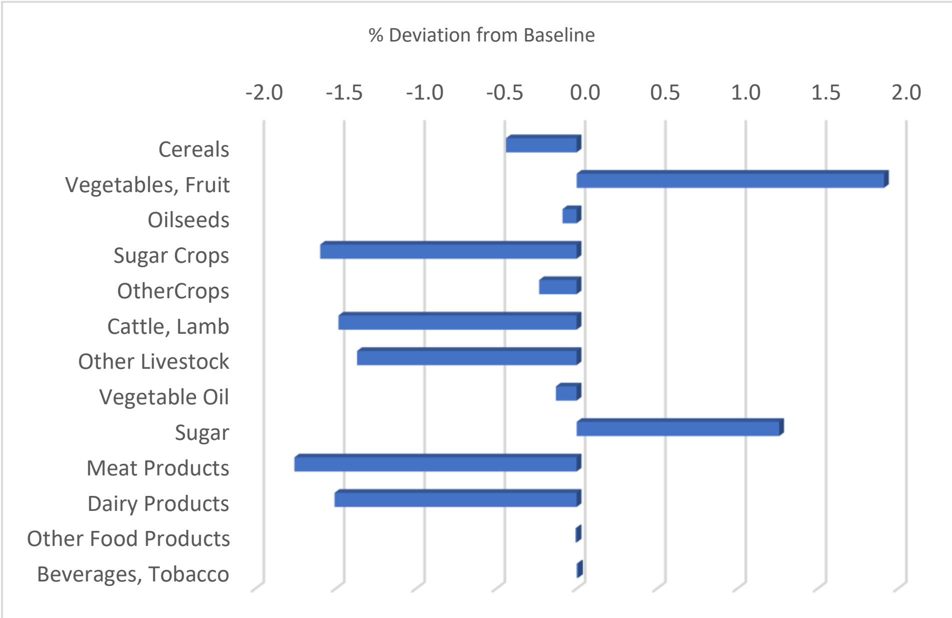


Table 4.1: Change in Utilised Agricultural Area – Tax Reform Scenario

(Deviations from Baseline)

	Germany	RoEU	Germany	RoEU	EU27
Year	*kha*		*% Deviation from Baseline*		*kha*
2023	-88.3	6.1	-0.56	0.004	-82.2
2024	-85.4	8.1	-0.55	0.006	-77.3
2025	-82.2	10.0	-0.53	0.007	-72.3
2026	-78.9	11.7	-0.51	0.008	-67.2
2027	-75.8	13.6	-0.49	0.010	-62.2
2028	-72.7	15.3	-0.47	0.011	-57.5
2029	-69.6	17.0	-0.45	0.012	-52.7
2030	-66.5	18.7	-0.43	0.013	-47.9

The fiscal impacts of the tax reform in the absence of compensatory transfers to the private household sector is displayed in Table 4.2. The annual additional VAT revenue from final consumption of meat and dairy products amounts to 3.6 – 3.8 billion Euro[14] and the sugar excise tax raises about 0.3 billion Euro per annum, while the annual loss of VAT revenue

[14] This figure is close to the corresponding estimates in WBAE / WBW (2016: Table 4.1)

from fruit and vegetable consumption amounts to 0.9 – 1.0 billion Euro. However, the general equilibrium repercussions of the tax reform across the economy also affect the VAT and excise tax revenue from other products and services as well as the revenue from taxes minus subsidies on production and income. Moreover, the endogenous price changes throughout the price system affect the expenditure required to maintain the path of real government consumption of goods and services by commodity group at baseline levels. The sum of these other tax revenue effects and the government spending adjustment is shown in column (6) of Table 4.1 and must be added to the sum of VAT / excise tax revenue changes for meat, dairy, sugar, fruits and vegetables in column (5) to arrive at the net fiscal space opened up by the tax reform. This net fiscal space amounts to 2.0 – 2.4 billion Euro per year and represents the sum available for the government-budget-neutral compensation of lower-income households for the welfare losses associated with the tax reform.

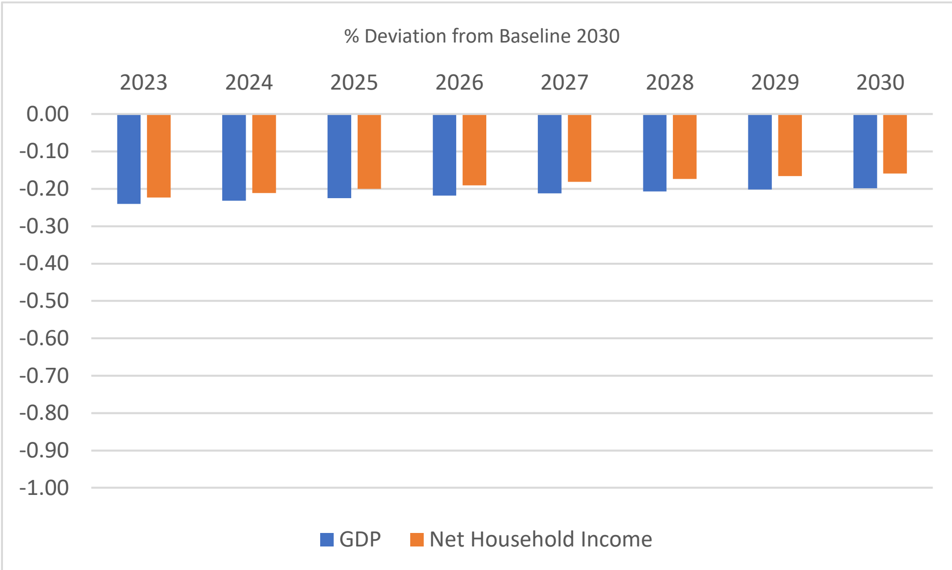
Table 4.2: Impact on Tax Revenue and Net Fiscal Space – Tax Reform Scenario A.1

(Billion Euros at 2018 Prices)

	Additional VAT / Excise Tax Revenue from						
Year	Vegetables, Fruit	Meat Products	Dairy Products	Sugar	Sum (1)+(2)+(3)+(4)	Other Tax Revenue[1]	Fiscal Space
	(1)	(2)	(3)	(4)	(5)	(6)	(5)+(6)
2023	-0.930	2.742	1.059	0.308	**3.178**	-1.152	**2.026**
2024	-0.936	2.720	1.057	0.309	**3.150**	-1.053	**2.097**
2025	-0.943	2.697	1.055	0.311	**3.120**	-0.961	**2.159**
2026	-0.949	2.673	1.052	0.312	**3.087**	-0.875	**2.212**
2027	-0.955	2.644	1.048	0.313	**3.050**	-0.788	**2.262**
2028	-0.961	2.614	1.044	0.314	**3.010**	-0.707	**2.304**
2029	-0.967	2.583	1.039	0.315	**2.970**	-0.631	**2.339**
2030	-0.974	2.551	1.034	0.316	**2.927**	-0.560	**2.367**

[1] Adjusted for change in government expenditure required to keep level and composition of real government consumption at baseline level.

Figure 4.5: Impact on Real GDP and Net Household Income – Tax Reform Scenario A.2



Note: Numeraire is the 2014 household consumption basket.

4.2. Tax Reform Scenario A.1 – Microsimulation Results

Turning to the analysis of distributional impacts on households by net income bracket in the absence of recycling of the additional net tax revenue to the domestic household sector on basis of the microsimulation approach outlined in section 2.2 above, Figure 4.6 displays the annual equivalent variation (EV) for the year 2030. As noted earlier, the EV is a money-metric measure of the change in consumer welfare triggered by the policy reform in question – here tax reform scenario A.1. The EV is here the hypothetical amount of money that would have to be taken away from a household's net income in the baseline scenario to generate the same welfare loss as suffered in the tax reform scenario. Thus, e.g. for an average household in the lowest income bracket (H1), the welfare loss experienced under scenario A.1 in 2030 is equivalent to a loss of annual net income of Euro 31.70 in the baseline scenario situation in 2030.[15] Expressed in relation to H1 baseline income in 2030, that is a decline by 0.31 percent (Figure 4.7).

In absolute terms, the welfare loss rises with rising income, primarily because higher-income households spend higher absolute amounts on the food items subject to higher taxation (Table 2.2, top panel). However, better-off households also have a larger household size – according to the EVS data for 2018 households in the bottom bracket are single-person households while households in the top income bracket have on average 2.9 household members (Table 2.1). Thus, when expenditure is compared on a per capita basis – see middle panel of Table 2 - the differences in spending on the food items subject to higher taxation become far less pronounced. Correspondingly, the differences in EV per household member across household groups also displayed in Figure 6 are likewise far less pronounced than the differences in EV per household. However, decisive for the degree of regressivity of the tax reform scenario in the absence of compensation measures are the differences in the relevant expenditure shares across households as displayed in the bottom panel of Table 2.1 for 2018. Total food expenditure shares and the food expenditure shares for the items subject to rising prices are significantly higher for low-income than for high-income income households. Fruit and vegetable shares in total spending are also higher for the bottom brackets and so the tax cut on fruits and vegetables has per se a mildly progressive effect.

As income elasticities of demand are well below unity for all food commodity groups, the food expenditure shares drop slightly over time in the baseline scenario projection to 2030 for all household groups, but this drop is more pronounced for households at the upper end of the income distribution. Thus, these differences in expenditure shares across household groups increase towards 2030.

As shown in Figure 4.7, expressed in percentage terms, the welfare loss is unsurprisingly noticeably higher for lower-income households – so the distributional impact in the absence of compensation measures is clearly regressive.

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[15] Note that like in the CGE model there is no monetary price inflation in the microsimulation model – so Euro figures need to be interpreted as 2018 Euros, i.e. in the model 1 Euro in 2030 buys as many units of the average initial consumption basket as in 2018.

The Hicksian compensating variation defined in section 2.2 above, which measures the compensation payment a household would have to receive after the implementation of the policy reform to restore welfare to the baseline is numerically very close to the sign-inverted value of the EV, e.g. the CV in 2030 is just half a cent (Euro 0.005) lower than -EV for H1 and 26 cents lower for H8. Thus, we can – without apology (to paraphrase Willig, 1976) – use the EV figures from Figure 4.6 directly to calculate the total compensation payments required by each household group and set the resulting cumulated sums in relation to the net fiscal space measure of from Table 4.2 for 2030, which shows the amount available for a budget-neutral compensation scheme. The results of this calculation are shown in Table 4.3. The Table indicates that all households up to the H7 income bracket could in principle be compensated in a budget-neutral manner, provided that the administrative burden of implementing the compensation scheme does not exceed the remaining 14.2 percent of the total fiscal space generated by the net tax revenue of the reform. Of course, less burdensome schemes are conceivable, such as a uniform payment to all households at an annual rate of Euro 58.63 (total fiscal space / total no of households). This would overcompensate households in H1 to H3 as well as households in H4 with incomes below the group mean, and thus generate a positive inclusivity effect.

Figure 4.6: Equivalent Variation by Household Type 2030 – Tax Reform Scenario A.1

(Euro / Year)

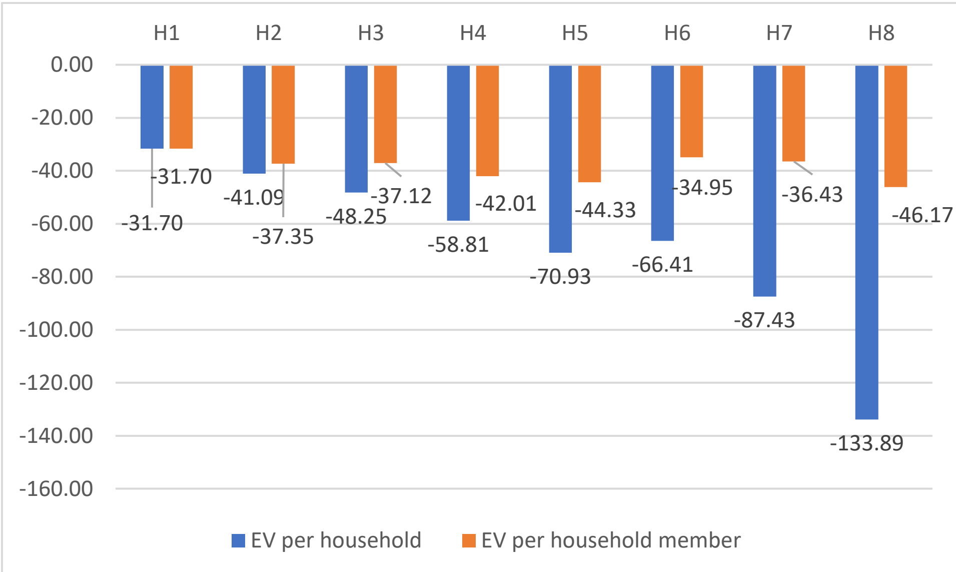


Figure 4.7: Equivalent Variation by Household Type 2030 in Percent of Baseline Net Income– Tax Reform Scenario A.1

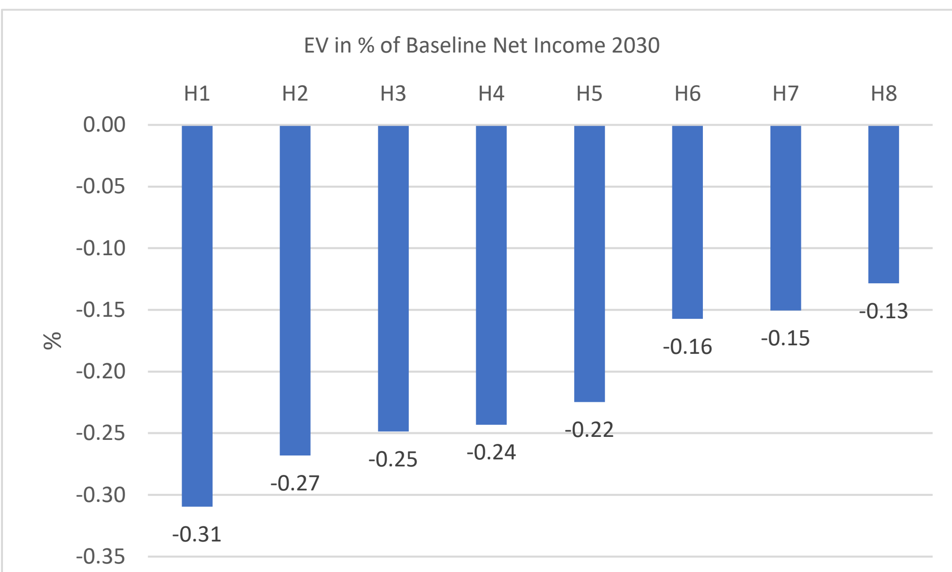


Table 4.3: Compensation Requirements and Relation to Net Fiscal Space 2030

Household Group	Average EV per Household	Number of Households	Total Compensation Requirement	Cumulated Total Compensation Requirement	Cumulated Share of Fiscal Space
	Euro/ / Year	*million*	*Billion Euro*	*Billion Euro*	*%*
H1	-31.70	1,990	0.063	0.063	2.7
H2	-41.09	3,386	0.139	0.202	8.5
H3	-48.25	1,802	0.087	0.289	12.2
H4	-58.81	4,766	0.280	0.569	24.1
H5	-70.93	5,432	0.385	0.955	40.3
H6	-66.41	7,194	0.478	1.432	60.5
H7	-87.43	6,841	0.598	2.031	85.8
H8	-133.89	8,954	1.199	3.229	136.4

EV per household from Figure 4.6. Extrapolated No. of household from Table 2.1 adjusted for drop in total projected population between 2018 and 2030. Total compensation requirement is -EV times number of households. Cumulated total compensation requirement shows total compensation payments up to Hx when full compensation is paid to Hx and lower income groups. Fiscal space is Euro 2.367 from Table 4.2. E.g., full compensation up to H5 requires 955 million Euros (not counting the additional administrative costs of the compensation scheme) and exhausts 40.3% of the total available fiscal space generated by the tax reform.

4.3. GHG Emission Impacts – Tax Reform Scenario A.2

Table 4.5 serves to indicate the broad order of magnitude of the impact of the tax reform package on Germany's agricultural GHG emissions suggested by the simulation analysis. The assessment covers the three main components of agricultural emissions in Germany, which together account for 92.5 percent of Germany's total agricultural GHG emissions in 2020 (56.1 million tCO_2e)[16]. These are CH_4 emissions from enteric fermentation (42.5 percent), CH_4 and N_2O emissions associated with manure management (16.7 percent) and N_2O emissions from agricultural soils (33.2 percent).

For the calculation of the emission impacts, the annual agricultural land use baseline projection for 2021 to 2030 from the CGE model are applied to the agricultural soils emission data for 2020 from Vos et al (2022b) to obtain the dynamic baseline projection for this category at an annual timestep , and then the deviations in agricultural land use from the baseline under the tax reform scenario from Table 4.1 are used to obtain the annual emission

[16] Vos et al (2022a: Table 2.1). This source and Vos et al (2022b) provide the agricultural GHG emission data for Germany's latest National GHG Report (UBA, 2022).

for agricultural soils reported in Table 4.5. Similarly, for the determination of changes in emissions from enteric fermentation, the 2020 emissions data for cattle, sheep, goats and horses from Vos et al (2022) are linked to the real output changes for the *Bovine Cattle, Sheep, Goats, Horses* sector of the CGE model, and the emission data for pigs from the same source to are linked to the real output changes for the *Other Livestock Agriculture* sector of the CGE sector. The same approach is used for CH_4 and N_2O emissions associated with manure management, but in this case the emissions for *Other Livestock Agriculture* include poultry in addition to pig manure management emissions.

Table 4.5: GHG Emission Impacts – Tax Reform Scenario A.2

(Deviations of annual emissions from Baseline in million tCO_2e)

Emissions from	2023	2024	2025	2026	2027	2028	2029	2030	2023-2030
Agricultural Soils	-0.102	-0.098	-0.095	-0.091	-0.087	-0.084	-0.080	-0.077	**-0.713**
Enteric Fermentation	-0.446	-0.437	-0.427	-0.415	-0.403	-0.390	-0.375	-0.361	**-3.253**
Manure Management	-0.180	-0.177	-0.173	-0.169	-0.165	-0.160	-0.155	-0.150	**-1.328**
Total	**-0.727**	**-0.712**	**-0.695**	**-0.675**	**-0.655**	**-0.633**	**-0.611**	**-0.587**	**-5.294**

Global Warming Potential (GWP) coefficients of 25 for CH_4 and 298 for N_2O are used for the conversion into CO_2 equivalents.

The estimated annual emission reductions are around 0.590 to 0.730 million tCO2e, that is a reduction by 1.2 to 1.4 percent of covered baseline agricultural emissions. The cumulated emission reduction effect over the period 2023 to 2030 shown in the last column of Table 4.5 amounts to 5.3 million tCO2e.

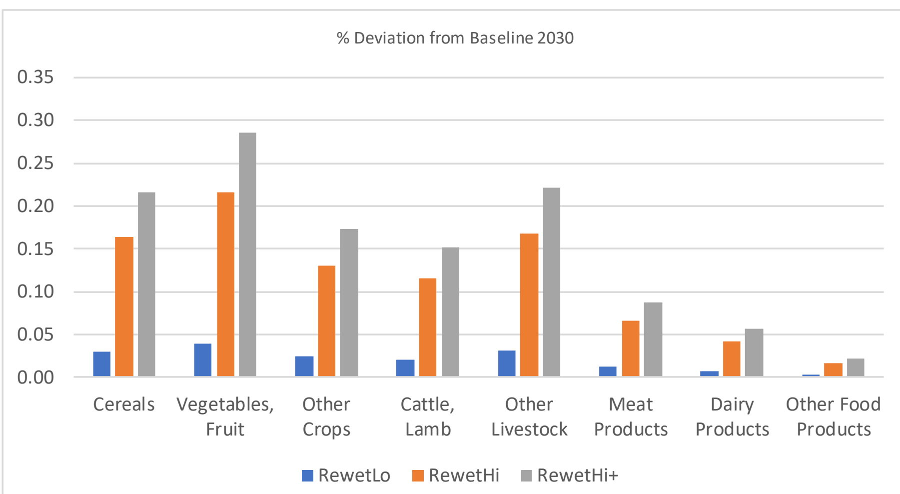
4.4. Peatland Restoration Scenarios – CGE Simulation Results

4.4.1. Economic Impacts

In the RewetLo scenario, which reflects the moderate ambitions of Germany’s National Peatland Protection Strategy, the rewetted peatland area withdrawn from agricultural production by 2030 amounts to 0.31 percent of the 2030 baseline UAA in productivity-adjusted terms. In the more ambitious RewetHi and RewetHi+ scenarios, the corresponding productivity-adjusted shares are respectively 1,69 and 2.21 percent.

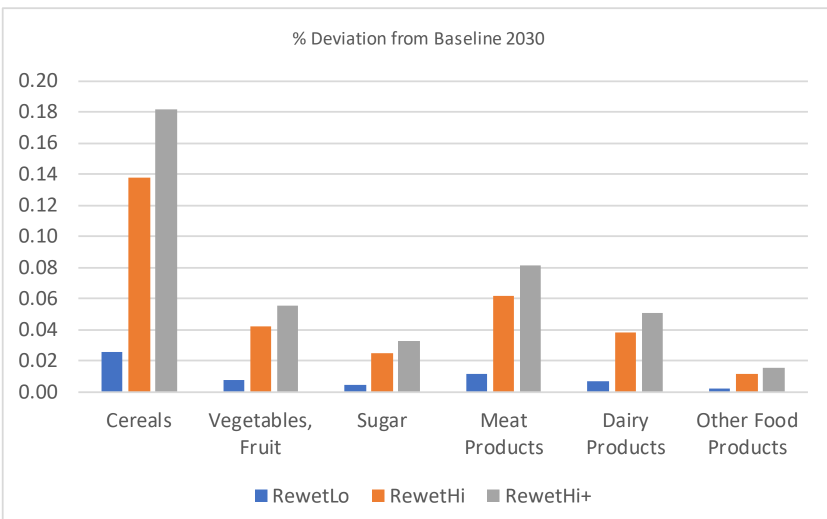
The effective agricultural land supply reduction entails upward pressure on agricultural land rents in Germany and this pushes domestic agricultural production costs and hence producer prices up to some extent (Figure 4.8). However, since the rewetted areas are small in relation to Germany's total UAA (16.6 million ha in 2020), the size order of this cost-push effect is small under the RewetHi scenarios and negligibly small under the RewetLo scenario. The resulting increases in consumer prices for food in Germany at the 2030 endpoint of the transformation pathway remain well below 0.05 percent under RewetLo and well below 0.2 percent under RewetHi+ (Figure 4.9). Correspondingly, the impact on domestic food consumption quantities is virtually nil in RewetLo and remains below 0.1 percent in RewetHi+ across all food commodity groups (Table A-5).

Figure 4.8: Impact on Producer Prices 2030 in Germany – Peatland Restoration Scenarios



The increase in prices for food commodities of German origin relative to the rest of the world induce a rise in German imports and a drop in German exports of agricultural commodities and processed food products (Table 4.6). In percentage terms, the export reduction in the RewetHi+ scenario is most pronounced for fruit and vegetables (Table A-6) – which is the sector with the highest share of land rents in total cost and the strongest increase in producer prices (Figure 4.8). However, in absolute volume terms the strongest decline in exports is registered by the meat processing sector (Table A-7), as the baseline export volume of German processed meat products is far higher than the baseline export volume of German fruit and vegetable exports. From a macroeconomic perspective, the trade volume effects reported in Table 4.6 are tiny in relation to Germany's total trade volumes: The total reduction in agricultural and processed food exports for 2030 in the RewetHi+ scenario amounts to 0.012 percent of Germany's projected total 2030 baseline exports of goods and services. On the import side, the sum of the volume reductions amounts to around 0.009 percent of Germany's projected total 2030 baseline imports of goods and services.

Figure 4.9: Impact on Consumer Prices 2030 in Germany – Peatland Restoration Scenarios



Note: Prices are measured relative to the consumer price index. The figure shows changes in composite price indices over domestic and imported commodities.

The resulting impacts on Germany's agricultural and processed food output by commodity group at the endpoint of the simulation horizon are shown in Figure 4.10. Vegetable and fruit production registers the strongest decline relative to the baseline. This is the commodity group with the highest producer price increase (Figure 4.8) and a commodity group with a relatively high baseline export-output ratio. For all other commodity groups, the output reductions remain well below 0.6 percent of 2030 baseline production in the RewetHi scenarios and below 0.1 percent in the RewetLo scenario.

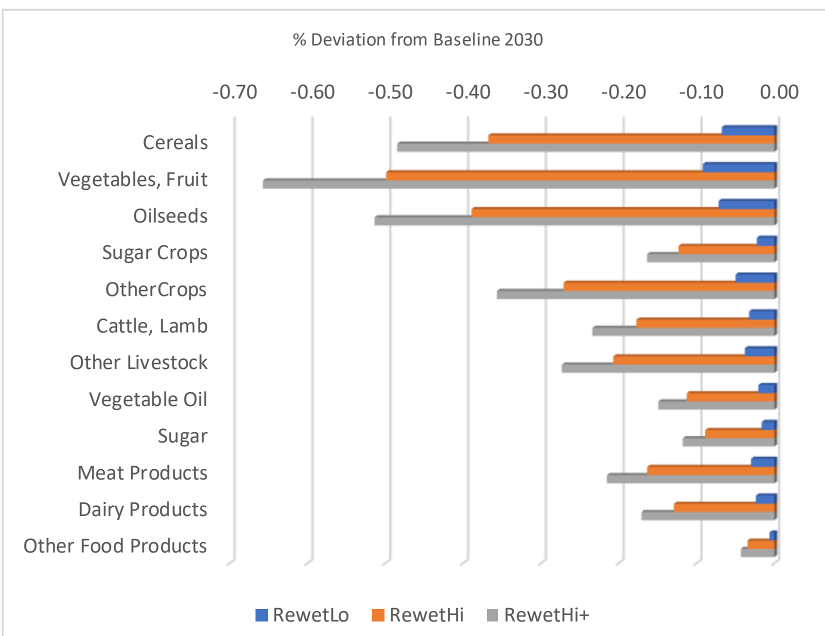
Table 4.6: Impact on German Export and Import Volumes in 2030 – Peatland Restoration Scenarios

(Deviation from Baseline 2030)

	Imports to Germany			Exports from Germany		
	RewetLo	RewetHi	RewetHi+	RewetLo	RewetHi	RewetHi+
			Million Euro			
Agricultural Products	7.4	40.0	75.9	-11.7	-63.8	-84.2
Processed Food	5.0	26.9	54.4	-13.9	-75.3	-100.0
Total Agri-Food	**12.3**	**67.0**	**130.3**	**-25.6**	**-139.1**	**-184.2**
			%			
Agricultural Products	0.02	0.12	0.22	-0.10	-0.53	-0.69
Processed Food	0.01	0.04	0.08	-0.02	-0.11	-0.15
Total Agri-Food	0.01	0.07	0.13	-0.03	-0.17	-0.23

Note: Export and import volumes are quantities valued at 2030 baseline prices. Disaggregated trade effects by commodity group are shown in Tables A-6 and A-7.

Figure 4.10: Impact on Domestic Production in 2030 in Germany – Peatland Restoration Scenarios



Note: Export and import volumes are quantities valued at 2030 baseline prices. Disaggregated trade effects by commodity group are shown in Tables SI-4 and SI-5.

The impacts on real GDP and net real household income are negligibly small in all scenarios: Under RewetHi+, 2030 real GDP is -0.004 percent lower than in the baseline and under RewetLo the GDP effect for 2030 is -0.001 percent. Results for net household income are of the same order of magnitude. The temporary household income tax increases required to finance the additional government expenditure are 0.036 (2023) to 0.064 (2030) percentage-points under RewetHi+, 0.027 to 0.045 percentage-points under RewetHi, and 0.005 to 0.008 percentage-points under RewetLo.

4.4.2. Leakage Effects

Table 4.7 reports the effects on agricultural land use suggested by the simulation analysis. The net land use reductions in Germany are lower than the assumed agricultural peatland area reductions (Table 4.2), because the model allows for an endogenous land supply response to the rise in agricultural land rents triggered by the peatland restoration.

Both the increases in German agri-food imports and the decreases in German agri-food exports entail a rise in agricultural land use in the rest of the world. This indirect land use effect occurs again predominantly in the rest of the EU[17]. Thus, in comparison to the 2030 baseline level Germany's UAA drops by 522 kha in the RewetHi+ scenario – which is the net effect of the reduction in peatland use by 709 kha and a rise in mineral-soil land use by 187 kha in response to the agricultural produce price increase - while the UAA in the RoEU rises by around 24 kha, so that the EU27 (i.e. RoEU + Germany) UAA drops on balance by around 497 kha.

[17] In the RewetHi+ scenario, agricultural land use in 2030 rises by 0.0011 percent in Africa, by 0.0010 percent in RoLMI and by 0.0029 percent in RoHI relative to the baseline.

Table 4.7: Change in Utilised Agricultural Area – Peatland Restoration Scenarios

	Germany			RoEU	Germany	RoEU	EU27
	Organic Soil	Mineral Soil	Total	Total	Total	Total	Total
	kha	*kha*	*kha*	*kha*	*% Deviation from Baseline*		*kha*
			RewetLo				
2023	-9.4	2.4	-7.0	0.5	*0.0*	*0.00*	-6.5
2024	-18.7	4.8	-13.9	0.9	*-0.1*	*0.00*	-12.9
2025	-28.1	7.3	-20.8	1.3	*-0.1*	*0.00*	-19.4
2026	-37.4	9.7	-27.7	1.8	*-0.2*	*0.00*	-25.9
2027	-46.8	12.2	-34.6	2.2	*-0.2*	*0.00*	-32.5
2028	-56.1	14.6	-41.6	2.6	*-0.3*	*0.00*	-39.0
2029	-65.5	17.0	-48.5	3.0	*-0.3*	*0.00*	-45.6
2030	-74.8	19.4	-55.5	3.4	*-0.4*	*0.00*	-52.1
			RewetHi				
2023	-59.2	17.8	-41.5	2.7	*-0.3*	*0.00*	-38.8
2024	-118.5	35.8	-82.7	5.0	*-0.5*	*0.00*	-77.7
2025	-177.7	53.8	-123.9	7.3	*-0.8*	*0.01*	-116.6
2026	-237.0	71.9	-165.1	9.5	*-1.1*	*0.01*	-155.5
2027	-296.2	89.8	-206.5	11.8	*-1.3*	*0.01*	-194.7
2028	-355.5	107.6	-247.9	13.9	*-1.6*	*0.01*	-234.0
2029	-414.7	125.3	-289.5	16.1	*-1.9*	*0.01*	-273.4
2030	-474.0	142.8	-331.1	18.3	*-2.1*	*0.01*	-312.9
			RewetHi+				
2023	-87.0	10.4	-76.6	1.9	*-0.5*	*0.00*	-74.7
2024	-174.0	21.1	-152.9	3.2	*-1.0*	*0.00*	-149.7
2025	-261.0	31.9	-229.1	4.5	*-1.5*	*0.00*	-224.6
2026	-348.0	50.5	-297.5	6.9	*-1.9*	*0.00*	-290.6
2027	-403.2	62.1	-341.1	8.2	*-2.2*	*0.01*	-332.9
2028	-505.2	104.2	-401.0	14.0	*-2.6*	*0.01*	-387.0
2029	-607.2	145.9	-461.3	19.2	*-3.0*	*0.01*	-442.1
2030	-709.2	187.3	-521.9	24.4	*-3.4*	*0.02*	-497.4

4.4.3. GHG Emission Impacts – Peatland Restoration Scenarios

To assess the total net impact on Germany's GHG emissions from agriculture and agricultural land use suggested by the simulation, Table 4.8 sets the emission reductions from organic soils directly attributable to the rewetting of drained cropland and grassland from Table 3.3 in relation to the indirect emission changes due to the induced shifts towards agricultural production on mineral soils reported in Table 4.7 and the reductions in German cattle and other livestock production (Figure 4.10) triggered by the rewetting scheme. The assessment of these indirect effects covers the three main components of agricultural emissions in Germany, which together account for 92.5 percent of Germany's total agricultural GHG emissions in 2020 (56.1 million tCO_2e)[18]. These are CH_4 emissions from enteric fermentation (42.5 percent), CH_4 and N_2O emissions associated with manure management (16.7 percent) and N_2O emissions from agricultural soils (33.2 percent).

For the calculation of the indirect emission impacts, the annual agricultural land use baseline projection for 2021 to 2030 from the CGE model is applied to the agricultural soils emission data for 2020 from Vos et al (2022b) to obtain the dynamic baseline projection for this category at an annual timestep , and then the deviations in agricultural land use from the baseline under the peatland rewetting scenarios from Table 4.7 are used to obtain the annual emissions for agricultural soils reported in Table 4.8. Similarly, for the determination of changes in emissions from enteric fermentation, the 2020 emissions data for cattle, sheep, goats and horses from Vos et al (2022a) are linked to the real output changes for the *Bovine Cattle, Sheep, Goats, Horses* sector of the CGE model, and the emission data for pigs from the same source to are linked to the real output changes for the *Other Livestock Agriculture* sector of the CGE sector. The same approach is used for CH_4 and N_2O emissions associated with manure management, but in this case the emissions for *Other Livestock Agriculture* include poultry in addition to pig manure management emissions.

The results indicate that the reduction in emissions from organic soils strongly dominate the increase in emissions from mineral soils. As shown in Table 4.9, the carbon leakage effects associated with the induced increases in the UAA and in livestock production within the RoEU are likewise small in relation to the direct emission reduction effect.

Table 4.8: Impact on Germany's GHG Emissions – Peatland Restoration Scenarios

[18] Vos et al (2022a: Table 2.1). This source and Vos et al (2022b) provide the agricultural GHG emission data for Germany's latest National GHG Report (UBA, 2022).

(Deviations of annual emissions from Baseline in million tCO_2e)

Emissions from	2023	2024	2025	2026	2027	2028	2029	2030	2023-2030
					RewetHi+				
Organic Soils	-2.600	-5.200	-7.800	-10.041	-11.454	-14.075	-16.695	-19.316	**-87.181**
N_2O Mineral Soils	0.011	0.023	0.034	0.054	0.067	0.112	0.157	0.201	**0.658**
Enteric Fermentation	-0.004	-0.007	-0.010	-0.016	-0.019	-0.031	-0.043	-0.056	**-0.186**
Manure Management	-0.002	-0.003	-0.004	-0.007	-0.008	-0.013	-0.018	-0.023	**-0.078**
Total	**-2.594**	**-5.187**	**-7.780**	**-10.008**	**-11.414**	**-14.007**	**-16.600**	**-19.194**	**-86.785**
					RewetHi				
Organic Soils	-2.096	-4.192	-6.168	-8.059	-9.914	-11.599	-13.284	-14.969	**-70.282**
N_2O Mineral Soils	0.019	0.038	0.058	0.077	0.096	0.115	0.134	0.153	**0.692**
Enteric Fermentation	-0.005	-0.011	-0.016	-0.021	-0.026	-0.032	-0.037	-0.042	**-0.191**
Manure Management	-0.002	-0.004	-0.007	-0.009	-0.011	-0.013	-0.015	-0.018	**-0.079**
Total	**-2.085**	**-4.169**	**-6.133**	**-8.011**	**-9.855**	**-11.529**	**-13.202**	**-14.876**	**-69.860**
					RewetLo				
Organic soils	-0.438	-0.875	-1.313	-1.750	-2.188	-2.625	-3.063	-3.500	**-15.750**
N_2O Mineral Soils	0.003	0.005	0.008	0.010	0.013	0.016	0.018	0.021	**0.094**
Enteric Fermentation	-0.001	-0.002	-0.003	-0.004	-0.005	-0.006	-0.007	-0.008	**-0.034**
Manure Management	0.000	-0.001	-0.001	-0.002	-0.002	-0.002	-0.003	-0.003	**-0.015**
Total	**-0.436**	**-0.873**	**-1.309**	**-1.745**	**-2.181**	**-2.617**	**-3.054**	**-3.490**	**-15.705**

Global Warming Potential (GWP) coefficients of 25 for CH_4 and 298 for N_2O are used for the conversion into CO_2 equivalents.

Table 4.9: Impact on Rest of European Union GHG Emissions – Peatland Restoration Scenarios

(Deviations of annual emissions from Baseline in million tCO_2e)

	2023	2024	2025	2026	2027	2028	2029	2030	2023-2030
RewetLo	0.001	0.003	0.004	0.005	0.006	0.007	0.009	0.010	**0.045**
RewetHi	0.008	0.014	0.021	0.028	0.034	0.041	0.047	0.054	**0.246**
RewetHi+	0.006	0.009	0.013	0.020	0.024	0.041	0.056	0.072	**0.242**

4.4.4. General Equilibrium Assessment of Social Costs and Benefits

Table 4.10 provides a summary assessment of the social costs and benefits of agricultural peatland rewetting under the three scenarios. The assessment covers the period 2023 to 2049 to take account of the ongoing annual maintenance and monitoring costs and foregone land returns for 20 years after the initial land conversion. For the period 2023 to 2030, the annual social costs for Germany are determined by the Hicksian equivalent variation (EV), which provides a model consistent money-metric measure of the consumer welfare change due to the general equilibrium price and household income changes triggered by the policy reform. The EV measures the hypothetical amount by which the household sector's consumption budget would have to be reduced *in the absence of* the policy reform to generate a welfare effect that is equivalent to that of the policy reform.

Table 4.10: Long-Run Social Costs and Benefits – Peatland Restoration Scenarios

	RewetLo	RewetHi	RewetHi+
Present Value of Social Cost 2023-2049			
Discount Rate = 0 *(Million Euro)*	1,052	5,666	8,160
Discount Rate = 0.03 *(Million Euro)*	911	4,906	7,130
Present Value of Social Benefit 2023-2049			
Discount Rate = 0 *(Million Euro)*	15,769	66,997	86,694
Discount Rate = 0.03 *(Million Euro)*	10,506	44,906	57,805
Social Benefit-Cost Ratio			
Discount Rate = 0	15.0	11.8	10.4
Discount Rate = 0.03	11.5	9.2	8.5
Social Rate of Return	1.018	0.878	0.762
Cumulated Net GHG Reduction 2023-2049 (*Million tCO2e***)**	-69.5	-295.9	-382.3
Average Social Abatement Cost			
Discount Rate = 0 *(Euro/tCO2e)*	15.13	19.15	21.73
Discount Rate = 0.03 *(Euro/tCO2e)*	13.11	16.58	17.84
Marginal Social Abatement Cost *(Euro/tCO2e)*	15	17 to 23	20 to 27

The undiscounted cumulated consumer welfare losses as measured by the model-based EV over the period 2023 to 2030 amount to 0.75 billion Euro under RewetLo, 4.0 billion Euro under RewetHi and 5.9 billion Euro under RewetHi+. These figures are close to a simpler alternative social cost estimate obtained by just adding up rewetting costs and foregone land returns over the same period. Together with ongoing annual maintenance and monitoring costs and foregone land returns between 2031 and 2049[19], the total undiscounted social cost up to 2049 ranges from 1 billion Euro (RewetLo) to 8.3 billion Euro (RewetHi) (Table 4.10).

The present values of the social benefits in the Table are calculated by evaluating the annual net GHG emission reductions (net of leakage effects) using the carbon prices recommended by the German Environmental Agency for use in cost-benefit analysis, which rise from 201 Euro/tCO_2e for 2023 to 250 Euro/tCO_2e for 2050 (Matthey and Bünger, 2023). The social internal rate of return – that is the discount rate at which the present value of the social costs is equated to the present value of the social benefits – is 102 percent for the RewetLo scenario, 88 percent for the RewetHi scenario and 76 percent for the RewetHi+ scenario.

4.4.5. Sensitivity of Results – Peatland Restoration Scenarios

4.5. Joint Implementation of Tax Reform and Peatland Restoration – Scenario C

Scenario C considers the simultaneous implementation of the tax reform policy bundle with compensatory income transfers (scenario A.2) and the RewetHi peatland restoration incentivation scheme (scenario B.2). Results for economic key variables are shown in Table 4.11. As can be seen, the results for this scenario are largely the simple algebraic sums of the (A.2 and B.2) parts, but not more than that. For example, the real consumption effect for Other Livestock in Germany is -3.18 under A.2, -0.06 under B.2 (Table A-5) and the simulation result for scenario C (-3.22, Table 4.7) turns out to be approximately equal to the sum of the parts, but not greater than the sum of the parts. Thus, the two scenarios reinforce each other in the desired direction of reduced meat and dairy consumption as in both scenarios the consumer prices of animal source food products are driven upwardse.However, there is no genuine synergy effect, that would make the joint effect bigger than the sum of the parts. In contrast, a trade-off arises with respect to fruit and vegetables consumption,

[19] For the area rewetted in 2023 (2030) ongoing costs are included up to 2042 (2049) in this social cost-benefit analysis. Correspondingly, emission reduction benefits for the area rewetted in 2023 (2030) are assumed to materialize from 2024 (2031) and are included up to 2043 (2050).

where the consumer price effects of the VAT reduction and the peatland restoration scheme drag in opposite directions, though the VAT reduction effect explstrongly dominates.

Overall, a joint implementation appears highly recommendable, as A.2 generates very small emission reduction effects but moderately strong consumption effects whereas B.2 generates large emission reduction effects and negligible consumption effects. Correspondingly, a policy bundle that comprises both a tax reform with compensation payments for low-income households aimed at inducing shifts in dietary choices on the demand side and a peatland rewetting incentive scheme aimed at land-based GHG emissions on the supply side would induce positive change along both the health and the environment dimension while avoiding regress along the inclusion dimension.

Table 4.11: Summary Table for Scenario C – Joint Implementation of Scenarios A.2 and B.2

(Percentage Deviations from Baseline 2030)

	Real Consumption					Real Output	Exports	Imports
	Germany	RoEU	Africa	RoLMI	RoHI	Germany	Germany	Germany
Cereals	-0.01	0.00	0.00	0.00	0.00	-0.48	-0.47	-0.21
VegFruit	2.47	0.01	0.00	0.00	0.00	1.09	0.25	1.97
Oilseeds	-0.02	0.00	0.00	0.00	0.00	-0.27	-0.33	-0.04
Sugar Crops	0.00	-0.01	0.00	0.00	0.00	-1.86	-1.02	-1.46
OtherCrops	-0.01	0.00	0.00	0.00	0.00	-0.31	-0.34	-0.06
Cattle, Lamb	-4.77	0.00	0.00	0.00	0.00	-1.73	-0.94	-1.41
Other Livestock	-3.22	-0.01	0.00	0.00	0.00	-1.80	-1.31	-1.17
Forestry, Fishing	-0.01	0.00	0.00	0.00	0.00	0.02	0.03	0.00
Mining	-0.03	0.00	0.00	0.00	0.00	0.04	-0.01	0.07
Vegetable Oils	0.00	0.00	0.00	0.00	0.00	-0.11	-0.08	-0.12
Sugar	-1.09	-0.01	0.00	0.00	0.00	-2.31	-3.72	1.29
Meat Products	-3.30	-0.01	0.00	0.00	0.00	-1.96	-1.33	-1.61
Dairy Products	-3.83	-0.01	0.00	0.00	0.00	-1.65	-1.01	-1.45
O Food Products	-0.04	0.00	0.00	0.00	0.00	-0.15	-0.20	0.01
Beverages, Tobac	-0.05	0.00	0.00	0.00	0.00	-0.08	-0.12	0.02
Manufacturing	-0.02	0.00	0.00	0.00	0.00	0.10	0.08	0.06
Utilities	0.00	0.00	0.00	0.00	0.00	0.03	0.07	-0.02
Construction	-0.01	0.00	0.00	0.00	0.00	0.25	0.14	0.18
Trade, Transport	0.00	0.00	0.00	0.00	0.00	0.02	0.05	-0.02
Other Services	0.00	0.00	0.00	0.00	0.00	0.04	0.06	0.00

5. Conclusions

5.1. Tax Reform Package

The tax reform analysis presented in this study considers a scenario in which from 2023 onwards the German VAT rates on meat products and dairy products are raised from the current reduced rate of 7 percent to the full rate of 19 percent, the VAT rate on fruits and vegetables is reduced from the current rate of 7 percent to zero, and a new excise tax on intermediate and final consumption of refined sugar at an ad-valorem-equivalent rate of 10 percent is imposed.

The tax reform raises household consumption of fruits and vegetables by 2.2 to 2.5 percent, while consumption of meat products drops by 3.3 to 3.8 percent, consumption of dairy products by 3.8 to 4.0 percent and sugar intake falls by -1.1 to -1.5.

In response, the domestic meat processing sector shrinks by 1.8 percent and agricultural livestock production by 1.6 percent relative to the baseline. The associated reductions in feedstock demand entail a noticeable backward linkage effect on the domestic production and imports of Cereals, Other Crops, and Other Food Products. The output of Germany's sugar processing sector drops by 2.3 percent and as a result domestic sugar crop production drops by 1.8 percent, whereas domestic production of fruits and vegetables rises by 1.6 percent relative to the baseline projection.

The changes in agricultural production entail a moderate net reduction in agricultural land use in Germany by 67,000 to 88,000 ha, as the area reductions for livestock including feed crop production and sugar crop production together dominate the rise in land area devoted to fruit and vegetable production.

The resulting estimated annual GHG emission reductions are around 0.590 to 0.730 million tCO2e, that is a reduction by 1.2 to 1.4 percent of baseline agricultural emissions from soils, enteric fermentation and manure management. The cumulated GHG emission reduction effect over the period 2023 to 2030 amounts to 5.3 million tCO2e.

A microsimulation analysis based on the latest household income and expenditure survey for Germany indicates that the distributional impact of the tax reform package in the absence of compensation measures is clearly regressive. Households in the lowest income bracket experience a consumer welfare loss on the order of -Euro 38.40 per annum – that is -0.31 percent of baseline real income - while the welfare loss for the average household in the highest income bracket is only –0.13 percent. However, the tax reform package generates more than enough additional net tax revenue to allow in principle a full compensation of all households in the below-average income brackets. Administratively less burdensome compensation schemes are conceivable. For instance, the additional fiscal space generated by the additional net tax revenue would allow a budget-neutral uniform lump-sum payment to all households at an annual rate of about Euro 58. This would overcompensate all households in the lowest three income brackets and thus generate a positive inclusivity effect.

5.2. Peatland Restoration Package

In 2020, Germany's GHG emissions from drained peatland under agricultural cultivation amounted to 42.5 million tCO_2e, accounting for 5.9 percent of Germany's total GHG emissions. While the peatland area used for agricultural production (1283 kha) represented just 7.7 percent of Germany's total utilized agricultural area in 2020, it contributed over 40 percent of the country's total GHG emissions from agriculture and agricultural land use. The present study considers three abatement scenarios in which peatland users are incentivised to reduce these emissions on a voluntary basis.

In the RewetLo scenario, which reflects the moderate ambitions of Germany's National Peatland Protection Strategy, 88 kha (6.9 percent) of agricultural peatland is rewetted by 2030 to attain a direct annual emission reduction by 3.5 million tCO_2e (-8.2 percent) at private short-run abatement costs of 35 Euro/tCO_2e. In the RewetHi scenario, 474 kha (36.9 percent) of peatland is rewetted by 2030 to attain a direct annual emission reduction by 15 million tCO_2e (-35.2 percent) at marginal private abatement costs between 35 and 49 Euro/tCO_2e. In the RewetHi+ scenario, which draws upon results of an earlier study by Röder et al (2015) for the determination of the private abatement cost schedule, 729 kha (55.2 percent) of peatland is rewetted by 2030 to attain a direct annual emission reduction by 19.3 million tCO_2e (-45.4 percent) at marginal abatement costs between 27 and 61 Euro/tCO_2e. The economy-wide marginal social abatement costs range from 15 Euro/tCO_2e under RewetLo to 27 Euro/tCO_2e under RewetHi+.

The effective agricultural land supply reduction entails upward pressure on agricultural land rents in Germany and this pushes domestic agricultural production costs and hence producer prices up to some extent. Since the rewetted areas are small in relation to Germany's total UAA, the size order of this cost-push effect is small under the RewetHi scenarios and negligibly small under the RewetLo scenario. The resulting increases in consumer prices for food in Germany at the 2030 endpoint of the transformation pathway remain well below 0.05 percent under RewetLo and below 0.3 percent under RewetHi+ Correspondingly, the impact on domestic food consumption quantities is negligible in the RewetLo scenario and remains below 0.1 percent in the RewetHi+ scenario. The increase in prices for food commodities of German origin relative to the rest of the world induce a rise in German agri-food import volumes by 0.01 to 0.13 percent and a drop in German agri-food exports by -0.03 to -0.23 percent towards 2030. The impacts on real GDP and net real household income are negligibly small in all scenarios. Carbon leakage effects due to induced indirect land use change in Germany and the rest of the European Union reduce the global net emission reduction impact by 0.7 to 1.0 percent of the direct emission reduction.

In conclusion, a sizable reduction of Germany's GHG emissions from agriculture and land use appears achievable at a low macroeconomic cost by moving beyond the moderate ambitions of the country's current National Peatland Restoration Strategy.

5.3. Joint Implementation of Tax Reform and Peatland Restoration

A policy bundle that comprises both a tax reform with compensation payments for low-income households aimed at inducing shifts in dietary choices on the demand side and a peatland rewetting incentive scheme aimed at land-based GHG emissions on the supply side would induce positive change along both the health and the environment dimension while avoiding regress along the inclusion dimension.

Appendix: Supplementary Information

Main Features of the CGE Model

The global CGE model is an extended recursive-dynamic version of the comparative-static GLOBE model originally developed by McDonald, Thierfelder and Robinson (2007) which incorporates capital accumulation, population growth, labor force growth, and technical progress. The individual country or region blocs that together provide complete coverage of the global economy are linked through international trade and capital flows. Each region bloc represents the entire economy of that region at a sectorally disaggregated level. The economic interactions among producers, consumers, and the government as well as economic transactions with other regions are explicitly captured. Producers in each region combine primary factors (skilled and unskilled labor, physical capital, land, and other natural resources) with intermediate inputs obtained from the same and other production sectors at home and abroad to produce output. The output is sold to domestic households, the domestic government, to domestic producers (for use as intermediate input or as an addition to the productive capital stock), and to other regions of the world. In all traded commodity groups, imports and goods of domestic origin are treated as imperfect substitutes in both final and intermediate demand.

The production process generates factor income in the form of wages, land and natural resource rents, and returns to capital as well as production tax income for the government. The factor income flows to households. Households use their income to pay income taxes, to buy consumer goods, and to save for future consumption. The government receives additional tax revenue from sales taxes including revenue from import duties.

Domestic producers in the model are price-takers in output and input markets and maximise intra-temporal profits subject to technology constraints. The technologies for the transformation of inputs into real outputs are described by sectoral constant-returns-to-scale production functions with a constant elasticity of substitution between primary factors and a Leontief technology for intermediate inputs.

Consumer behaviour is derived from intra-temporal utility-maximising behaviour subject to within-period budget constraints, whereby consumer preferences are represented by a Stone-Geary utility function.

Producer and consumer responses to price and income changes are modeled in accordance with microeconomic theory, and the parameters governing these responses to changes in input and output prices are based on available econometric evidence.

Table A-1: GLOBE Production Activity / Commodity Group Aggregation

Production Sector / Commodity Group	GTAP Sector Code
Agriculture	
Cereals	pdr wht gro
Vegetables and Fruits	v_f
Oilseeds	osd
Sugar Crops	c_b
Other Crops	ocr pfb
Bovine Cattle, Sheep, Goats, Horses	ctl
Other Livestock Agriculture	oap rmk wol
Other Primary Resource Extraction	
Forestry and Fishing	frs fsh
Mining and Quarrying	coa oil gas oxt
Food Processing	
Vegetable Oils	vol
Sugar	sgr
Meat Products	cmt omt
Dairy Products	mil
Other Processed Food Products	pcr ofd
Beverages and Tobacco	b_t
Other Manufacturing	
Other Manufacturing	tex wap lea lum ppp bph rpp nmm i_s nfm fmp ele eeq ome mvh otn omf
Construction and Utilities	
Construction	cns
Utilities	ely wtr gdt
Services	
Trade and Transport Services	trd otp wtp atp
Other Services	afs whs cmn ofi ins rsa obs ros osg edu hht dwe

Technical Description of the Household Microsimulation Model

In concordance with the specification of consumer demand in the CGE model, household consumption preferences in the microsimulation model are represented by Stone-Geary utility functions

(1) $U_h(C_h) = \prod_i (C_{h,i} - \gamma_{h,i})^{\beta_{h,i}}$,

where h is an index over household types (H1,…, H8), i an index over consumption goods, the time index has been suppressed and $C_{h,i}$ denotes the consumption quantity of good i by household h.

Utility maximization subject to the household budget constraint

(2) $\sum_i P_i C_{h,i} = E_h = (1 - s_h) Y_h$

entails Marshallian demand functions of the LES form

(3) $C_{h,i}(P, Y_h) = \gamma_{h,i} + \frac{\beta_{h,i}}{P_i}\left((1 - s_h)Y_h - \sum_j \gamma_{h,j} P_j\right)$,

where E_h denotes household h's total consumption expenditure, P_i the consumer price of good i, s_h the marginal propensity to save, and Y_h household h's net income, i.e. the sum of labour income, capital income and net transfer income minus direct tax payments. The household-specific preference parameters β and γ are initially calibrated such that the baseline microsimulation for the year 2018 exactly replicates the consumption expenditure patterns by household type and commodity group from the EVS displayed in Table 2.2 and the implied income elasticities are on average equal to the corresponding elasticities for the aggregate single household in the CGE model.

In both the dynamic baseline simulation to 2030 and the policy reform scenario simulations, the time paths for consumer prices, wage rates and returns to capital projected by the CGE model are passed on to the microsimulation model. The determination of the time paths for capital income by household type takes account of the differentials in saving rates s_h across households. Saving rates by household are calibrated to match the EVS data and are significantly higher for higher-income households than for low-income households. Correspondingly, capital asset stock growth and hence capital income growth is higher for households in the higher-income brackets. The household-specific income tax rates are likewise calibrated to replicate the EVS data and transfer income evolves in line with the baseline GDP growth path projected by the CGE model. The calibration approach ensures that the household-group-size-weighted average household net income growth path of the microsimulation model closely matches the corresponding aggregate household net income growth path of the CGE model.

The microsimulation model is used to determine the saving-adjusted Hicksian equivalent variation (EV) and compensating variation (CV), which are money-metric measures of the consumer welfare change due to the policy reform bundle under consideration. Let superscripts 0 and 1 refer to variable values prior to the policy reform (i.e., baseline values) and after the policy reform respectively. Consider a policy reform that changes the vector of consumer prices from P^0 to P^1 and net income of a household in the absence of compensation payments from baseline level Y^0 to Y^1 (dropping the household subscript for notational convenience). The CV measures the compensation payment a household would have to receive after the policy reform (in the case of a welfare-reducing policy change) on top of its post-reform net income Y^1 or pay (in the case of a welfare-raising policy change) to keep household welfare at the baseline level U^0. Formally,

(4) $$CV = M(P^1, U^0) - Y^1 = M(P^1, V(P^0, Y^0)) - Y^1 \ ,$$

where M(P,U) is the (saving-adjusted) expenditure function which gives the net income required by a household with saving rate s to reach utility level U when faced with the consumer price vector P, and V(P,Y) is the indirect utility function, which returns the utility level reachable by a household with net income Y at price vector P. The functional form of the indirect utility function associated with direct utility function (1) can be obtained by inserting (3) into (1), and the functional form of M(P,U) is then found by equating M with Y and inverting the indirect utility function.

Thus,

(5) $$CV = \prod_i \left(\frac{P_i^1}{P_i^0}\right)^{\beta_i} \left(Y^0 - \sum_j P_j^0 \gamma_j/(1-s)\right) - \left(Y^1 - \sum_j P_j^1 \gamma_j/(1-s)\right).$$

The EV measures the hypothetical payment a household would have to receive *in the absence of* the policy reform (in the case of a welfare-raising policy change) on top of its baseline net income Y^0 or pay (in the case of a welfare-reducing policy change) to generate a welfare effect that is equivalent to that of the policy reform. Formally,

(6) $$EV = M(P^0, U^1) - Y^0 = M(P^0, V(P^1, Y^1)) - Y^0 .$$

With Stone-Geary preferences, the equivalent variation takes the form

(7) $$EV = \prod_i \left(\frac{P_i^0}{P_i^1}\right)^{\beta_i} \left(Y^1 - \sum_j P_j^1 \gamma_j/(1-s)\right) - \left(Y^0 - \sum_j P_j^0 \gamma_j/(1-s)\right).$$

Table A-2: Empirical Household Food Demand Elasticity Estimates for Germany and Europe

Source	Region	Period	Meat Products	Dairy Products	Fruit, Vegetables	Sugar	Other Food Products
			Uncompensated Own-Price Elasticity				
Feminia (2019)	EU	1973-2014	-0.49	-0.55	-0.49		-0.53
GTAP	Germany	1997	-0.73	-0.73			-0.86
IMPACT	Europe		-0.25 to -0.41	-0.21	-0.26	-0.25	
IMPACT	Germany		-0.33 to -0.58	-0.21	-0.32 to -0.43	-0.26	
Effertz et al (2015)	Germany		-0.37	-0.19	-0.20	-0.60	
Roosen et al (2022)	Germany	2012-14	-0.86 to -0.91				
Thiele (2008)	Germany	2003	-1.02	-1.00	-0.55 to -0.80		
Schröck (2013)	Germany	2004-08	-0.85	-0.67	-0.53 to -0.67		
Muhammad et al (2011)	Germany	2005	-0.35	-0.36	-0.23		-0.43
			Income Elasticity				
			Meat Products	**Dairy Products**	**Fruit, Vegetables**	**Sugar**	**Other Food Products**
Feminia (2019)	EU	1973-2014	0.69	0.64	0.45		0.61
GTAP	Germany	1997	0.91	0.91			0.83
IMPACT	Europe		0.11 to 0.17	0.14	0.24	0.30	
IMPACT	Germany		0.12 to 0.37	0.13	0.33	0.30	
Roosen et al (2022)	Germany	2012-14	0.27-0.45				
Thiele (2008)	Germany	2003	0.36	0.27	0.30		
Schröck (2013)	Germany	2004-08	0.29	0.26	0.22		
Muhammad et al (2011)	Germany	2005	0.47	0.49	0.31		0.61

Notes**:** Femenia (2019) provides a meta-analysis 93 primary studies published between 1973 and 2014. The figures above are weighted averages for the European Union as reported in Femenia (2019: Table 2). GTAP elasticities for Germany are from Hertel, van der Mensbrugghe (2019) and are based on Reimer, Hertel (2004). Figures for meat /dairy in this source refer to a meat-dairy composite. IMPACT figures are SSP2 reference scenario values used in IFPRI's IMPACT model drawn from data files for Rosegrant et al (2021). The IMPACT demand elasticities shift gradually over time in line with expert opinion (Robinson et al, 2015). Reported figures above are for 2023. The estimates in Roosen et al (2022) refer to fresh meat only. Schröck (2013) and Thiele (2008) report elasticities with respect to a one-percent increase in total food expenditure rather than ordinary income elasticities. These expenditure elasticities have been transformed into income elasticities by multiplication with an estimate of the elasticity of food expenditure with respect to total expenditure, using the value of 0.3 proposed by Thiele (2008: fn 8).

Details of Baseline Construction

Table A-3: Annual Population Growth Rates by GLOBE Region

(%)

	Germany	RoEU	RoHI	Africa	RoLMI
2015	-0.04	0.35	0.83	2.24	0.94
2016	-0.05	0.24	0.71	2.10	0.83
2017	-0.05	0.24	0.72	2.10	0.83
2018	-0.05	0.24	0.72	2.11	0.84
2019	-0.05	0.24	0.73	2.11	0.84
2020	-0.05	0.24	0.73	2.11	0.84
2021	-0.06	0.20	0.66	1.93	0.70
2022	-0.06	0.21	0.66	1.94	0.70
2023	-0.06	0.21	0.67	1.94	0.71
2024	-0.06	0.21	0.67	1.94	0.71
2025	-0.06	0.21	0.67	1.95	0.71
2026	-0.08	0.17	0.59	1.77	0.57
2027	-0.08	0.17	0.59	1.78	0.57
2028	-0.08	0.17	0.59	1.78	0.57
2029	-0.08	0.17	0.60	1.78	0.58
2030	-0.08	0.17	0.60	1.79	0.58

Source: Author's aggregation from IFPRI IMPACT SSP2 baseline.

Table A-4: Annual Baseline GDP Growth Rates by GLOBE Region

(%)

	Germany	RoEU	RoHI	Africa	RoLMI
2015	1.5	2.8	2.2	3.6	4.4
2016	2.2	2.1	1.7	2.6	4.6
2017	2.7	3.1	2.2	3.1	4.9
2018	1.1	2.6	2.3	3.5	4.7
2019	1.1	2.3	1.6	3.2	3.8
2020	-4.6	-6.3	-3.9	-1.6	-2.1
2021	2.9	6.1	5.1	4.1	7.0
2022	2.1	3.1	3.4	4.1	3.8
2023	2.7	2.4	2.3	3.7	4.5
2024	1.5	2.3	1.5	3.8	4.7
2025	1.4	2.0	1.6	3.9	4.6
2026	1.2	1.9	1.6	3.9	4.5
2027	1.1	1.8	1.5	4.1	4.4
2028	1.1	1.7	1.6	4.1	4.4

2029	1.1	1.7	1.6	4.1	4.4
2030	1.1	1.7	1.6	4.1	4.4

Sources: 2015-2027: International Monetary Fund (2022), World Bank (2022) (for Sub-Saharan Africa 2019 to 2024), and author's calculations. 2028-2030: Author's aggregations of SSP2 baseline GDP projections by country from IFPRI IMPACT data files chain-linked to 2027 figures above.

Additional Results for Peatland Restoration Scenarios

Table A-5: Impacts on Real Household Consumption 2030 by Food Commodity Group – Peatland Restoration Scenarios

(Percentage deviations of 2030 household consumption quantities from Baseline 2030)

	RewetLo	RewetHi	RewetHi+
Cereals	-0.01	-0.03	-0.04
Vegetables, Fruit	-0.01	-0.03	-0.04
Oilseeds	-0.01	-0.04	-0.05
Sugar Crops	0.00	-0.02	-0.02
OtherCrops	0.00	-0.03	-0.04
Cattle, Lamb	-0.01	-0.07	-0.10
Other Livestock	-0.01	-0.06	-0.08
Vegetable Oil	0.00	-0.01	-0.02
Sugar	0.00	-0.01	-0.01
Meat Products	-0.01	-0.03	-0.05
Dairy Products	-0.01	-0.03	-0.04
Other Food Products	0.00	-0.03	-0.04

Table A-6: Impact on Germany's Agri-Food Trade 2030 by Commodity Group

(Percentage deviations of 2030 trade volumes from Baseline 2030)

	Imports to Germany			Exports from Germany		
	RewetLo	RewetHi	RewetHi+	RewetLo	RewetHi	RewetHi+
Cereals	0.04	0.23	0.31	-0.11	-0.58	-0.77
Vegetables, Fruit	0.01	0.06	0.08	-0.12	-0.62	-0.82
Oilseeds	0.01	0.05	0.06	-0.10	-0.55	-0.73
Sugar Crops	0.02	0.14	0.18	-0.05	-0.26	-0.35
OtherCrops	0.03	0.18	0.24	-0.09	-0.48	-0.63
Cattle, Lamb	0.01	0.07	0.10	-0.05	-0.28	-0.38
Other Livestock	0.04	0.20	0.27	-0.09	-0.48	-0.63

Vegetable Oil	0.00	0.01	0.01	-0.02	-0.13	-0.17
Sugar	0.01	0.04	0.05	-0.02	-0.14	-0.18
Meat Products	0.03	0.16	0.22	-0.05	-0.29	-0.38
Dairy Products	0.01	0.06	0.08	-0.03	-0.19	-0.25
Other Food Products	0.00	0.02	0.03	-0.01	-0.05	-0.07
Beverages, Tobacco	0.00	0.01	0.02	-0.01	-0.03	-0.04

Table A-7: Impact on Germany's Agri-Food Trade 2030 by Commodity Group

(Deviations of 2030 trade volumes from Baseline 2030 in million Euro)

	Imports to Germany			Exports from Germany		
	RewetLo	RewetHi	RewetHi+	RewetLo	RewetHi	RewetHi+
Cereals	1.2	6.5	12.2	-3.8	-20.4	-27.0
Vegetables, Fruit	1.5	7.9	15.4	-2.8	-15.5	-20.4
Oilseeds	0.4	2.0	3.8	-0.4	-2.1	-2.8
Sugar Crops	0.0	0.1	0.2	-0.1	-0.6	-0.9
OtherCrops	2.9	15.8	29.7	-1.9	-10.4	-13.7
Cattle, Lamb	0.0	0.1	0.2	-0.3	-1.8	-2.4
Other Livestock	1.4	7.7	14.4	-2.4	-12.9	-17.0
Vegetable Oil	0.1	0.5	1.1	-0.9	-5.0	-6.6
Sugar	0.1	0.3	0.7	-0.3	-1.6	-2.1
Meat Products	2.8	15.0	28.5	-5.4	-29.3	-38.8
Dairy Products	0.8	4.4	8.5	-3.5	-19.2	-25.5
Other Food Products	1.0	5.5	12.6	-3.1	-17.0	-22.6
Beverages, Tobacco	0.2	1.2	3.0	-0.6	-3.3	-4.3
Total Agri-Food	**12.3**	**67.0**	**130.3**	**-25.6**	**-139.1**	**-184.2**

Sensitivity of the Peatland Restoration Scenario Results

To assess the sensitivity of results to assumptions about the average installation and maintenance cost for physical infrastructure required to raise water levels on peatland permanently back to near-surface level, a variation of the RewetHi scenario has been simulated, in which average upfront investment costs were ceteris paribus raised by 25 percent from Euro 8,000/ha to Euro 10,000/ha. However, as this demand component remains small both in relation to the total volume of government expenditure and in relation to total baseline demand for construction and other services, this variation has no noteworthy impact on the results.

An alternative government sector budget closure under which the additional government expenditure is debt-financed rather than tax-financed has been considered as part of the sensitivity analysis. This entails a marginally stronger reduction in Germany's aggregate macroeconomics savings volume available for capital accumulation and thus a slight shift in the time profile of the aggregate consumption effects: Under the income-tax-finance closure, Germany's aggregate real capital stock towards 2030 drops by 0.0002 percent relative to the baseline in the RewetHi+ scenario, while under the debt-finance closure Germany's aggregate real capital stock towards 2030 drops by 0.06 percent relative to the baseline. This means that under the debt-finance closure the household consumption sacrifices required to pay for the peatland restoration measures are postponed to some extent, as the household sector does not experience instant drops in net income due to tax rate increases but rather a gradual reduction in capital income over time. While noteworthy from a theoretical perspective, none of the conclusions in the main text are affected by this change in the macro closure assumptions.

References

ADB (2019) Ending Hunger in Asia and the Pacific by 2030: An Assessment of Investment Requirements in Agriculture. Manila: Asian Development Bank.

Aguiar, A., Chepeliev, M., Corong, E.L., McDougall, R., van der Mensbrugghe, D. (2019) The GTAP Data Base: Version 10. *Journal of Global Economic Analysis* 4, 1-27.

Banse, M., Sturm, V. (2019) Preissetzung auf agrarrelevante THG-Emissionen auf der Produktions- vs. Konsumseite: Was bringt mehr? *Schriftenreihe der Rentenbank* 35: Herausforderung Klimawandel: Auswirkungen auf die Landwirtschaft. Frankfurt am Main: Edmund Rehwinkel-Stiftung der Landwirtschaftlichen Rentenbank, 7-41.

Blum, B. (2020) Fleischbesteuerung in Deutschland – Mengen- oder Mehrwertsteuer? Diskussion und Politische Implikationen. *Constitutional Economics Network Working Paper* No. 01-2020, University of Freiburg.

BMEL (2022) Den Wandel gestalten! Zusammenfassung zum GAP-Strategieplan 2023 – 2027. Bundesministerium für Ernährung und Landwirtschaft.

BMU (2021) *National Peatland Protection Strategy*. Bundesministerium für Umwelt, Naturschutz und nukleare Sicherheit. September.

Bonn, A., Berghöfer, A., Couwenberg, J., Drösler, M., Jensen, R., Kantelhardt, J., Luthardt, V., Permien, T., Röder, N., Schaller, L., Schweppe-Kraft, B., Tanneberger, F., Trepel, M., Wichmann, S. (2015) Klimaschutz durch Wiedervernässung von kohlenstoffreichen Böden. V. Hartje, H. Wüstemann, A. Bonn (eds) *Naturkapital und Klimapolitik: Synergien und Konflikte*. Berlin, Leipzig: Technische Universität Berlin, Helmholtz-Zentrum für Umweltforschung – UFZ, 124-147.

Buschmann, C., Röder, N., Berglund, K., Berglund, Ö., Lærke, P.E., Maddison, M., Mander, Ü., Myllyse, M., Osterburg, B., van den Akker, J.H.J. (2020) Perspectives on Agriculturally Used Drained Peat Soils: Comparison of the Socioeconomic and Ecological Business Environments of Six European Regions. *Land Use Policy* 90: 104181.

Chang, G.H., Chang, K.J. (2022) A Standard CGE Model for VAT Taxes. *SSRN Paper* 4141707.

Cirera, X., Masset, E. (2010) Income Distribution Trends and Future Food Demand. *Philosophical Transactions of the Royal Society* 365, 2821–2834.

Clark, M., Tilman, D. (2017) Comparative Analysis of Environmental Impacts of Agricultural Production Systems, Agricultural Input Efficiency, and Food Choice. *Environmental Research Letters* 12(6): 064016.

Council Directive (EU) 2022/542 of 5 April 2022 amending Directives 2006/112/EC and (EU) 2020/285 as regards rates of value added tax. *Official Journal of the European Union* L107/1, 6.4.2022.

Dellink, R., Chateau, J., Lanzi, E., Magné, B. (2017) Long-Term Economic Growth Projections in the Shared Socioeconomic Pathways. *Global Environmental Change* 42, 200-214.

Drösler, M., Schaller, L., Kantelhardt, J., Schweiger, M., Fuchs, D., Tiemeyer, B., Augustin, J., Wehrhan, M., Förster, C., Bergman, L., Kapfer, A., Krüger, G.-M. (2012). Beitrag von Moorschutz- und -revitalisierungsmaßnahmen zum Klimaschutz am Beispiel von Naturschutzgroßprojekten. *Natur und Landschaft* 87, 70–76.

Effertz, T., Adams, M. (2015) Effektive Prävention von Adipositas durch Kindermarketing-verbote und Steuerstrukturänderungen. *Prävention und Gesundheitsförderung* 10, 55-61.

European Commission (2022) Proposed CAP Strategic Plans and Commission Observations: Summary Overview for 27 Member States.

Femenia, F. (2019) A Meta-Analysis of the Price and Income Elasticities of Food Demand. *German Journal of Agricultural Economics* 68(2), 77-98.

Gaupp, F., Ruggeri Laderchi, C., Lotze-Campen, H., DeClerck, H.F., Bodirsky, B.L., Lowder, S., Popp, A., Kanbur, R., Edenhofer, O., Nugent, R., Fanzo, J., Dietz, S., Nordhagen, S., Fan, S. (2021) Food System Development Pathways for Healthy, Nature-Positive and Inclusive Food Systems. *Nature Food* 2(12), 928–934.

Glenk, K., Martin-Ortega, J. (2018) The Economics of Peatland Restoration. *Journal of Environmental Economics and Policy* 7 (4), 345-362.

GMC (2020) Stellungnahme des Greifswald Moor Centrum zum Diskussionspapier Moorschutzstrategie der Bundesregierung. Greifswald: Greifswald Moor Centrum.

Grethe, H., Martinez, J., Osterburg, B., Taube, F., Thom, F. (2021) *Klimaschutz im Agrar- und Ernährungssystem Deutschlands: Die drei zentralen Handlungsfelder auf dem Weg zur Klimaneutralität*. Gutachten für die Stiftung Klimaneutralität.

Günther, A., Barthelmes, A., Huth, V, Joosten, H., Jurasinski, G., Koebsch, F., Couwenberg, J. (2020) Prompt Rewetting of Drained Peatlands Reduces Climate Warming Despite Methane Emissions. *Nature Communications* 11: 1644.

Hertel, T.W., van der Mensbrugghe, D. (2019) Behavioral Parameters. *GTAP Resource* No. 5950.

Hirschelmann, S., Raschke, I., Stüber, M., Wichmann, S., Peters, J. (2020) Moorschutz in der Gemeinsamen Agrarpolitik – Instrumente für eine klimaverträgliche Moornutzung in Deutschland. *Berichte über Landwirtschaft* 98(3).

Hofer, B. Köbbing, J. (2021) Faktencheck – Was bedeutet die Vorgabe der Deutschen Moorschutzstrategie „Einsparung von Emissionen in Höhe von 5 Millionen t CO2 Äquivalenten pro Jahr aus Moorböden in Deutschland bis 2030“ in der praktischen Umsetzung? *TELMA - Berichte der Deutschen Gesellschaft für Moor- und Torfkunde* 51, 153 – 164.

Humpenöder, F., Karstens, K., Lotze-Campen, H., Leifeld, J., Menichetti, L., Barthelmes, A. Popp, A. (2020) Peatland Protection and Restoration are Key for Climate Change Mitigation. *Environmental Research Letters* 15: 10.

International Monetary Fund (2022) *World Economic Outlook Database*, April 2022.

Isermeyer, F., Heidecke, C., Osterburg, B. (2019) Einbeziehung des Agrarsektors in die CO2-Bepreisung. *Thünen Working Paper* 136.

Joosten, H. (2021) Global Guidelines for Peatland Rewetting and Restoration. *Ramsar Technical Report* No. 11. Gland: Secretariat of the Convention on Wetlands.

Komarek, A.M., Dunston, S., Enahoro, D., Godfray, H.C.J., Herrero, M., Mason-D'Croz, D., Rich, K.M., Scarborough, P., Springmann, M., Sulser, T.B., Wiebe, K., Willenbockel, D. (2021) Income, Consumer Preferences, and the Future of Livestock-Derived Food Demand. *Global Environmental Change* 70: 102343.

Komarek, A.M., Cenacchi, N., Dunston, S., Sulser, T.B., Wiebe, K., Willenbockel, D. (2021) Employment and Income Implications of Transitions towards More Sustainable Global Diets. *SocArxiv Papers*, December 22.

Krimly T., Angenendent E., Bahrs E, Dabbert S. (2016) Global Warming Potential and Abatement Costs of Different Peatland Management Options: A Case Study for the Pre-Alpine Hill and Moorland in Germany. *Agricultural Systems* 145, 1-12.

Leifeld, J., Menichetti, L. (2018) The Underappreciated Potential of Peatlands in Global Climate Change Mitigation Strategies. *Nature Communications* 9: 1071.

Leip, D., Crawford, M., Hunecke, C., Collignon, Q., Bodirsky, B.L., Gaupp, F., Lotze-Campen, H. (2022) The Importance of Analyzing Interdependencies to Build a Healthy, Nature-Positive, and Inclusive Food System. PIK / FSEC.

Mason-D’Croz, D., Bogard, J.R., Herrero, M., Robinson, S., Sulser, T.B., Wiebe, K., Willenbockel, D., Godfray, H.C.J. (2020) Modelling the Global Economic Consequences of a Major African Swine Fever Outbreak in China. *Nature Food* 1(4), 221-228.

Matthey, A., Bünger, B. (2023) Methodological Convention 3.1 for the Assessment of Environmental Costs: Value Factors. Version 12/2020. Dessau-Roßlau: German Environment Agency.

Mason-D’Croz, D., Sulser, T.B., Wiebe, K., Rosegrant, M.W., Lowder, S.K., Nin-Pratt, A., Willenbockel, D., Robinson, S., Zhu, T., Cenacchi, N., Dunston, S., Robertson, R.D. (2019) Agricultural Investments and Hunger in Africa: Modeling Potential Contributions to SDG2 – Zero Hunger. *World Development* 116, 38–53.

McDonald, S., Thierfelder, K., Robinson, S. (2007) GLOBE: A SAM Based Global CGE Model using GTAP Data. *USNA Working Paper* No.14. Annapolis: US Naval Academy.

Mielcarek-Bocheńska, P., Rzeźnik, W. (2021) Greenhouse Gas Emissions from Agriculture in EU Countries—State and Perspectives. *Atmosphere* 12(11): 1396.

Moxey, A., Moran, D. (2014) UK Peatland Restoration: Some Economic Arithmetic. *Science of The Total Environment* 484: 114-120.

Muhammad, A.J., Seale, J.L., Meade, B., Regmi, A. (2011) International Evidence on Food Consumption Patterns: An Update Using 2005 International Comparison Program Data. *USDA ERS Technical Bulletin* No. 1929.

Nitsch, H., Schramek, J. (2020) *Grundlagen für eine Moorschutzstrategie der Bundesregierung: Synopse der Ergebnisse aus dem gleichnamigen F+E-Vorhaben*. Frankfurt / Main: Institut für Ländliche Strukturforschung (IfLS) an der Goethe-Universität Frankfurt am Main.

Reimer, J.J., Hertel, T.W. (2004) International Cross Section Estimates of Demand for Use in the GTAP Model. *GTAP Technical Paper* No.23.

Osterburg B., Rüter S., Freibauer A., De Witte T., Elsasser P., Kätsch S., Leischner B., Paulsen H.M., Rock J., Röder N., Sanders J., Schweinle J., Steuk J., Stichnothe H., Stümer W., Welling J., Wolff A. (2013) Handlungsoptionen für den Klimaschutz in der deutschen Agrar- und Forstwirtschaft. *Thünen Report* 11. Braunschweig: Thünen-Institut.

Ringler, C., Willenbockel, D., Perez, N., Rosegrant, M., Zhu, T, Matthews, N. (2016) Global Linkages among Energy, Food and Water: An Economic Assessment. *Journal of Environmental Studies and Sciences* 6, 161-171.

Röder, N., Henseler, M., Liebersbach, H., Kreins, P. Osterburg, B. (2015) Evaluation of Land Use Based Greenhouse Gas Abatement Measures in Germany. *Ecological Economics* 117, 193-202.

Röder, N., Grützmacher, F. (2012) Emissionen aus landwirtschaftlich genutzten Mooren—Vermeidungskosten und Anpassungsbedarf. *Natur und Landschaft* 87, 56–61.

Roosen, J., Staudigel, M., Rahbauer, S. (2022) Demand Elasticities for Fresh Meat and Welfare Effects of Meat Taxes in Germany. *Food Policy* 106:102194.

Rosegrant, M.W., Sulser, T.B., Dunston, S., Cenacchi, N., Wiebe, K.; Willenbockel, D. (2021) Estimating the global investment gap in research and innovation for sustainable agriculture intensification in the Global South. Colombo: Commission on Sustainable Agriculture Intensification.

Schaller, L.L. (2014) Landwirtschaftliche Nutzung von Moorflächen in Deutschland - Sozioökonomische Aspekte einer klimaschonenden Bewirtschaftung. PhD Thesis, TU Munich.

Schaller, L., Kantelhardt, J., Drösler, M. (2011) Cultivating the Climate: Socio-Economic Prospects and Consequences of Climate-Friendly Peat Land Management in Germany. *Hydrobiologia* 674**,** 91–104.

Schröck, R. (2013) Analyse der Preiselastizitäten der Nachfrage nach Biolebensmitteln unter Berücksichtigung nicht direkt preisrelevanten Verhaltens der Verbraucher. Giessen: Justus-Liebig-Universität Giessen.

Soergel, B., Kriegler, E., Weindl, I., Rauner, S., Dirnaichner, A., Ruhe, C., Hofmann, M., Bauer, N., Bertram, C., Bodirsky, B.L., Leimbach, M., Leininger, J., Levesque, A., Luderer, G., Pehl, M., Wingens, C., Baumstark, L., Beier, F., Dietrich, J.P., Humpenöder, F., von Jeetze, P., Klein, D., Koch, J., Pietzcker, R., Strefler, J., Lotze-Campen, H., Popp, A. (2021) A Sustainable Development Pathway for Climate Action within the UN 2030 Agenda. *Nature Climate Change* 11**,** 656–664.

Springmann, M. (2020) Valuation of the Health and Climate-Change Benefits of Healthy Diets. Background Paper for The State of Food Security and Nutrition in the World 2020. *FAO Agricultural Development Economics Working Paper* 20-03.

Statistisches Bundesamt (2021) Konsumausgaben und Lebenshaltungskosten: Aufwendungen privater Haushalte für Nahrungsmittel,Getränke und Tabakwaren nach dem monatlichen Haushaltsnettoeinkommen. *Ergebnisse der Einkommens- und Verbrauchsstichprobe (EVS) - Feinaufzeichnungsheft.*

Statistisches Bundesamt (2020) Wirtschaftsrechnungen: Einkommens- und Verbrauchsstichprobe: Einnahmen und Ausgaben privater Haushalte. *Fachserie 15 Heft 4*.

Sulser, T.B., Wiebe, K., Dunston, S., Cenacchi, N., Nin-Pratt, A., Mason-D'Croz, D., Robertson, R., Willenbockel, D., Rosegrant, M.W. (2021) Climate Change and Hunger: Estimating Costs of Adaptation in the Agrifood System. *IFPRI Food Policy Report*. Washington DC: International Food Policy Research Institute.

Tanneberger, F., Abel, S., Couwenberg, J., Dahms, T., Gaudig, G., Günther, A., Kreyling, J., Peters, J., Pongratz, J., Joosten, H. (2021) Towards Net Zero CO_2 in 2050: An Emission Reduction Pathway for Organic Soils in Germany. *Mires and Peat* 27: 05.

Tanneberger, F., Appulo, L., Ewert, S., Lakner, S., Ó Brolcháin, N., Peters, J., Wichtmann, W., (2021) The Power of Nature-Based Solutions: How Peatlands Can Help Us to Achieve Key EU Sustainability Objectives. *Advanced Sustainable Systems* 5: 2000146.

Target Agreement (2021) *Target Agreement Between the Federation and the Länder on Climate Change Mitigation Through Peat Soil Conservation*. (As of July 2021).

Tiemeyer, B., Freibauer, A., Albiac Borraz, E., Augustin, J., Bechtold, M., Beetz, S., Beyer, C., Eblie, M., Eickenscheidt, T., Fiedler, S., Förster, C., Gensior, A., Giebels, M., Glatzel, S., Heinichen, J., Hoffmann, M., Höper, H., Jurasinski, G., Laggner, A., Leiber-Sauheitl, K., Peichl-Brak, M., Drösler, M. (2020) A New Methodology for Organic Soils in National Greenhouse Gas Inventories: Data Synthesis, Derivation and Application. *Ecological Indicators* 109: 105838.

Thiele, S. (2008) Elastizitäten der Nachfrage privater Haushalte nach Nahrungsmitteln – Schätzung eines AIDS auf Basis der Einkommens- und Verbrauchsstichprobe 2003. *Agrarwirtschaft* 57(5), 258-68.

Tinbergen, J. (1952) *On the Theory of Economic Policy*. Amsterdam: North-Holland.

UBA (2022) Submission under the United Nations Framework Convention on Climate Change and the Kyoto Protocol 2022: National Inventory Report for the German Greenhouse Gas Inventory 1990 – 2020. Dessau-Roßlau: Umweltbundesamt.

Valin, H., Sands, R.D., van der Mensbrugghe, D., Nelson, G.C., Ahammad, H., Blanc, E., Bodirsky, B., Fujimori, S., Hasegawa, T., Havlik, P., Heyhoe, E., Kyle, P., Mason d'Croz, D., Paltsev, S., Rolinski, S., Tabeau, A., van Meijl, H., von Lampe, M., Willenbockel, D. (2014) The Fture of Food Demand: Understanding Differences in Global Economic Models. Agricultural Economics 45(1), 51–67.

Vos, C., Rösemann, C., Haenel, H.-D., Dämmgen, U., Döring, U., Wulf, S., Eurich-Menden, B., Freibauer, A., Döhler, H., Schreiner, C., Osterburg, B., Fuß, R. (2022a) Calculations of Gaseous and Particulate Emissions from German Agriculture 1990 – 2020: Report on Methods and Data (RMD) Submission 2022. *Thünen Report* 91. Braunschweig: Thünen-Institut.

Vos, C., Rösemann, C., Haenel, H.-D., Dämmgen, U., Döring, U., Wulf, S., Eurich-Menden, B., Freibauer, A., Döhler, H., Schreiner, C., Osterburg, B., Fuß, R. (2022b) Calculations of Gaseous and Particulate Emissions from German Agriculture 1990 – 2020: Input Data and Emission Results. Open Agrar Repository.

WBAE (2020) *Politik für eine nachhaltigere Ernährung: Eine integrierte Ernährungspolitik entwickeln und faire Ernährungsumgebungen gestalten*. Berlin: Wissenschaftlicher Beirat für Agrarpolitik, Ernährung und gesundheitlichen Verbraucherschutz beim Bundesministerium für Ernährung und Landwirtschaft.

WBAE / WBW (2016) *Klimaschutz in der Land- und Forstwirtschaft sowie den nachgelagerten Bereichen Ernährung und Holzverwendung*. Gutachten. Berlin: Wissenschaftlicher Beirat Agrarpolitik, Ernährung und gesundheitlicher Verbraucherschutz und Wissenschaftlicher Beirat Waldpolitik beim Bundesministerium für Ernährung und Landwirtschaft.

Wiebe, K., Sulser, T.B., Dunston, S., Rosegrant, M.W., Fuglie, K., Willenbockel, D., Nelson, G.C. (2021) Modeling Impacts of Faster Productivity Growth to Inform the CGIAR Initiative on Crops to End Hunger. *PLoS ONE* 16(4): e0249994.

Willenbockel, D., Robinson, S., Mason-D'Croz, D., Rosegrant, M.W., Sulser, T.B., Dunston, S., Cenacchi, N. (2018) Dynamic Computable General Equilibrium Simulations in Support of Quantitative Foresight Modeling to Inform the CGIAR Research Portfolio: Linking the IMPACT and GLOBE Models. *IFPRI Discussion Paper* No. 01738. Washington, DC: International Food Policy Research Institute.

Willenbockel, D. (2015) Reflections on the Prospects for Pro-Poor Low-Carbon Growth. L. Haddad, H. Kato, N. Meisel (eds) *Growth is Dead, Long Live Growth: The Quality of Economic Growth and Why it Matters*. Tokyo: JICA Research Institute, 159-185.

Willig, R.D. (1976) Consumer's Surplus Without Apology. *American Economic Review* 66(4), 589-597.

World Bank (2022) *Global Economic Prospects June 2022*. Washington, DC: International Bank for Reconstruction and Development.

ZKL (2021a) *Zukunft Landwirtschaft. Eine gesamtgesellschaftliche Aufgabe*. Berlin: Zukunftskommission Landwirtschaft.

ZKL (2021b) *The Future of Agriculture: A Common Agenda*. Berlin: Commission on the Future of Agriculture.