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GTAP10NOR: Adjusted GTAP database v10 based on national accounting data of Norway

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Summary

Title: GTAP10Nor: Adjusted GTAP database v10 based on national accounting data of Norway

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Abstract. The Model for Global Responses to Anthropogenic Changes in the Environment (GRACE) was developed for economic analysis of climate change issues including mitigation, impacts and adaptation. Since 2005, GRACE has been updated in line with the latest Global Trade Analysis Project (GTAP) database. So far, Norway has not been a specific region in GRACE. To include Norway in a new version of GRACE, we need a GTAP database which ensures consistency with the official national accounting data of Norway. This report describes how we adjust the GTAP v. 10 data to achieve this consistency. For this purpose, we apply the official input-output (IO) table of Norway for the year 2014 and the annually updated Table 11123 of the National accounts to adjust macroeconomic data of the original GTAP database for components of GDP like production, income and expenditure. The balance between supply and demand of products is finally taken care of by introducing an additional parameter in the adjusted GTAP data as "changes in inventory" for all regions. The official energy accounts and CO₂ emissions data of Norway are used to replace the corresponding data of Norway in the GTAP database.

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Introduction

The Model for Global Responses to Anthropogenic Changes in the Environment (GRACE) (Aaheim et al., 2018, Aaheim and Rive, 2005) is a global computable general equilibrium (CGE) model developed for economic analysis of climate change issues including mitigation, impact and adaptation used in various studies (e.g., Wei et al., 2019, Carattini et al., 2019, Aaheim et al., 2012). The GRACE model has been updated over time in line with the latest Global Trade Analysis Project (GTAP) database (Aguilar et al., 2019). Recently a new version (GRACE-Nor) has been developed to study climate and energy implications for Norway in the green shift. The data related to the Norwegian economy in the GTAP database can differ considerably from the official national accounting data of Norway, however. In this document, we describe how we adjust the GTAP database v10 (Aguilar et al., 2019) to obtain a database suitable for analysis of specific issues for Norway by adopting the exact official national accounting data of Norway.

The GTAP database is built mainly on available regional input-output tables and bilateral trade data. To make it consistent, various adjustments (Figure 1) have been implemented on the original regional input-output tables based on international datasets including bilateral trade, macroeconomic variables, production, and energy data (Walmsley et al., 2018). As a result, the differences in value-added can be large between the GTAP database and some regional IO tables. Hence, in this report we check how much the GTAP data deviate from the official national accounting data published by Statistics Norway. Since we found considerable differences between the data sources, we adjust the GTAP data related to the Norwegian economy to be consistent with the official national accounting data of Norway.

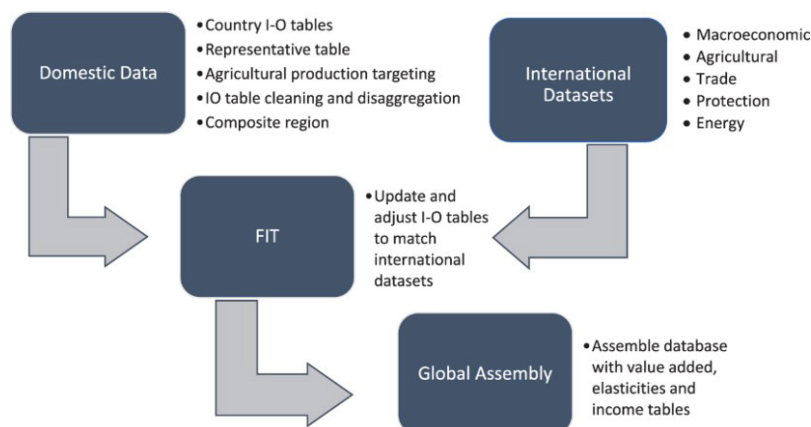


Figure 1. GTAP database construction procedure. Source: Walmsley et al. (2018).

1. Differences between the GTAP data and the official national accounting data of Norway

1.1 Macroeconomic indicators

There are two versions of macroeconomic indicators from the national accounting data released by Statistics Norway (SSB): the input-output (IO) table of the year 2014 for Norway (SSB, 2016) and the Table of non-financial and financial accounts by institutional sector (Table 11123 from SSB, 2021c). Both tables contain GDP data based on the three approaches of production, income, and expenditure. For 2014, we have data from both sources. However, data from the two tables differ for 2014 (Table 1). The differences are trivial and below 1%, except for “Other taxes on production, net” and “Gross capital formation”. We adopt the data from the annually updated Table 11123 rather than the IO table, while the IO table for 2014 has not been updated since 2016.

Table 1. The macroeconomic data of Norway in 2014 from two tables of official national accounting data from Statistics Norway (SSB)

	Table 11123 (million NOK)	IO Table (million NOK)	Deviation from Table 11123 (%)
Production output	5220797	5223615	0.05
- Intermediate consumption	2412222	2415758	0.15
= GROSS VALUE ADDED	2808575	2807857	-0.03
+ VAT and taxes on imports	332239	332514	0.08
= GROSS DOMESTIC PRODUCT (GDP)	3140814	3140371	-0.01
- Consumption of fixed capital	522912	519598	-0.63
- Compensation of employees	1447013	1448528	0.10
- Other taxes on production, net	-24495	-30647	25.12
= OPERATING SURPLUS, NET	867919	870378	0.28
GDP by expenditure	3140814	3140371	-0.01
Household consumption	1288402	1284876	-0.27
Government consumption	686825	691969	0.75
<i>Gross capital formation (from Table 09189)</i>	872567	883931	1.30
Export	1224803	1220367	-0.36
Import	-931783	-940772	0.96

Sources: The input-output (IO) table of 2014 is from SSB (2016) and Table 11123 of non-financial and financial accounts by institutional sector is from SSB (2021c).

For the modified GTAP database we need macroeconomic indicators for Norway in United States Dollars (USD). In the GTAP database v10, the original IO table of a region is transformed from local currency to USD by shifting the data in the IO table proportional to the ratio of the gross domestic product (GDP) in local currency to the GDP at USD from the World Bank database (Herath and Aguiar, 2019). For Norway, GDP in 2014 is NOK 3 140 814 million in Table 11123 and USD 506 822 million in the GTAP data based on the World Bank database. Hence, the implicit exchange rate in GTAP is

6.1971 NOK/USD, which we use to transform all data in NOK terms to the GTAP, or vice versa.

The GDP for Norway in GTAP is the same as that from SSB if the exchange rate of 6.1971 NOK/USD is used (Table 2). However, the components of GDP in GTAP differ considerably from those of SSB. Compared to the official national accounting data released by SSB, the gross value added (GVA) in GTAP is 0.7% lower, although both production output and intermediate consumption of SSB are much higher. The difference of GVA between GTAP and SSB is subtracted from the “VAT and taxes on imports” in GTAP, which is then almost the same as the SSB number.

On the income side, the GTAP data on “Consumption of fixed capital” is as much as 31% below SSB level. “Compensation of employees” is also 3% lower, whereas production subsidies (“Other taxes on production, net”) turn out to be 8% higher. As a result, “OPERATING SURPLUS, NET” is slightly higher in GTAP (0.3%).

On the expenditure side, GTAP data on consumption of both households and government is 4.6% higher than that of SSB, while “Gross capital formation” is much lower (12%). Export and import in GTAP are 6% and 10% lower, respectively.

Hence, the differences between GTAP and SSB data are not trivial regarding the components of GDP, although the GDP itself is the same in both sources.

Table 2. The macroeconomic data at basic prices from SSB and GTAP

	SSB Table 1123 (million NOK)	GTAP (million NOK)	Deviation from SSB (%)
Production output	5220797	5359220	2.65
- Intermediate consumption	2412222	2569748	6.53
= GROSS VALUE ADDED	2808575	2789471	-0.68
+ VAT and taxes on imports	332239	351344	5.75
= GROSS DOMESTIC PRODUCT (GDP)	3140814	3140815	0.00
- Consumption of fixed capital	522912	360031	-31.15
- Compensation of employees	1442239	1402752	-2.74
- Other taxes on production, net	-24495	-26482	8.11
= OPERATING SURPLUS, NET	867919	870378	0.28
GDP by expenditure	3140814	3140815	0.00
Household consumption	1288402	1348200	4.64
Government consumption	686825	718407	4.60
<i>Gross capital formation</i>	872567	766492	-12.16
Net export	293020	307716	5.02
Export (b.o.f)	1224803	1149824	-6.12
Import (c.i.f)	-931783	-842108	-9.62

Sources: Own calculation, Statistics Norway (SSB, 2021c), and GTAP database v10 (Chepeliev, 2019).

1.2 Differences of input structure at the sectoral level

GTAP also has sectoral production and consumption data, which are based on national input-output tables supplemented by other data sources. Below we compare the sectoral structures of inputs in production and in final demand in the GTAP data with the data from the official IO table of SSB.

The sectoral classifications of the IO table from SSB and GTAP are different and the first step is mapping and aggregating sectors to harmonize sector classifications (Table 4 in the Appendix). A sector in the SSB table can be an aggregate of several sectors in GTAP, and vice versa. In these cases, we compare the values in the aggregated sectors by summing up across subsectors. For example, we aggregate the 12 agricultural sectors in GTAP to be one agricultural sector, which is compared to the agricultural sector in SSB.

Cases of zeros in one data source but not in the other

Among all the sectoral inputs to production and final demand in the IO table, there are only four non-zero input shares in the official IO table that appear to be zero in the GTAP data (Table 3). In the official IO table, the intermediate input of fishery products (R03) in the air transport services (R51) is 0.0014% of the sectoral output, which becomes zero in GTAP. Paper (ppp) and power&gas (RD) is used by government (GGovt) in the official IO table but not in GTAP. Further, power&gas (RD) accounts for nearly 0.25% of total capital formation in the official IO table, but not in GTAP. All the four numbers are very small and would not make significant differences for any analysis. Hence, we keep the four input shares at zero as in the GTAP data.

Table 3. Non-zero input shares in the official IO table that are zero in GTAP. Per cent.

	Air transport (R51)	Government consumption (GGovt)	Total capital formation (KKAP)
Fishery (R03)	0.001371		
Paper (ppp)		0.000297	
Power&gas (RD)		0.004228	0.243485

There are more zero input shares in the official IO table that become non-zero in GTAP. However, these values are very small and can be neglected (the maximum is less than 0.03%). Hence, we adopt the zeros already in the official IO table.

Input structure of production sectors and final demand

We assume that GTAP data are acceptable if the differences of input shares between the official IO table and GTAP are less than 1%. Hence, we focus on the numbers of the differences greater than 1%. In general, the input structures indicated by the GTAP data may be very different from that by the SSB data for many sectors. For input of labour, represented by the compensation of employees, there are 32 of 49 production sectors

with differences above 1% between the two sources. For the returns to capital, 26 of 49 sectors have differences of above 1%. The largest one is for returns to capital in agriculture, where the GTAP data are nearly 20% lower than SSB data. If our focus is on agriculture in Norway, then the GTAP data may provide considerably biased results for the labor and capital inputs. Hence, a model based on the GTAP data may not be suitable for analysis of certain issues related to a small country like Norway.

2. Apply Norwegian national accounting data in GTAP

As shown in Table 1, there are two versions of macroeconomic data (GDP and its components) in the official national accounting released by SSB. Hence, we will first adjust the official IO table of 2014 to make its macroeconomic data the same as the annually updated data in Table 11123. After the adjustment, the GDP itself in the adjusted IO table is set equal to the GDP in GTAP by using the implicitly derived exchange rate of 6.1971 NOK/USD. The GTAP data of sectoral output, intermediate inputs, consumption of fixed capital, compensation of employees, other taxes on production- net, and operation surplus - net are then replaced by that in the adjusted IO table. This also means that we adopt the latest national accounting data of value added and value-added taxes (VAT) released by SSB. Similarly, we adjust the final demand elements by sector in GTAP to align with the SSB data. To balance supply and demand of products, we introduce an additional parameter in GTAP as “changes in inventory” in the adjusted IO table. The adoption of national account data for imports and exports from Norway also leads to imbalance in international trade for other trade partner regions in GTAP. Hence, we also introduce a ‘changes in inventory’ parameter for other regions, which absorbs the imbalance of international trade due to the adjustment. Energy accounts data (Table 11558 from SSB, 2020) are used to transform values to physical quantities of energy use, which are further linked to CO₂ emissions

(Table 08940 from SSB, 2021a). The adjustment details are described below.

2.1 Adjusting the official IO table for 2014 to be consistent with the latest official macroeconomic data of Norway

After the steps of modest adjustments in this subsection, the macroeconomic data in the adjusted IO table 2014 will be aligned with the most recent version of Table 11123 (SSB, 2021c). The 2014 data of the import matrix (Table 1950 from SSB, 2016) are adjusted proportionally to align with the "Total imports" in Table 11123. The sectoral imports from the adjusted import matrix are used to replace the rows of imports in the official IO table (Table 1750 from SSB, 2016). The other data in the official IO table (Table 1750) are adjusted as follows.

All sectoral total outputs are adjusted proportionally to sum up to the latest aggregated total output shown in Table 11123 (SSB, 2021c). The same adjustment procedure is applied to "Value added" and its components including "Compensation of employees", "Consumption of fixed capital", "Other taxes on production, net", and "Operating surplus, net". However, the "VAT and other production tax" from Table 11123 is allocated to sectors by assuming the same VAT rate for all sectors.

Sectoral aggregated intermediate inputs are calculated as the sectoral total output minus "Value added" and "VAT and other production tax". For production sectors, the intermediate inputs in GTAP are adjusted proportionally to sum up to the new aggregated intermediate inputs.

The final demand for sectoral goods is adjusted proportionally to sum up to the latest aggregated final demand including "Household final consumption", "Final consumption of NPISHs"¹, "Final consumption of general government", "Gross fixed capital formation", and "Total exports", as shown in Table 11123. If necessary, more detailed data from Table 09189 (SSB, 2021b) are used as benchmark data for the adjustment. Finally, sectoral "Changes in inventory" is calculated as the difference between total supply and total demand without the "Changes in inventory".

2.2 Adopting the adjusted national account IO table data in GTAP

Based on the adjusted IO table at basic prices and the data in the import matrix of 2014 in Section 3.1 above, we adjust corresponding data in the GTAP database. GDP can be decomposed for Norway from both sources. A list of definitions of the parameters in this section are provided in Table 5 in the Appendix.

In the GTAP database, GDP by expenditure of Norway can be decomposed by the following procedure:

¹ NPISHs is the short name of "households and non-profit institutions serving households".

$$GDP_n = \underbrace{\sum_i (VDPA_{i,n} + VIPA_{i,n})}_{\text{Household consumption}} + \underbrace{\sum_i (VDGA_{i,n} + VIGA_{i,n})}_{\text{Government consumption}} + \underbrace{\sum_i (VDFA_{i',CGDS',n} + VIFA_{i',CGDS',n})}_{\text{Gross investments}} + \underbrace{\sum_{i,r} VXWD_{i,n,r}}_{\text{Exports}} - \underbrace{\sum_{i,r} VIWS_{i,r,n}}_{\text{Imports}}$$

In the adjusted IO table, GDP of Norway by expenditure can be expressed by

$$GDP_n^{SSb} = \underbrace{\sum_i (FCD_{i',RADJ',H} + FCI_{i',RADJ',H})}_{\text{Household consumption}} + \underbrace{\sum_i (FCD_{i',RADJ',G} + FCI_{i',RADJ',G})}_{\text{Government consumption}} + \underbrace{\sum_i (KKAPD_{i',RADJ'} + KKAPI_{i',RADJ'})}_{\text{Fixed capital formation}} + \underbrace{\sum_i CINV_{i',RADJ'}}_{\text{Changes in inventory}} + \underbrace{\sum_i EX_{i',RADJ'}}_{\text{Exports}} - \underbrace{\sum_i IM_{i',RADJ'}}_{\text{Imports}}$$

where the subscript 'n' represents Norway. As mentioned above, we calculate the implicit exchange rate (R) between USD and NOK by assuming GDP from both sources are the same,

$$R = GDP_n^{SSb} / GDP_n$$

The exchange rate is used to convert the NOK values in the adjusted IO table into USD values used in the GTAP database. The next step is to replace the corresponding data in the GTAP database with the adjusted IO table data for Norway.

The GTAP classification of production sectors is different from the adjusted IO table. Hence, we make a list mapping sectors from both sources (Table 4 in the Appendix). There are three cases of the sectoral mapping: One SSB sector belongs to several GTAP sectors, several sectors of SSB belong to one sector of GTAP, and the sector is the same in both sources. For the latter two cases, we can directly add up the SSB data by sector to obtain the corresponding GTAP sectoral data. For the first case, e.g., oil and gas are separate sectors in GTAP, we calculate the shares of each sector relative to the aggregate amount of both sectors based on the GTAP data. The shares are then multiplied with the aggregate amount of the SSB data to obtain the amount of each sector in the adjusted GTAP database.

The intermediate input of imported goods from the adjusted IO table of Norway replaces the corresponding GTAP data ($VIFM_{i,j,n}$). Similarly, the final consumption of imported good from the same SSB IO table replaces the corresponding GTAP data, i.e., $VIPM_{i,n}$ and $VIGM_{i,n}$. We assume that $KKAP_i$ in the SSB table corresponds to gross investments in GTAP ($VIFA_{i',CGDS',n}$). Then, we add one additional parameter in GTAP ($VICM_{i,n}$) corresponding to the additional term of 'Changes in inventory' in the SSB table. The new parameter 'changes in inventory' ($VICM_{i,n}$) in GTAP is treated as the residual term to balance the total supply and demand of imported goods to Norway. For other countries, the 'Changes in inventory' is used to balance the international trade due to the adjustment of trade for Norway.

The data of domestically produced goods and value added are obtained by subtracting the imports from the adjusted IO table of Norway from the total amounts of production. Following the same procedure, we replace the GTAP data for Norway including intermediate inputs and investments ($VDFM_{i,j,n}$), final consumption ($VDPM_{i,n}$ and $VDGM_{i,n}$), and add the new parameter of 'Changes in inventory' ($VDCM_{i,n}$).

We then assume the same rates of taxes and subsidies for a sector product of both imported and domestic origin. The difference between domestic consumption of goods at market prices and at agent prices is the so-called sales taxes in the GTAP database, which corresponds to "Taxes less subsidies on products" (the row 'RNTS') in the adjusted IO table of Norway. Hence, we allocate the "Taxes less subsidies on products" proportionally to the new GTAP data of domestic consumption to obtain data at agent prices ($VIFA_{i,j,n}$, $VIPA_{i,n}$, $VIGA_{i,n}$, $VICA_{i,n}$, $V DFA_{i,j,n}$, $VDPA_{i,n}$, $VDGA_{i,n}$, and $VDCA_{i,n}$).

Primary factors in the adjusted IO table of Norway include labor and capital. However, in the GTAP database, labor is divided into five types, 2 skilled (professionals and technical) and 3 unskilled (agricultural, clerical and other unskilled). Capital is divided into land, produced capital, and natural resources in GTAP. Hence, we allocate the SSB primary factor income proportional to their shares in GTAP capital income. The primary factor income from SSB is allocated to GTAP at agent prices, i.e., $EVFA_{f,i,n}$. The corresponding values at market prices ($VFM_{f,i,n}$) are found by scaling up/down agent prices to match the original market price level in GTAP ($EVFA_{f,i,n}$), which then implicitly assumes the same factor taxes in production as that in GTAP. Similarly, we get the new parameter ($EVOA_{f,n}$) by assuming the same direct factor income tax rates as that implicit in GTAP.

We also replace the capital depreciation in GTAP ($VDEP_n$) by summing up the 'Consumption of fixed capital' in the adjusted IO table data of Norway.

We shift up/down all the imports (or exports) by region ($VIWS_{i,r,n}$ or $VXWD_{i,n,r}$) by the same rate to make the sectoral imports (or export) data in GTAP the same as that in the SSB data. We obtain the corresponding data at market prices ($VIMS_{i,r,n}$ or $VXMD_{i,n,r}$) by assuming the same trade tax/tariff rates implicit in GTAP.

The international transaction ($VST_{i,n}$) is obtained by shifting the GTAP data up/down proportional to the exports of the corresponding transport sectors.

2.3 Adopting energy accounts data from SSB

In the GTAP database, there is a separate file (gdsvole.gdx/har) including energy use data in physical terms (mtoe). The energy use data can be adjusted to be consistent with the energy accounts data from SSB (Table 11558 from SSB, 2020). Adjusting the energy use in physical terms for Norway does not affect data of other regions in GTAP. .

The sectors listed in the SSB energy accounts are different from both the IO tables of SSB and GTAP. Hence, we make a list, mapping the energy accounts sectors to GTAP sectors (Table 6 in the Appendix). Then we allocate the energy use data from SSB energy accounts to the GTAP sectors proportional to the new adjusted values of corresponding

energy carriers in the basic GTAP database, if necessary. Otherwise, we simply aggregate the energy use data in the Table 11558 (SSB, 2020).

2.4 Adjusting CO₂ emissions from fossil fuel use

We adopt the SSB data of CO₂ emissions from fossil fuel use (Table 08940 from SSB, 2021a). We allocate the CO₂ emissions to GTAP energy use proportional to the adjusted physical energy use data in the previous section, which are used to replace the corresponding energy data in a revised GTAP file of CO₂ emissions (CO2.gdx/har). The process emissions shown in the SSB Table 08940 are allocated to relevant sectors in GTAP (Table 7 in the Appendix shows the mapping of sectors). If one sector in the SSB Table 08940 corresponds to several GTAP sectors, then we allocate the stationary emissions proportional to the output share of the involved GTAP sectors, and so for the process emissions, which is allocated based on sectoral outputs in the GTAP data. Similar treatment can be done for other GHGs in SSB Table 08940, if necessary.

3. Concluding remark

We obtain an adjusted GTAP database adopting exactly the national accounting data of Norway including input-output table, energy accounts and CO₂ emissions from fossil fuels and industrial processes. Note that in the new database, we add a new parameter called "changes in inventory" to balance the demand and supply in Norway and to absorb the imbalance of international trade for other regions. We choose to keep it there and users can decide how to deal with it rather than no other options. For example, in a recursive dynamic CGE model, the "changes in inventory" can be exogenously assumed to get closer to zero over time until later when it remains zero.

This is a first attempt to adjust a GTAP database based on national accounting data of Norway. In the future, we could continue to adjust the database to improve the representation for Norwegian economy in GRACE.

Appendix

Table 4. Mapping sectors between input-output table of SSB and GTAP

Sector here	IO sector from SSB		GTAP v.10 sector	
Code	Code	Explanation	Code	Explanation
R01	R01	Products of agriculture, hunting and related services	pdr	Paddy rice
			wht	Wheat
			gro	Cereal grains nec
			v_f	Vegetables, fruit, nuts
			osd	Oil seeds
			c_b	Sugar cane, sugar beet
			pfb	Plant-based fibers
			ocr	Crops nec
			ctl	Bovine cattle, sheep and goats, horses
			oap	Animal products nec
			rmk	Raw milk
wol	Wool, silk-worm cocoons			
R02	R02	Products of forestry, logging and related services	frs	Forestry
R03	R03	Fish and other fishing products; aquaculture products; support services to fishing	fsh	Fishing
R10_12	R10_12	Food products, beverages and tobacco products	b_t	Beverages and tobacco products
			cmt	Bovine meat products
			mil	Dairy products
			ofd	Food products nec
			omt	Meat products nec
			pcr	Processed rice
			sgr	Sugar
vol	Vegetable oils and fats			
R13_15	R13_15	Textiles, wearing apparel and leather products	lea	Leather products
			tex	Textiles

			wap	Wearing apparel
R16	R16	Wood and of products of wood and cork, except furniture; articles of straw and plaiting materials	lum	Wood products
ppp	R17	Paper and paper products	ppp	Paper products, publishing
	R18	Printing and recording services		
R21	R19	Coke and refined petroleum products	p_c	Petroleum, coal products
R21	R20	Chemicals and chemical products	chm	Chemical products
R21	R21	Basic pharmaceutical products and pharmaceutical preparations	bph	Basic pharmaceutical products
R22	R22	Rubber and plastics products	rpp	Rubber and plastic products
R23	R23	Other non-metallic mineral products	nmm	Mineral products nec
R24	R24	Basic metals	i_s	Ferrous metals
			nfm	Metals nec
R25	R25	Fabricated metal products, except machinery and equipment	fmp	Metal products
R26	R26	Computer, electronic and optical products	ele	Computer, electronic and optical products
R27	R27	Electrical equipment	eeq	Electrical equipment
R28	R28	Machinery and equipment n.e.c.	ome	Machinery and equipment nec
R29	R29	Motor vehicles, trailers and semi-trailers	mvh	Motor vehicles and parts
R30	R30	Other transport equipment	otn	Transport equipment nec
omf	R31_32	Furniture; other manufactured goods	omf	Manufactures nec
	R33	Repair and installation services of machinery and equipment		
wtr	R36	Natural water; water treatment and supply services	wtr	Water
	R37_39	Sewerage; waste collection, treatment and disposal activities; materials recovery; remediation activities and other waste management services		

trd	R45	Wholesale and retail trade and repair services of motor vehicles and motorcycles	trd	Trade
	R46	Wholesale trade services, except of motor vehicles and motorcycles		
	R47	Retail trade services, except of motor vehicles and motorcycles		
R49	R49	Land transport services and transport services via pipelines	otp	Transport nec
R50	R50	Water transport services	wtp	Water transport
R51	R51	Air transport services	atp	Air transport
R52	R52	Warehousing and support services for transportation	whs	Warehousing and support activities
cmn	R53	Postal and courier services	cmn	Communication
	R58	Publishing services		
	R59_60	Motion picture, video and television programme production services, sound recording and music publishing; programming and broadcasting services		
	R61	Telecommunications services		
	R62_63	Computer programming, consultancy and related services; information services		
ofi_ins	R64	Financial services, except insurance and pension funding	ofi	Financial services nec
	R65	Insurance, reinsurance and pension funding services, except compulsory social security	ins	Insurance (formerly isr)
	R66	Services auxiliary to financial services and insurance services	ofi ins	Financial services nec Insurance (formerly isr)
R68	R68A	Imputed rents of owner-occupied dwellings	dwe	Dwellings
R68	R68B	Real estate activities (excluding imputed rents)	rsa	Real estate activities
obs	R69_70	Legal and accounting services; services of head offices; management consulting services	obs	Business services nec

	R71	Architectural and engineering services; technical testing and analysis services		
	R72	Scientific research and development services		
	R73	Advertising and market research services		
	R74_75	Other professional, scientific and technical services; veterinary services		
	R77	Rental and leasing services		
	R78	Employment services		
ros	R79	Travel agency, tour operator and other reservation services and related services	ros	Recreational and other services
	R80_82	Security and investigation services; services to buildings and landscape; office administrative, office support and other business support services		
osg	R84	Public administration and defence services; compulsory social security services	osg	Public Administration and defense
hht	R86	Human health services	hht	Human health and social work activities
	R87_88	Social work services		
ros	R90_92	Creative, arts and entertainment services; library, archive, museum and other cultural services; gambling and betting services	ros	Recreational and other services
	R93	Sporting services and amusement and recreation services		
	R94	Services furnished by membership organisations		
	R95	Repair services of computers and personal and household goods		
	R96	Other personal services		
RB	RB	Mining and quarrying	coa	Coal
			gas	Gas
			oil	Oil
			oxt	Other Extraction (formerly omn Minerals nec)
RD	RD		ely	Electricity

		Electricity, gas, steam and air-conditioning	gdt	Gas manufacture, distribution
RF	RF	Constructions and construction works	cns	Construction
RI	RI	Accommodation and food services	afs	Accommodation, Food and service activities
RP	RP	Education services	edu	Education
ros	RT	Services of households as employers; undifferentiated goods and services produced by households for own use	ros	Recreational and other services
osg	RU	Services provided by extraterritorial organisations and bodies	osg	Public Administration and defense

Sources: Own compilation, Statistics Norway (SSB, 2016), and GTAP database v10 (Chepeliev, 2019).

Table 5. A list of definitions of parameters in Section 3.2

Name	Explanation
R	Derived exchange rate (NOK/USD)
<i>From GTAP v10 database (Chepeliev, 2019)</i>	
GDP_n	Gross domestic product (GDP) of Norway (n)
$VDPA_{i,n}$	Household consumption of domestically produced goods i at agent prices
$VIPA_{i,n}$	Household consumption of imported goods i at agent prices
$VDGA_{i,n}$	Government consumption of domestically produced goods i at agent prices
$VIGA_{i,n}$	Government consumption of imported goods i at agent prices
$VDF A_{i,CGDS',n}$	Demand for domestically produced goods i Induced by gross investments at agent prices
$VIFA_{i,CGDS',n}$	Demand for imported goods i Induced by gross investments at agent prices
$VXWD_{i,n,r}$	Exports of goods i from Norway to a region r
$VIWS_{i,r,n}$	Imports of goods i from a region r to Norway
$VDF A_{i,j,n}$	Intermediate consumption of domestically produced goods i by sector j at agent prices
$VIFA_{i,j,n}$	Intermediate consumption of imported goods i by sector j at agent prices
$VDFM_{i,j,n}$	Intermediate consumption of domestically produced goods i by sector j at market prices
$VIFM_{i,j,n}$	Intermediate consumption of imported goods i by sector j at market prices
$VDPM_{i,n}$	Household consumption of domestically produced goods i at agent prices at market prices
$VIPM_{i,n}$	Household consumption of imported goods i at agent prices at market prices

$VDGM_{i,n}$	Government consumption of domestically produced goods i at market prices
$VIGM_{i,n}$	Government consumption of imported goods i at market prices
$VDCM_{i,n}$	Changes in inventory of domestically produced goods i (a new parameter after adjustments)
$VICM_{i,n}$	Changes in inventory of imported goods i (a new parameter after adjustments)
$EVFA_{f,i,n}$	Input of primary factor f in production of sector i at agent prices
$VFM_{f,i,n}$	Input of primary factor f in production of sector i at market prices
$EVOA_{f,n}$	Input of primary factor f in production of sector i at agent prices
$VDEP_n$	Capital depreciation
$VST_{i,n}$	International transaction cost of sector i
<i>From national accounting data of Norway (SSB, 2016)</i>	
GDP_n^{ssb}	Gross domestic product (GDP) of Norway (n)
$FCD_{i,RADJ',H}$	Household consumption of domestic produced goods i
$FCI_{i,RADJ',H}$	Household consumption of imported goods i
$FCD_{i,RADJ',G}$	Government consumption of domestic produced goods i
$FCI_{i,RADJ',G}$	Government consumption of imported goods i
$KKAPD_{i,RADJ'}$	Demand for domestic produced goods i Induced by gross investments
$KKAPI_{i,RADJ'}$	Demand for imported goods i Induced by gross investments
$CINV_{i,RADJ'}$	Changes in inventory of goods i
$EX_{i,RADJ'}$	All exports of goods i from Norway
$IM_{i,RADJ'}$	All imports of goods i to Norway

Sources: Own compilation and GTAP database v10 (Chepeliev, 2019).

Table 6. Mapping sectors between SSB energy accounts and GTAP database

Industry in energy accounts (SSB, 2020)	GTAP v.10 sector
N010101 Agriculture and hunting	pdr, wht, gro, v_f, osd, c_b, pfb, ocr, ctl, oap, rmk, wol
N010102 Forestry and logging	frs
N010200 Fishing	fsh
N010300 Aquaculture	fsh
N020100 Mining and quarrying	coa, oxt
N020200-020300 Oil and gas extraction, including service activities and transport via pipelines	oil, gas, gdt
N030100 Food products, beverages and tobacco products	cmt, omt, vol, mil, pcr, sgr, ofd, b_t
N030200 Textiles, wearing apparel, leather	tex, wap, lea
N030301 Wood and wood products, except furniture	lum
N030302 Paper and paper products	ppp
N030400 Printing and reproduction of recorded media	ppp
N030500 Refined petroleum products, chemicals and chemical products, pharmaceutical products	p_c, chm, bph
N030601 Rubber and plastic products	rpp
N030602 Other non-metallic mineral products	nmm

N030700 Basic metals	i_s
N030801 Fabricated metal products, except machinery and equipment	nfm, fmp
N030802 Computer and electronic products	ele
N030803 Electrical equipment	eeq
N030804 Machinery and other equipment	ome
N030901 Motor vehicles and trailers	mvh
N030902 Other transport equipment	otn
N031000 Furniture and other manufacturing	omf
N031100 Repair and installation of machinery and equipment	omf
N040100 Electricity, gas, steam and air conditioning supply	TnD, NuclearBL, CoalBL, GasBL, WindBL, OilBL, OtherBL, GasP, OilP, SolarP, HydroBL, HydroP, gdt
N040201 Water collection, treatment and supply	wtr
N040202 Sewerage and waste management	wtr
N050000 Construction	cns
N060100 Wholesale and retail trade, repair of motor vehicles	trd
N060200 Accommodation and food service activities	afs
N070100 Post and telecommunications	cmn
N070201 Publishing activities	cmn
N070202 Motion picture, video and music production, broadcasting	cmn
N070203 Computer programming and information service activities	cmn
N070300 Financial and insurance activities	ofi, ins
N070400 Real estate activities	rsa
N070500 Other service activities	obs, ros
N080100 Transport via pipelines	otp
N080200 Ocean transport	wtp
N080301 Land transport, except transport via pipelines	otp
N080302 Inland water and costal transport	wtp
N080303 Air transport	atp
N080304 Warehousing and support activities for transportation	whs
N090100 Education	edu
N090201 Human health activities	hht
N090202 Residential care and other social work activities	hht
N100000 Public administration and defence	osg
H000000 Households	hh

Source: Own compilation, Statistics Norway (SSB, 2020) and GTAP database v10 (Chepeliev, 2019).

Table 7. Mapping sectors between SSB emissions data and GTAP database

Source (or sector) of SSB (2021a)	GTAP v.10 sector	Emission type
1_1 Oil and gas extraction - stationary combustion	oil, gas	stat
1_2 Oil and gas extraction - process emissions	oil, gas	proc
2_1_1_0 Wood processing - stationary combustion	lum	stat
2_1_2_0 Oil refining - stationary combustion	p_c	stat
2_1_3_1 Petrochemistry - stationary combustion	chm	stat

2_1_3_2 Fertilizer - stationary combustion	chm	stat
2_1_3_3 Other chemical industries - stationary combustion	chm	stat
2_1_4_1 Cement	nmm	stat
2_1_4_2 Other mineral industries - stationary combustion	nmm	stat
2_1_5_0 Metal industry - stationary combustion	i_s, nfm, fmp	stat
2_1_9_0 Other industries and mining - stationary combustion	coa, oxt, gdt, cmt, omt, vol, mil, pcr, sgr, ofd, b_t, tex, wap, lea, ppp, bph, rpp, ele, eeq, ome, mvh, otn, omf, wtr, cns	stat
2_2_1_0 Wood processing - process emissions	lum	proc
2_2_2_0 Oil refining - process emissions	p_c	proc
2_2_3_1 Petrochemistry - process emissions	chm	proc
2_2_3_2 Fertilizer - process emissions	chm	proc
2_2_3_3 Carbides - process emissions	chm	proc
2_2_3_9 Chemical industri, other - process emissions	chm	proc
2_2_4_1 Cement - process emissions	nmm	proc
2_2_4_9 Mineral industry, other - process emissions	nmm	proc
2_2_5_1 Iron, steel and ferro-alloys - process emissions	i_s	proc
2_2_5_2 Aluminium - process emissions	nfm	proc
2_2_5_3 Other metals - process emissions	nfm	proc
2_2_5_4 Anodes - process emissions	ele	proc
2_2_9_1 Coal mining (process emissions)	coa	proc
2_2_9_2 Other mining - process emissions	oxt	proc
2_2_9_3 Fermentation (bread and beer) - process emissions	ofd, b_t	proc
2_2_9_9 Other industries - process emissions	oil, gas, cmt, omt, vol, mil, pcr, sgr, tex, wap, lea, ppp, bph, rpp, fmp, eeq, ome, mvh, omf, wtr, cns	proc
3_0_0_0 Energy supply	-	-
3_1_1_0 Gas power and other electric power production	TnD, NuclearBL, CoalBL, GasBL, WindBL, OilBL, OtherBL, GasP, OilP, SolarP, HydroBL, HydroP, gdt	stat
3_1_2_0 District heating (except waste incineration)	TnD, NuclearBL, CoalBL, GasBL, WindBL, OilBL, OtherBL, GasP, OilP, SolarP, HydroBL, HydroP	stat
3_1_3_0 Waste incineration	TnD, OtherBL	stat
4_1_1_0 Heating in primary industries	pdr, wht, gro, v_f, osd, c_b, pfb, ocr, ctl, oap, rmk, wol, frs, fsh, coa, oxt, oil, gas	stat
4_1_2_0 Heating in construction and building	cns	stat

4_1_3_0 Heating in other service industries	trd, afs, cmn, ofi, ins, rsa, obs, ros, whs, edu, hht, osg	stat
4_2_0_0 Heating in households	cgds	stat
5_1_1_0 Passenger cars - petrol	otp	stat
5_1_2_0 Passenger cars - diesel	otp	stat
5_2_1_0 Light duty vehicles - petrol	otp	stat
5_2_2_0 Light duty vehicles - diesel	otp	stat
5_3_1_0 Heavy duty vehicles - petrol	otp	stat
5_3_2_0 Heavy duty vehicles - diesel etc_	otp	stat
5_4_1_0 Motor cycles	otp	stat
5_4_2_0 Mopeds	otp	stat
6_1_0_0 Railways	otp	stat
6_2_1_0 Domestic aviation < 1000 m	atp	stat
6_2_2_0 Domestic aviation > 1000 m	atp	stat
6_3_1_0 Navigation - coastal traffic etc	wtp	stat
6_3_2_0 Navigation - fishing	wtp	stat
6_4_1_0 Leisure boats	wtp	stat
6_4_2_0 Snowmobiles	otp	stat
6_4_3_0 Tractors	otp	stat
6_4_4_0 Motorized equipment: petrol	otp	stat
7_1_1_0 Enteric fermentation	ctl	stat
7_1_2_0 Manure	ctl	stat
7_2_1_0 Fertilizer	pdr, wht, gro, v_f, osd, c_b, pfb, ocr	stat
7_2_9_0 Agriculture	pdr, wht, gro, v_f, osd, c_b, pfb, ocr, ctl, oap, rmk, wol, frs, fsh	stat
9_1_0_0 Landfill gas	wtr	stat
9_2_1_0 Road wear	otp	stat
9_2_2_0 Tyre and brake wear	otp	stat
9_2_3_0 Railway contact wire abrasion	otp	stat
9_3_1_0 Products containing fluorinated gases	chm	stat
9_3_2_0 Other products	chm	stat
9_9_1_0 Fires	frs	stat
9_9_2_0 Gas distribution	gdt	stat
9_9_3_0 Petrol distribution	p_c	stat
9_9_4_0 Whitening of industrial waste	wtr	stat
9_9_5_0 Waste water and waste water handling	wtr	stat
9_9_6_0 Composting and biogas facilities	gdt	stat
9_9_9_0 Sources not mentioned elsewhere	-	-

Note: In the last column, "stat" refers to emissions from stationary combustion and "proc" refers to process emissions.

References

- 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.
- CARATTINI, S., KALLBEKKEN, S. & ORLOV, A. 2019. How to win public support for a global carbon tax. *Nature*, 565, 289-291.
- CHEPELIEV, M. 2019. GTAP-Power 10 Data Base: A Technical Note [Online]. Available: https://www.gtap.agecon.purdue.edu/resources/res_display.asp?RecordID=5938 [Accessed 20 Nov. 2021].
- HERATH, N. & AGUIAR, A. 2019. Macroeconomic Data T2 - Global Trade, Assistance, and Production: The GTAP 10 Data Base A2 - Aguiar, Angel. Department of Agricultural Economics, Purdue University, West Lafayette, IN: Global Trade Analysis Project (GTAP).
- SSB. 2016. Supply and Use and Input-Output tables [Online]. Available: https://www.ssb.no/en/nasjonalregnskap-og-konjunkturer/tables/supply-and-use-and-input-output#published_31_August_2016 [Accessed 11 Nov. 2021].
- SSB. 2020. 11558: Energy accounts. Production and consumption of energy products, by industries and households by energy account item, energy product accounts, contents, year and industry [Online]. Available: <https://www.ssb.no/en/statbank/table/11558> [Accessed 11 Nov. 2020].
- SSB. 2021a. 08940: Greenhouse gases, by source, energy product and pollutant 1990 - 2020 [Online]. Available: <https://www.ssb.no/en/statbank/table/08940> [Accessed 11 Nov. 2021].
- SSB. 2021b. 09189: Final expenditure and gross domestic product 1970 - 2020 [Online]. Available: <https://www.ssb.no/en/statbank/table/09189> [Accessed 11 Nov. 2021].
- SSB. 2021c. 11123: Non-financial and financial accounts by institutional sector (NOK million) 1996 - 2020 [Online]. Available: <https://www.ssb.no/en/statbank/table/11123/> [Accessed 11 Nov. 2021].
- WALMSLEY, T., NARAYANAN, B., AGUIAR, A. & MCDOUGALL, R. 2018. Building a global database: consequences for the national I-O data. *Economic Systems Research*, 30, 478-496.
- WEI, T., ZHANG, T., CUI, X., GLOMSRØD, S. & LIU, Y. 2019. Potential Influence of Climate Change on Grain Self-Sufficiency at the Country Level Considering Adaptation Measures. *Earth's Future*, 7, 1152-1166.
- AAHEIM, A., AMUNDSEN, H., DOKKEN, T. & WEI, T. 2012. Impacts and adaptation to climate change in European economies. *Global Environmental Change-Human and Policy Dimensions*, 22, 959-968.

AAHEIM, A., ORLOV, A., WEI, T. & GLOMSRØD, S. 2018. GRACE model and applications. Report. Oslo, Norway: CICERO.

AAHEIM, A. & RIVE, N. 2005. A Model for Global Responses to Anthropogenic Changes in the Environment (GRACE). Report. Oslo, Norway: CICERO.

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