CO2 Emissions in GTAP-E: Ready-for-aggregation GTAP 6.0 data

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Introduction

This document describes the transformation of CO2 emissions data (Lee, 2002) into a database for use in the GTAP-E model. The current GTAP-E model and database available was constructed by Burniaux and Truong (2002) with a specific sectoral and regional aggregation. This present CO2 data has been built to be used with a new version of GTAP-E (Golub and McDougall, 2007). This GTAP-E version corrects some errors in the original version, and ads more features, like providing more technological change possibilities.

Therefore, the main objective of preparing these data is to have a database that can be fully aggregated into a certain regional and sectoral specification, and not just an application limited to certain regions and sectors as the GTAP-E model has been until now. The dimensions of these data are 87 regions and 57 sectors, as off GTAP database version 6.0.

We have used Lee's latest CO2 emissions release, which major difference with previous releases of CO2 emissions data is the treatment of Petroleum Products (p_c) usage by "p_c" that changed from fully emitting to non-emitting. This new treatment is closer to the truth (globally, about two thirds is non-emitting).

Data contents

The accompanying zip file "GTAP-E CO2 V6.ZIP" includes the following files:
1) GTAP_V6_CO2.HAR: Original data from Lee (2002)
2) ASETS.HAR: file containing sets used with CO2Emmissions2.TAB.
3) CO2Emmissions.TAB: file that transforms GTAP_V6_CO2.HAR into GTAP-E format.
4) CO2Emmissions.CMF: command file for use with CO2Emmissions.TAB.

OUTPUT FILES:
5) GTAP_E_CO2.HAR: CO2 data in GTAP-E format without modifications.
6) GTAP_E_CO2_WIU.HAR: CO2 emissions in GTAP-E format without emissions for some inter-energy sector intermediate use in Gigagrams.
7) GTAP_E_CO2_DIFF.HAR: file that compares GTAP_E_CO2.HAR and GTAP_E_CO2_WIU.HAR, before and after intermediate use modification.
8) GTAP_E_CO2_WIUT.HAR: CO2 emissions in GTAP-E format without emissions for some inter-energy sector intermediate use in Tonnes.

Instructions for use

These data (all headers) should be added to the GTAP database version 6.0 (both base data and parameter file), and aggregated using the aggregation program Flexagg.

Additionally, in retaining the standard GTAP 57 sectors, we have kept "gdt" separate from "gas". However, to work with the current GTAP-E solution program, it would be best always to aggregate them together before running the model.

Base data

Data used for basedata.har were built from two main data sources: CO2 emissions data from Lee (2007) and the basedata.har file from GTAP 6.0 database (Table 1). The data from GTAP database v6.0 (headers DFNC, DGNC, DPNC, IFNC, IGNC, IPNC in Table 1) was copied directly from basedata.har with only name changes, since nominal carbon tax in the original data (NTAX) is equal to zero, which makes values in both datasets are the same. To do this, we aggregated GTAP 6.0 database into a fully disaggregated dataset (87 regions and 57 sectors), and then copied the headers. Because of GTAP licensing issues, these data has not been posted with the CO2 emissions data.

Lee (2007) CO2 emissions data, presents CO2 emissions data from energy commodities consumption by firm's intermediate use, households, and government, both from domestic and import sources. Energy commodities include coal extraction (coa), crude oil (oil), natural gas extraction (gas), petroleum products (p_c), electricity (ely) and gas manufacture and distribution (gdt). CO2 emissions for electricity are equal to zero, as well as for all other non-energy commodities.

Table 1. Source Data for BASEDATA.HAR in GTAP-E

Name	Header	Dimension	Data Source
CO_2 emissions quota (M tons of C)	CO2Q	REG	GTAP_V6_CO2.HAR [CO2] [*Sum EGY] [*Sum SRC] [*Sum ALLSEC] *REG
Intermediates - Domestic inputs net of C tax	DFNC	TRAD *PROD *REG	VDFA in BASEDATA.HAR in GTAP 6.0
Government – Domestic purchases net of C tax	DGNC	TRAD *REG	VDGA in BASEDATA.HAR in GTAP 6.0
Private Households -Domestic purchases net of C tax	DPNC	TRAD *REG	VDPA in BASEDATA.HAR in GTAP 6.0
Intermediates – Imported inputs net of C tax	IFNC	TRAD *PROD *REG	VIFA in BASEDATA.HAR in GTAP 6.0
Government – Imported purchases net of C tax	IGNC	TRAD *REG	VIGA in BASEDATA.HAR in GTAP 6.0
Private Households - Imported purchases net of C tax	IPNC	TRAD *REG	VIPA in BASEDATA.HAR in GTAP 6.0
Nominal carbon tax in USD per ton of C.	NTAX	REG	Vector of zeros
CO_2 due to private consumption of domestic	CODP	TRAD *REG	GTAP_V6_CO2.HAR [CO2]*EGY_COMM[*dom] [*HH]*REG
CO_2 due to private consumption of imports	COIP	TRAD *REG	GTAP_V6_CO2.HAR [CO2]*EGY_COMM[*imp] [*HH]*REG
CO_2 due to government consumption of domestic	CODG	TRAD *REG	GTAP_V6_CO2.HAR | [CO2]*EGY_COMM[*dom] [*Govt]*REG
CO_2 due to government consumption of imports	COIG	TRAD *REG	GTAP_V6_CO2.HAR [CO2]*EGY [*imp] [*Govt]*REG
CO_2 due to intermediate use of domestic	CODF	TRAD *PROD *REG	GTAP_V6_CO2.HAR [CO2] [*each EGY] [*dom] [*PROD]*REG
CO_2 due to intermediate use of imports	COIF	TRAD *PROD *REG	GTAP_V6_CO2.HAR [CO2] [*each EGY] [*imp] [*PROD]*REG

* EGY_COMM sectors include coa, oil, gas, p_c, ely, and gdt.

Data adjustments[1]

Not all consumption of energy commodities generates carbon dioxide emissions. Most obviously, this is so where the purchasing sector does not burn the fuel, but transforms it into fuel of another kind, most importantly, for crude oil inputs into petroleum refining. Other examples involve intra-industry usage, that is, transfers between establishments within the same sector, for example, between coal mines and coal cleaning plants, both classed as "coa" in the GTAP sectoral classification.

The GTAP data energy data derive not from the contributed I-O tables but from the IEA's extended energy balances. For inputs into energy industries, these distinguish between non-emitting "transformation" flows and emitting "energy sector" flows. Flows involving neither combustion nor transformation, such as those involved in coal cleaning, are generally ignored.

We turn therefore to those source data for guidance on the appropriate treatment of energy inputs into energy industries. From them, we find:
- Coal and crude oil inputs into petroleum refining are mostly transformed, but gas inputs mostly combusted.
- Coal inputs into gas works are mostly transformed.
- Petroleum products inputs into coal, oil, and gas extraction are combusted.
- Gas inputs into coal extraction are combusted.

Some special issues arise with natural gas usage in oil and gas extraction. First, in the source data, this entry is puzzlingly high, five times total energy usage in coal mining, raising the question whether it really is ordinary energy usage, as the source data indicate. On the other hand, the notes to the source data say that it excludes flaring. Second, in preparing the data for GTAP, we commit an error in apportioning the flow: as intended, we assign 100% to the gas industry, but inadvertently, we assign 60% to the oil industry. So we overstate considerably total fossil fuel usage in fossil fuel extraction (there is also an erroneous assignment of oil usage to the gas industry, but that is much smaller).

On balance, we prefer to treat the coal-coal, oil-oil, and gas-gas flows as emitting, but not the oil-gas and gas-oil flows. For the first set, we prefer to take the IEA data at face value, and see if that provokes any informative response, than to suppress it. For the second set, for abatement simulations it's probably more important for the emissions estimate to be accurate than to be consistent with the energy usage estimate.

There is a divergence between our treatment of intra-industry usage and that of the Burniaux-Truong (2002) version of GTAP-E, in which all such usage is treated as non-emitting, that assumption being coded into the theory of the model. In the Golub-McDougall (2007) version, the distinction between emitting and non-emitting flows is entirely data-driven; users may convert any flow from emitting to non-emitting by zeroing out the appropriate cell of the appropriate emissions array.

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[1] Notes in this section follow discussions and suggestions by Robert McDougall and Huey-Lin Lee.

Table 2 summarizes adjustments to CO2 emissions data from Lee (2007), where cells with zeros denote treatment of intermediate energy commodities input into fuel sectors as non emitting and pluses (+) denote CO2 emissions.

Table 2. CO2 emissions treatment of intermediate energy commodities input into fuel sectors

Sector	Coal extraction (coa)	Oil extraction (oil)	Gas extraction (gas)	Gas distribution (gdt)	Petroleum products (p_c)	Electricity (ely)
Coal extraction (coa)	+	0^1	0^2	0^2	0	+
Oil extraction (oil)	0^1	+	0	0	0	+
Gas extraction (gas)	$+^3$	0	+	+	+	+
Gas distribution (gdt)	$+^3$	0	+	+	+	+
Petroleum Prod. (p_c)	$+^3$	$+^3$	$+^4$	$+^4$	0	+
Electricity (ely)	0	0	0	0	0	0

[1] data preparation artifact; [2] transformation; [3] energy use; [4] energy use > transformation

Parameter data

In terms of additional data and information for parameters, GTAP-E requires specific parameters for energy substitution. These are outlined in Table 3. All elasticities of substitution for sub-production from GTAP-E sectors were mapped directly to standard GTAP sectors and regions using the mapping in Appendix 1, 2, and 3. Values for ELEN, ELKE, ELNC and ELNE were taken from GTAP-E and mapped into sectors and regions using the values in Table 3.

The last two rows of Table 3 relate to scenarios of carbon emission trading. TRBL refers to trading blocks of carbon emissions, and MAPB refers to the mapping between regions and trading blocks.

Table 3. GTAP-E specific parameters in DEFAULT.PRM

Name	Dimension	coa, oil, gas, p_c, gdt, cgds	All other GTAP sectors
Elasticity of substitution in endowment-energy sub-production (ESUBVA)	PROD *REG	-	-
Substitution elasticity in energy sub-production (ELEN)	PROD *REG	0	1.0
Substitution elasticity in capital-energy sub-production (ELKE)	PROD *REG	0	0.5
Substitution elasticity in non-coal energy sub-production (ELNC)	PROD *REG	0	1.0
Substitution elasticity in non-electricity energy sub-production (ELNE)	PROD *REG	0	0.5
Set TR_BLOCK emissions trading blocs (TRBL)		-	-
Mapping REGTOBLOC from REG to TRBL (MAPB*)		-	-

* Depends on elements of set TRD_BLOCK, and it changes depending on scenario of carbon emissions trading.

However, there is one major change between the standard GTAP and the GTAP-E database. The elasticity of substitution of value added (ESUBVA) changes in terms of dimensionality, adding a regional dimension, with region specific values (Table 4). Burniaux and Truong (2002) do not report how this regional dimension was added; on the contrary, it reports (p. 33 f.) regionally uniform elasticities, contrary to the actual parameters files. Not only that, but for some industries the actual parameter settings are far different from standard GTAP; for coal, for instance, they range between 3.923 and 3.999, whereas in standard GTAP, and in Burniaux and Truong (2002),

it's 0.2. For now, we follow GTAP technical paper No. 16, and expand the original regions in Burniaux and Truong (2002) to the 87 regions in GTAP version 6.0 using Appendix 1, 2, and 3.

Table 4. Elasticity of substitution in endowment-energy sub-production

Sector	USA	EU	EEFSU	Japan	RoA1	Energy Exporters (EEx)	China and India	Rest of the World
Agriculture	0.0294	0.1525	0.0861	0.2203	0.1466	0.1175	0.1130	0.1218
Coal	3.9993	3.9856	3.9955	3.9969	3.9725	3.9284	3.9928	3.9226
Oil	0.4000	0.3908	0.3999	0.3999	0.3966	0.3984	0.3995	0.3899
Gas	0.0415	0.3529	0.9518	1.3079	1.0349	0.7578	0.8671	0.3923
Oil Products	1.2600	1.2600	1.2600	1.2600	1.2600	1.2600	1.2600	1.2600
Electricity	1.2600	1.2600	1.2600	1.2600	1.2600	1.2600	1.2600	1.2600
Energy intensive Industries	1.1885	1.1885	1.1885	1.1885	1.1885	1.1885	1.1885	1.1885
Other Industries and Serv.	1.3582	1.3582	1.3582	1.3582	1.3582	1.3582	1.3582	1.3582
Capital Goods (CGDS)	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000

Source: Burniaux and Truong, 2002

References

Burniaux, J.M. and T.P. Truong. 2002. GTAP-E: An Energy-Environmental Version of the GTAP Model. GTAP Technical Paper No. 16. January 2002

Lee, H. 2002. An Emissions Data Base for Integrated Assessment of Climate Change Policy Using GTAP. GTAP Working Paper No. XX. October, 2002

Lee, H. 2007. GTAP CO2 emissions for v6.0. August 2007. Zip file accessed August 2007.

Appendix 1. Regions in version 5.0 and 6.0 of GTAP-E database

Region	Regions in GTAP-E, version 6.0	Regions in GTAP-E, version 6.0
USA	United States	United States
EU	European Union: Austria, Belgium, Denmark, Finland, France, Germany, United Kingdom, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden	European Union: Austria, Belgium, Denmark, Finland, France, Germany, United Kingdom, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden
EEFSU	Eastern Europe and FSU: *Rest of Europe (xer)*, *Albania*, *Bulgaria*, *Croatia*, *Cyprus*, *Czech Republic*, Hungary, *Malta*, Poland, *Romania*, *Slovakia*, *Slovenia*, *Estonia*, *Latvia*, *Lithuania*, *Russian Federation*, former Soviet Union (xsu)	Eastern Europe and FSU: Hungary, Poland, *Rest of Central European Assoc (xce)*, Former Soviet Union (xsu)
JPN	Japan	Japan
RoA1	Other Annex 1 countries: Australia, New Zealand, Canada, Switzerland, rest of EFTA (xef)	Other Annex 1 countries: Australia, New Zealand, Canada, Switzerland, rest of EFTA (xef)
EEx	Net Energy Exporters: Indonesia, Malaysia, Viet Nam, Mexico, Colombia, Venezuela, rest of Andean Pact (xap), Argentina, rest of Middle East (xme), rest of North Africa (xnf), *Rest of Southern African Development Community (xsd)*, rest of sub-Saharan Africa (xss)	Net Energy Exporters: Indonesia, Malaysia, Viet Nam, Mexico, Colombia, Venezuela, rest of Andean Pact (xap), Argentina, rest of Middle East (xme), rest of North Africa (xnf), *Other Southern Africa (xsf)*, rest of sub-Saharan Africa (xss), *rest of world (xrw)*
CHIND	China and India	China and India
RoW	Rest of the World: *Rest of Oceania (xoc)*, Hong Kong, Republic of Korea, Taiwan, Philippines, Singapore, Thailand, *Rest of East Asia (xea)*, *Rest of Southeast Asia (xse),* Bangladesh, Sri Lanka, rest of South Asia (xsa), *Rest of North America (xna)*, Peru, Brazil, Chile, Uruguay, rest of South America (xsm), *Central America (xca)*, *Rest of Free Trade Area of the Americas (xfa)*, *Rest of the Caribbean (xcb)*, Turkey, Morocco, *Tunisia*, Botswana, *South Africa*, rest of SACU (xsc), Malawi, Mozambique, Tanzania, Zambia, Zimbabwe, *Madagascar*, Uganda	Rest of the World: Hong Kong, Republic of Korea, Taiwan, Philippines, Singapore, Thailand, Bangladesh, Sri Lanka, rest of South Asia (xsa), Central America and Caribbean (xcm), Peru, Brazil, Chile, Uruguay, rest of South America (xsm), Turkey, Morocco, Botswana, rest of SACU (xsc), Malawi, Mozambique, Tanzania, Zambia, Zimbabwe, Uganda

Note: Regions in italic are those that have changed between version 5.0 and version 6.0.

Appendix 2. Regional mapping between version 5.0 and 6.0 of GTAP database

Regions in GTAP, version 6.0	Regions in GTAP, version 5.0
Bulgaria, Czech Republic, Romania, Slovakia, Slovenia	Rest of Central European Assoc (xce)
Estonia, Latvia, Lithuania, Russian Federation, former Soviet Union (xsu)	Former Soviet Union (xsu)
Rest of Oceania (xoc), Rest of Southeast Asia (xse), Rest of South Asia (xsa), Rest of Europe (xer), Albania, Croatia, Cyprus, Malta, rest of North America (xca)	Rest of world (xrw)
Rest of Southern African Development Community (xsd): Angola, Congo DR, Mauritius, Seychelles	Other southern Africa (xsf): Angola, Mauritius

Appendix 3. Sectoral mapping of GTAP-E sectors to standard GTAP sectors

GTAP-E Sectors	GSC2 Sectors
Agriculture	Paddy rice (pdr), Wheat (wht), Cereal grains nec (gro), Vegetables, fruit, nuts (v_f), Oil seeds (osd), Sugar cane, sugar beet (c_b), Plant-based fibers (pfb), Crops nec (ocr), Bovine cattle, sheep and goats (ctl), Animal products nec (oap), Raw milk (rmk), Wool, silk-worm cocoons (wol), Forestry (for), Fishing (fsh)
Coal mining	Coal (coa)
Crude Oil	Oil (oil)
Natural gas extraction and distribution	Gas extraction (gas), gas manufacture and distribution (gdt)
Energy intensive industries (En_Int_ind)	Minerals nec (omn), Chemical, rubber, plastic prod (crp), Mineral products nec (nmm), Ferrous metals (i_s), Metals nec (nfm)
Refined oil products (Oil_Pcts)	Petroleum, coal products (p_c)
Other industries and services (Oth_ind_ser)	Meat products (cmt), Meat products nec (omt), Vegetable oils and fats (vol), Dairy products (mil), Processed rice (pcr), Sugar (sgr), Food products nec (ofd), Beverages and tobacco products (b_t), Textiles (tex), Wearing apparel (wap), Leather products (lea), Wood products (lum), Paper products, publishing (ppp), Metal products (fmp), Motor vehicles and parts (mvh), Transport equipment nec (otn), Electronic equipment (ele), Machinery and equipment nec (ome), Manufactures nec (omf), Water (wtr), Construction (cns), Trade (trd), Transport nec (otp), Water transport (wtp), Air transport (atp), Communication (cmn), Financial services nec (ofi), Insurance (isr), Business services nec (obs), Recreational and other service (ros), Public admin. and defense, edu. (osg), Ownership of dwellings (dwe)
Electricity	Electricity (ely)

Source: Burniaux and Truong, 2002