Chapter 11

An Energy Data Base for GTAP

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11.1 Overview

For energy, as with agriculture, we prepare a special data set not just to supplement data from sector-generic sources (as we use the agricultural data set to disaggregate I-O tables) but to override them. This special treatment arises from users' concern about apparent divergences of energy data in earlier GTAP releases from International Energy Agency (*IEA*) data (see, e.g., Babiker and Rutherford, 1997). To address these concerns, we prepare an energy data set from IEA and other energy-oriented data, covering energy flows, prices, and taxes, and use it to modify the I-O (chapter 8), protection (chapter 10), and trade (chapter 9) data.

Also special to energy is the inclusion in the GTAP data set not only of money value data but also of volume data. Supplementing the core money value flows, we provide a separate file of I-O and international trade flows measured in millions of tons of oil equivalent (*MTOE*).

In this chapter, we describe the preparation of the GTAP energy data set (EDS). In the course of constructing the trade component of that data set, we modify the GTAP trade data set. In the energy data set, we include tax data, that later procedures (chapter 15) use instead of the main protection data set in handling energy sectors. We also include targets for money values of energy flows, used by later procedures to modify the I-O data.

Although, in the main, the energy data set overrides the I-O data, in a few cases we find it necessary to adjust energy data for compatibility with the I-O data, as explained in chapter 15. Furthermore, since the source data specific to the energy data set are incomplete, we draw on the

[1] We incorporate material from the documentation provided in McDougall and Lee (2006) and Burniaux and Truong (2002).

GTAP protection, I-O, and trade data sets as supplementary data inputs into construction of the energy data set.

Since our main source data do not support all the distinctions required for the GTAP sectoral classification (section 11.1), the energy data set uses its own special purpose sectoral classifications. The EDS industry classification (*EDSIC*) is a 22-sector aggregation of the GTAP sectoral classification, as listed in table 11.1. The EDS use classes include, beside intermediate usage by each of the EDS industries, just private consumption and exports; implicitly, we assume that government consumption and investment usage are zero. The EDS energy commodity classification (*EDSECC*) is a 5-sector aggregation of the 6 GTAP energy sectors: the GTAP sectors `gas` (primary gas production) and `gdt` (gas manufacture and distribution) map to the single EDSECC sector `gas`.

Table 11.1 Concordance between EDS Industries and GTAP Sectors

EDS industry		GTAP sector	
Code	**Description**	**Code**	**Description**
agr	Agriculture, forestry, fishing	pdr	Paddy rice
		wht	Wheat
		gro	Cereal grains n.e.c.
		v_f	Vegetables, fruit, nuts
		osd	Oil seeds
		c_b	Sugar cane, sugar beet
		pfb	Plant-based fibers
		ocr	Crops n.e.c.
		ctl	Bovine cattle, sheep and goats, horses
		oap	Animal products n.e.c.
		rmk	Raw milk
		wol	Wool, silk-worm cocoons
		frs	Forestry
		fsh	Fishing
coa	Coal	coa	Coal
oil	Oil	oil	Oil
gas	Gas	gas	Gas
		gdt	Gas manufacture, distribution
omn	Minerals n.e.c.	oxt	Other extraction
fpr	Food products, beverages	cmt	Bovine meat products
		omt	Meat products n.e.c.
		vol	Vegetable oils and fats
		mil	Dairy products
		pcr	Processed rice
		sgr	Sugar
		ofd	Food products n.e.c.
		b_t	Beverages and tobacco products
twl	Textiles, wearing apparel, leather	tex	Textiles
		wap	Wearing apparel
		lea	Leather products
lum	Wood products	lum	Wood products
ppp	Paper products, publishing	ppp	Paper products, publishing

EDS industry		GTAP sector	
Code	**Description**	**Code**	**Description**
p_c	Petroleum, coal products	p_c	Petroleum, coal products
crp	Chemical, rubber, plastic products	chm	Chemical products
		bph	Basic pharmaceutical products
		rpp	Rubber and plastic products
nmm	Mineral products n.e.c.	nmm	Mineral products n.e.c.
i_s	Ferrous metals	i_s	Ferrous metals
nfm	Non-ferrous metals	nfm	Metals n.e.c.
ome	Machinery and equipment n.e.c.	fmp	Metal products
		ele	Computer, electronic and optical products
		eeq	Electrical equipment
		ome	Machinery and equipment n.e.c.
teq	Transport equipment	mvh	Motor vehicles and parts
		otn	Transport equipment n.e.c.
omf	Manufactures n.e.c.	omf	Manufactures n.e.c.
ely	Electricity	ely	Electricity
cns	Construction	cns	Construction
tpt	Transport	otp	Transport n.e.c.
		wtp	Water transport
		atp	Air transport
ser		wtr	Water
		trd	Trade
		afs	Accommodation, Food and service activities
		cmn	Communication
		ofi	Financial services n.e.c.
		ins	Insurance
		rsa	Real estate activities
		obs	Business services n.e.c.
		ros	Recreational and other services
		osg	Public administration and defense
		edu	Education
		hht	Human health and social work activities
		dwe	Dwellings

The energy data set generated by the energy module includes data for:

— quantity of energy usage, by energy commodity and energy use class,

— money value of energy usage, by energy commodity and energy use class,

— FOB and CIF values of trade in energy commodities, by GTAP commodity, source region, and destination region,

— energy output subsidy rates by GTAP industry, and

— powers of taxes on intermediate usage and private consumption of energy commodities, by GTAP commodity and industry.

In broad outline, we proceed by constructing from separate sources an energy volumes data set (section 11.2) and an energy price and tax rate data set (section 11.3). We then integrate these two data sets with each other and with separately constructed data for trade and protection (section 11.4).

11.2 Energy Volumes: Initial Construction

The main data source for energy volumes is the International Energy Agency's "Extended Energy Balances" (*EEB*) (IEA, 2017). This provides a wide country coverage (143 non-overlapping countries), rich sectoral detail, and a high degree of internal consistency and completeness. The energy balance framework, though different in externals from the input-output framework, translates readily into it. The industry sector classification relies heavily on the International Standard Industry Classification (*ISIC*), the same basis as the GTAP sectoral classification, facilitating matching to GTAP sectors. The main difficulties arise from mismatches between IEA energy sectors and GTAP sectors, joint production, and special categories such as transfers, distribution losses, and international marine bunkers.

The energy balances constitute a large array of energy flows, measured in kilotons of oil equivalent, indexed by year, country, flow, and product. The flow index includes both basic elements such as primary production, imports, and exports, and elements such as "public electricity plant" or "iron and steel" corresponding to I-O industries. The products correspond to I-O commodities. We extract data for all countries, flows, and products; for years we extract just the GTAP 10 data base reference years – 2004, 2007, 2011 and 2014.

As noted above, the EEB data set generally maintains a high level of internal consistency. Nevertheless, it does exhibit some inconsistencies. Based as it is on individual country reports, it does not attempt to enforce cross-country balance, so there is no match between global exports and global imports. It also contains some small logical inconsistencies; for example, it reports both that some natural gas is used in oil and gas extraction in Estonia, and that Estonia produces no oil or gas (it may be that these reports are consistent under EEB conventions, but under I-O conventions we cannot allow non-zero inputs with zero output; we treat industries with zero output as non-existent).

The EEB and GTAP take different approaches to recording trade. The EEB includes re-exports in its trade flows, GTAP excludes them.

To prepare the energy volume data for GTAP use we take therefore the following steps:

1. map from the 143 non-overlapping EEB countries to the 244 standard GTAP countries;
2. map from EEB flows and products to EDS industries and commodities;
3. aggregate from the 244 standard GTAP countries to the 141 GTAP release 10 regions;
4. balance the energy flows for internal consistency;
5. remove re-exports; and
6. eliminate energy usage by non-existent industries.

In future, we may reverse the order of steps 1 and 2, and move step 6 before step 4, and, if practicable, move steps 4 to 6 before step 3.

The resultant energy volume data set records imports, production, intermediate usage, private consumption, and exports of energy, for 2004, 2007, 2011 and 2014, in millions of tons of oil equivalent. It uses the standard GTAP regional classification, the EDS commodity classification, and, for intermediate usage, the EDS industry classification.

11.2.1 Mapping from EEB to GTAP countries

The EEB's 143 non-overlapping countries include 140 that correspond to single GTAP countries, and three residual groups. "Other Africa" groups 25 GTAP countries, "Other Asia" seventeen, and "Other Latin America" 22. There remain 40 GTAP countries not covered in the EEB — all small. Table 11.2 shows the EEB-to-GTAP country mapping. To save space, we omit the one-to-one mappings.

Table 11.2. Mapping between EEB and GTAP Countries: Countries Grouped in or Absent from the EEB

EEB	GTAP
Other Africa	Burundi, Burkina Faso, Central African Republic, Cape Verde, Comoros, Djibouti, Guinea, Gambia, Guinea-Bissau, Equatorial Guinea, Liberia, Lesotho, Madagascar, Mali, Mauritania, Malawi, Réunion, Rwanda, Sierra Leone, Somalia, São Tomé and Príncipe, Swaziland, Seychelles, Chad, Uganda
Other Asia	Afghanistan, Bhutan, Cook Islands, Fiji, Kiribati, Lao People's Democratic Republic, Macau, Maldives, New Caledonia, Palau, Papua New Guinea, French Polynesia, Solomon Islands, Tonga, Timor-Leste, Vanuatu, Samoa
Other Latin America	Antigua and Barbuda, Aruba, Bahamas, Belize, Bermuda, Barbados, British Virgin Islands, Cayman Islands, Dominica, Falkland Islands (Malvinas), Guadeloupe, Grenada, French Guiana, Guyana, Saint Kitts and Nevis, Saint Lucia, Saint Pierre and Miquelon, Turks and Caicos Islands, Martinique, Montserrat, Puerto Rico (for natural gas and electricity),[1] Saint Vincent and the Grenadines
Absent	Anguilla, Aland Islands, Andorra, Netherland Antilles, American Samoa, Antarctica, French Southern Territories, Bouvet Islands, Cocos Islands, Christmas Islands, Western Sahara, Faroe Islands, Federated States of Micronesia, Guernsey, Greenland, Guam, Heard Island and McDonald Islands, Isle of Man, British Indian Ocean Territory, Jersey, Liechtenstein, Monaco, Marshall Islands, Northern Mariana Islands, Mayotte, Norfolk Island, Niue, Nauru, Pitcairn, Occupied Palestine Territory, Southern Georgia, Saint Helena, Svalbard and Jan Mayen, San Marino, Tokelau, Tuvalu, United States Minor Outlying Islands, Holy See, U.S. Virgin Islands, Wallis and Futuna

We divide the energy flows for the three residual EEB regions between the corresponding GTAP countries in proportion to their GDP. To the 40 GTAP countries not covered in the EEB, we assign flows equal to the EEB's world energy flows, multiplied by their share in world GDP. Since we recognize new flows in these countries, and take no flows away from the other countries, this step increases world energy flows. But since these countries are small, the increase also is small – less than 0.2 per cent of original world flow for 2014.

It is possible that some of the countries we have marked absent are in fact included in other reported flows, for example, Liechtenstein in Switzerland, or Guadeloupe in France. If so, our treatment overstates global energy flows. But any such error must be small.

11.2.2. Mapping from EEB Flows and Products to EDS Sectors

Although the EEB classification of energy flows and products is much more detailed than GTAP's, its classification of non-energy sectors is less detailed. Furthermore, unlike GTAP, it does not recognize gas distribution as a separate activity. Hence arises the need for the special energy data set sectoral classifications, less detailed than the standard GTAP sectoral classification, described in section 11.1.

For the most part, we treat the IEA EEB sectoral classifications as disaggregations of the EDS classifications. The exceptions fall into three classes. First, we discard some of the EEB sectors. These include sectors such as "statistical differences" that represent nothing in the real world, but are items of accounting convenience. We also choose to discard some EEB flows and products relating to energy production by predominantly non-energy sectors in the EDSIC. For instance, rather than treat the chemical industry as energy-producing, we discard the EEB flow "charcoal production plants" and the EEB product "charcoal". Second, some of the EEB flows belong in the EDS but not in the intermediate usage block. These include flows such as production, exports, and imports. Third, some EEB flows combine uses that the EDS must separate, for example the gas and crude oil industries, or the transport industry and private consumption. In particular:

- The EEB flow "oil and gas extraction" corresponds to the EDS industries "oil" and "gas". We assign all inflows of the EEB product "crude oil" into "oil and gas extraction" to the EDS industry "oil"; we assign all inflows of "natural gas" to "gas"; and we split all other inflows between "oil" and "gas" in proportion to production of "crude oil" and "natural gas".
- We apportion the EEB flow "non-specified energy sector" between all EDS energy using sectors in proportion to their own energy use (in future, we may apportion this flow across energy sectors only).
- The EEB flow "non-specified industry" formally corresponds to the ISIC rev. 4 divisions 22 (rubber and plastics products), 26 (computer electronic and optical products), 31 (furniture), 32 (other manufacturing) and 38 (waste collection and treatment). In the EDSIC, ISIC rev. 4 division 22 maps to `crp` (chemical, rubber, plastic products), division 26 to `ome` (machinery and equipment n.e.c.), 32 to `omf` (manufactures n.e.c.), and 38 to `ser` (services n.e.c.). In practice, as the IEA notes warn, countries are liable to use the "non-specified industry" category for any flows they find difficult to assign to particular industries. From the size of

the flow, we guess that most of it does in fact represent unclassified flows rather than its four proper ISIC divisions. We apportion 75 per cent of its inputs between the other EDS manufacturing industries and construction. The remaining 25 per cent we assign to the four properly matching EDS industries. For want of better knowledge, we apportion that remainder between these four industries in equal shares.

— The EEB flow "road" includes operation of road vehicles by the transport industry, as an ancillary activity by other industries, and by private households. We ignore the problem of ancillary activity by other industries. We assign one half of the road sector's usage of motor gasoline to private consumption, and one quarter of its usage of gas/diesel oil. Its remaining usage of motor gasoline and gas/diesel oil, and all usage of other fuels by "road" — liquefied petroleum gases, liquid biomass, etc. — we assign to the EDS transport industry.

— The EEB flow "commercial and public services" comprises 24 ISIC divisions, most of which map to EDS industry `ser`, "Services n.e.c.". One however, division 52, "warehousing and support activities for transportation", maps to EDS industry `tpt`, "transport". Not knowing how energy use varies across these 24 divisions, we apportion "commercial public and services flows" between the two EDS industries according to the division count, in the proportions 1:23.

— We apportion the EEB flows "non-energy use ind/transf/energy", "non-energy use in transport", and "non-energy use in other sectors" between all energy-using sectors in proportion to their total energy use of EEB commodities (in future, we may apportion "non-energy use in transport" between EDS transport sectors only, and similarly confine the apportionment of the other non-energy use flows.

Aside from these special cases, and basic elements such as production, exports, and imports, we treat the IEA flow classification as a disaggregation of the EDS industry classification. Similarly, we treat the IEA products as subclasses of EDS energy commodities. Table 11.3 shows the correspondence between IEA flows and EDS industries, and table 11.4 the correspondence between IEA products and EDS energy commodities.

Table 11.3. Concordance between EEB flows and EDS industries

EDS industry		EEB flows
Code	**Description**	**Description**
agr	Agriculture, forestry, and fishing	Agriculture
coa	Coal	Coal mines
oil	Oil	Oil and gas extraction (part)
gas	Gas	Oil and gas extraction (part), Gas works
omn	Minerals n.e.c.	Mining and quarrying
fpr	Food products, beverages	Food and tobacco
twl	Textiles, wearing apparel, leather	Textile and leather

lum	Wood products	Wood and wood products
ppp	Paper products, publishing	Paper, pulp and printing
p_c	Petroleum, coal products	Patent fuel plants, Coke ovens, Blast furnaces, Petrochemical industry, BKB plants, Petroleum refineries, Liquefaction plants, LNG plants
crp	Chemical, rubber, plastic products	Chemical and petrochemical, Non-specified industry (1/16)
nmm	Mineral products n.e.c.	Non-metallic minerals
i_s	Ferrous metals	Iron and steel
nfm	Metals n.e.c.	Non-ferrous metals
teq	Transport equipment	Transport equipment
ome	Machinery and equipment n.e.c.	Machinery, Non-specified industry (1/16)
omf	Manufactures n.e.c.	Non-specified industry (1/16)
ely	Electricity	Public electricity plant, Autoproducer electricity plant, Public CHP plant, Autoproducer CHP plant, Public heat plant, Autoproducer heat plant, Heat pumps, Electric boilers, Own use in electricity, CHP and heat plants, Pumped storage (electricity)
cns	Construction	Construction
tpt	Transport	International civil aviation, Domestic air transport, Road, Rail, Pipeline transport, Internal navigation, Non-specified transport, Commercial and public services (1/24)
ser	Services n.e.c.	Non-specified industry (1/16), Commercial and public services (23/24), Non-specified other
...	Production	Production, From other sources — primary energy
...	Private consumption	Residential
...	Exports	Exports, International marine bunkers
...	Imports	Imports
...	Special treatment	Transfers, Non-specified energy sector, Distribution losses, Non-specified industry (3/4), Non-energy use in ind/transf/energy, Non-energy use in transport, Non-energy use in other sectors

BKB brown coal briquettes
CHP combined heat and power

Table 11.4. Concordance between EEB Products and EDS Commodities

EDS commodity		EEB products
Code	**Description**	**Description**
coa	Coal	Coking coal, Other bituminous coal and anthracite, Sub-bituminous coal, Lignite/brown coal, Peat, Patent fuel, BKB/peat briquettes
oil	Oil	Crude oil

gas	Gas	Gas works gas, Natural gas, Natural gas liquids
p_c	Petroleum, coal products	Coke oven coke and lignite coke, Gas coke, Coke oven gas, Refinery feedstocks, Refinery gas, Ethane, Liquefied petroleum gases (LPG), Motor gasoline, Aviation gasoline, Gasoline type jet fuel, Kerosene type jet fuel, Other kerosene, Gas/diesel oil, Heavy fuel oil, Naphtha, White spirit and SBP, Lubricants, Bitumen, Paraffin waxes, Petroleum coke, Other petroleum products
ely	Electricity	Electricity, Heat
...	Discarded	Blast furnace gas, Oxygen steel furnace gas, Combustible renewables and waste, Industrial wastes, Municipal wastes renewables, Municipal wastes non-renewables, Primary solid biomass, Biogas, Liquid biomass, Non-specified combust. renewables and waste, Charcoal, Additives/blending compounds, Inputs other than crude or NGL, Nuclear, Hydro, Geothermal, Solar photovoltaics, Solar thermal, Tide, wave and ocean, Wind, Other fuel sources of electricity

Some of the sectoral mappings are doubtful of necessity or anomalous by inadvertence or choice. The main motive for the deliberate anomalies is to avoid recognizing energy production by EDS industries that predominantly produce non-energy goods (for example, blast furnace gas production by the ferrous metals industry), for fear that this might complicate later energy data processing.

— We record inflows into the EEB flow "international marine bunkers" as exports, but record no corresponding imports. International marine bunker usage is assigned to the right countries, on the basis of international services trade data. The assumption is that international marine bunker usage is proportional to water transport services exports (McDougall and Leeuwen, 2009). The ideal handling of bunkers requires much more than sectoral remapping. In principle, we should balance the trade flows by recording international marine bunker usage as imports into the country of residence of the ship operator, and as use by that country's transport industry. This being a sizable task, and data on ship operators' nationality being lacking, we set it aside as an area for future work.

— We class inflows of the EEB flow "transfers" as inputs into the petroleum and coal products industry, and outflows as production of petroleum and coal products. In fact, if we understand the EEB correctly, this flow is an accounting convenience, allowing the IEA to record production and consumption of the same substance under two different descriptions (for example, production as "natural gas liquids" but consumption as "liquefied petroleum gas"). The accounts are balanced by entries to the "transfers" flow (for example, inflow of natural gas liquids into "transfers", and outflow of liquefied petroleum gas from "transfers"). Our representing these fictitious flows as intra-industry usage of petroleum products is mostly harmless (but see section 11.4.4), for EEB products mapped to the ESD commodity "petroleum and coal products", but creates imbalances for EEB products mapped to other ESD commodities or discarded.

— We class the flow "heat" and the product "heat plant" with electricity. A more ISIC-compliant treatment would class them with gas, since the EDS sector `gas` includes the standard GTAP sector `gdt` which includes the ISIC group 353, "steam and hot water supply". We do not however feel bound by our own definition of `gdt`, since it was adopted without a view to energy data set construction, and since its I-O data are in any case to be overwritten with EDS data. Since a great part of heat output is produced jointly with electricity in combined heat and power plant (Chepeliev, 2020), and since in cost structure heat production is more similar to electricity than to gas, we find it expedient to class it with electricity.
— Since we class heat with electricity, we class the operation of combined heat and power plant, heat pumps, and electric boilers with electricity generation.
— Our treatment of patent fuel is inconsistent. We class the product with coal, but the flow "patent fuel plants" with petroleum and coal processing. ISIC compliance would class both flow and product with coal; in future we may adopt that treatment.
— Our treatment of blast furnace gas and blast furnaces is inconsistent. We discard the EEB products "blast furnace gas" and "oxygen steel furnace gas", but class the EEB flow "blast furnaces" with petroleum and coal processing. Blast furnace operation belongs in the ISIC to group 241, "manufacture of basic iron and steel", and so in the EDS industry `i_s`, "ferrous metals". On the other hand, a large part of blast furnace gas output is used in electricity plant or combined heat and power plant, and recording this as sales from iron and steel to electricity would turn the EDS ferrous metals industry into an energy industry. Resolving the inconsistency in the current treatment is an area for future work.
— Our treatment of the EEB flow "petrochemical industry" and the EEB product "refinery feedstocks" is not ISIC-compliant. Following the ISIC, we would class these in the EDS "chemical, rubber, plastic products"; in fact, we class them in "petroleum, coal products". Again, this allows us to avoid treating the chemical industry as an energy industry.
— We discard the EEB flow "gasification plants for biogas" and the EEB product "biogas". An ISIC-compliant treatment would map the flow to ISIC group 352 as "manufacture of gas", and therefore map both the flow and the product to EDS sector `gas`.
— We discard the EEB flow "nuclear industry". In the EEB this flow serves mainly to record consumption of electricity by nuclear power plants; in future, we may record this as sales of "electricity" to "electricity".
— We discard the EEB product "charcoal", which maps under the ISIC to basic chemicals, to avoid treating the chemicals industry as energy-producing.
— Some part of the EEB flow "residential", corresponding to such activities as heating of apartment blocks, should likely map to the EDS services sector. Lacking the data to split it, we assign it all to private consumption.

- What the EEB flow “non-specified other” includes is not altogether clear, but the IEA notes give one example, military fuel consumption. Military fuel consumption maps to ISIC division 84, “public administration and defense; compulsory social security”, and to EDS industry `ser`, “services n.e.c.”. Accordingly, we map “non-specified other” to `ser`.
- The EEB products “industrial wastes”, “municipal wastes renewables”, and “municipal wastes non-renewables” are difficult to locate in the ISIC. Part may be output of ISIC class 4669, “wholesale of other intermediate products, waste and scrap” (included in EDS industry “services n.e.c.”), part output of ISIC divisions 37-39 (sewerage, waste collection and treatment, etc.), (also included in “services n.e.c.), part output of the waste producing industries themselves, part sales by final buyers (i.e., households). We simply discard them.
- We discard the EEB product “primary solid biomass”, rather than recognize it as output of agriculture and forestry; likewise we discard “liquid biomass” (largely ethanol) and “additives/blending compounds”, rather than recognize them as output of the chemicals industry.
- We discard the EEB products “non-specified combust. renewables and waste” and “other fuel sources of electricity”, which we don’t know how to class.
- We discard the EEB products “nuclear”, “hydro”, “geothermal”, “solar photovoltaics”, “solar thermal”, “tide, wind, and ocean”, and “wind”, as items of convenience in the EEB system, but not required in the I-O accounts.

11.2.3. Mapping from GTAP Countries to GTAP Regions

After performing the sectoral mapping, we aggregate from GTAP countries to GTAP regions, a routine operation requiring no special comment.

11.2.4. Balancing for Internal Consistency

The IEA’s EEB data set is balanced within countries, in that total supply and total consumption of each product are equal. It is not balanced across countries, in that world exports and world imports of each commodity differ. We create further inconsistencies, in adding new regions, mapping some sectors inconsistently, and discarding some flows.

After mapping to GTAP categories, therefore, we have imbalances both between supply and use within countries (table 11.6), and between exports and imports globally (table 11.5). As table 11.5 shows, the export-import imbalances are all moderate. Table 11.6 shows the most serious supply-use imbalances; these are generally moderate; they mostly involve excess supply of petroleum and coal products or excess use of gas.

To remove the imbalances, in an I-O quantity model, we rescale use and supply in opposite senses to remove supply-use imbalances, and simultaneously rescale exports and imports in opposite senses to remove export-import imbalances. The re-scalings are interrelated, since imports are part of supply, and exports part of use. Tables 11.5 and 11.6 show, alongside the imbalances, the common balanced values.

Table 11.5. Balancing Imports and Exports (MTOE), 2014

	Before balancing		
Commodity	**Exports**	**Imports**	**After balancing**
Coal	846	812	830
Oil	2035	2111	2074
Gas	940	865	899
Petroleum products	1643	1641	1642
Electricity	59	62	61

Table 11.6. Balancing Supply and Use, Selected Cases (MTOE), 2014

		Before balancing		
Country	**Commodity**	**Supply**	**Use**	**After balancing**
Kazakhstan	Gas	28	40	36
Canada	Gas	107	119	117
Ghana	Oil	2	1	1
Greece	Gas	2	3	3
Mexico	Gas	69	78	75

11.2.5. Removing Reexports

The Extended Energy Balances record in each country's imports or exports all goods that cross the country's border. Thus, countries can export not only their own products but goods imported from elsewhere; these are called *reexports*. In GTAP however we do not record reexports in the transit countries trade; we record the trade as exports from the country of origin to the final destination. We need therefore to remove reexports from the trade data.

We do this in the simplest way, assuming that imports and domestic product have the same propensity to be exported. To the extent that trade is driven by product differentiation, this treatment may tend to over-adjust for reexports. The adjustment reduces global energy trade by 12.5 per cent, from 5.5 to 4.8 GTOE. Among commodities, the adjustment is greatest for petroleum and coal products, trade in which falls by 29 per cent, from 1.6 to 1.2 GTOE. Among countries, plausibly enough, the adjustment falls heavily on Singapore and the Netherlands; table 11.7 reports the adjustment for these and other selected countries.

Table 11.7. Trade before and after Removing Reexports, Selected Countries (MTOE), 2014

	Imports		Exports	
Country	**Before**	**After**	**Before**	**After**
Singapore	174	81	134	41
Netherlands	205	104	179	78
Hong Kong	45	30	14	0
United Kingdom	162	125	77	40
Rest of former Soviet Union	41	25	170	154
Germany	262	234	58	30
Canada	86	47	237	198
Belgium	86	69	38	20

11.2.6. Eliminating Energy Usage by Non-Existent Industries

We adjust the volumes data to eliminate certain internal inconsistencies. Specifically, we ensure that energy industries with zero output also have zero usage of energy commodities. We make the adjustment in two steps. In the first step, we zero out selected data cells to impose the condition just described. In the second step, we rebalance the data to restore certain balance conditions: that global imports and global exports are equal for each energy commodity, that domestic production is equal to usage of domestic product for each energy commodity in each country, and that domestic absorption is equal to net supply to the domestic market for each energy commodity in each country.

The adjustments in this step are few and small. Taiwanese coal sector initially uses 0.002 MTOE of petroleum products, despite itself having no output. The other one involves gas use by gas sector in Uruguay (0.002 MTOE).

11.3. Energy Prices and Tax Rates: Initial Construction

Since the GTAP data base is essentially a collection of money value flows, we must convert the energy volume data described in section 11.2 into money values in order to use it in the data base. And to do that, we require data on energy prices.

For energy prices, as for volumes, the principle data source is the IEA. But in every other way we face a far different situation. Whereas the EEB provides a unified, comprehensive, and consistent representation of energy volumes, for prices the data series are multiple, partial, and diverse in every way. To fill in some critical gaps in the IEA data, we employ several other data sources, including some non-serial publications, and some subsequently discontinued series.

In the initial implementation of the price data construction procedure, since uniformly up-to-date data could not be obtained, data were extracted for several reference years (Malcolm and Truong, 1999). These were updated to the GTAP data base reference year using time series data for energy price indices and exchange rates. For the GTAP 10 implementation we follow a similar approach to match different base years.

What has been said about prices applies equally to tax rates. It remains only to add that since the tax data comprise both tax-inclusive and tax-exclusive prices, we prepare price and tax data together.

For the more heterogeneous EDS energy commodities, especially "petroleum and coal products", we cannot expect to find prices at the EDS commodity level. At the same time, the available price data presents much less commodity detail than the EEB product level. The initial energy price data set (*EPDS*) therefore uses an intermediate (and incomplete) energy commodity classification, which we may call the energy price data commodity classification (*EPDCC*). This comprises nine commodities, mapped to EDS commodities as shown in table 11.8.

Table 11.8. EPD commodities, with Concordance to EDS Commodities

EPD commodity		EDS commodity	
Code	**Description**	**Code**	**Description**
`S`	Steaming coal	`coa`	Coal
`C`	Coking coal	`coa`	Coal
`O`	Crude oil	`oil`	Oil
`N`	Natural gas	`gas`	Gas

H	Heavy fuel oil	p_c	Petroleum, coal products
L	Light fuel oil	p_c	Petroleum, coal products
G	Gasoline	p_c	Petroleum, coal products
D	Diesel oil	p_c	Petroleum, coal products
E	Electricity	ely	Electricity

One feature of the available price and tax data is that they often present several prices for the same commodity and country, differentiated by user. Naturally the user detail is at much less than the EDS industry level, let alone the EEB flow level. To accommodate the available data we define an EPD use classification, with just four classes, as shown in table 11.9.

Table 11.9. EPD Use Classes

Code	**Description**	**Corresponding EDS use classes**
I	Industrial	Intermediate usage by industries other than electricity
H	Household	Private consumption
U	Utilities	Intermediate usage by the electricity industry
X	Exports	Exports

To accommodate the available data, we need much less than the GTAP standard country set. A set of 92 EPD countries is sufficient, the EPD country set. This is just a subset of the GTAP standard country set.

In constructing the energy price data set we deal with prices at several levels. *Purchasers' prices* include not only the cost of production but also taxes and trade and transport margins. Purchasers' prices are differentiated by use class. For the use class "exports", they cover margins incurred in bringing the goods to the point of export, and any export taxes or subsidies by the exporting country, but exclude international trade margins and import duties. Thus, they are equivalent to free-on-board (*FOB*) prices. *Basic prices* are prices at point of production, for domestic product, or landed duty-paid prices, for imports.

We construct an initial energy price data set that includes arrays of basic prices, FOB export prices, and tax rates. All prices and tax rates are measured in US dollars per TOE, or, equivalently, in millions of US dollars per MTOE. All are indexed by EPD commodity and country. The tax rates are also indexed by EPD use class. Production subsidy rates are not included in this data set.

We obtain basic price estimates in three different ways. In a few cases, they are available from source data. More often, we must calculate them, either from import prices or from purchasers' prices. For import-price-based estimates, we calculate basic (landed duty-paid) prices of imports from duty-free (CIF) prices and import duty rates. For purchasers'-price-based estimates, we take use-specific data for purchasers' prices, and calculate use-specific basic price estimates by removing taxes and margins. We then average across uses to obtain use-generic estimates of basic prices.

We then map these data set to EDS categories. First, we aggregate from EPD to EDS commodities, then extend from EPD to standard GTAP countries, then aggregate from GTAP countries to GTAP regions.

Key data sources for energy prices and taxes include:

— Energy Prices and Taxes (IEA, 2018),
— the Organización Latinoamericana de Energía's (*OLADE*'s) SIEE database (OLADE, 2018),
— the United States Department of Energy's *Petroleum Marketing Monthly* (DOE, 2011) and *International Energy Annual* (DOE, 2002),
— the Lawrence Berkeley National Laboratory's *China Energy Databook* (Fridley and Aden, 2008).

Because the prices and tax measures involve a variety of physical units — barrels, gallons, kilowatt hours, and so forth — we require physical conversion factors to bring all prices and taxes to a TOE basis.

We use value-share-weighted averages at many points, including averaging across uses and aggregating from EPD to EDS commodities; to calculate these, we need energy volume data. For reasons relating to difficulties in program maintenance, we use not the energy volume data set described in section 11.2, but an older data set acquired for the original implementation. To pass from purchasers' prices to basic prices, we need margin rates; for these we rely in part on comparison of import and purchasers' prices, in part on outside margin rate estimates.

The source data for the energy price data set therefore include physical conversion factors, exchange rates, price indices, import duty rates, import prices, margin rates, purchasers' prices, and tax rates.

11.3.1. Physical Conversion Factors

Prices for different energy products are expressed in a variety of units. Physical unit conversion factors are needed in order to convert these prices into tons of oil equivalent (*TOE*). A single conversion factor is used for all countries, though, in reality, net calorific contents differ somewhat from one country to another. Table 11.10 reports the conversion factors used in this version of the data base.

Table 11.10. Conversion Factors

Commodity	Unit	Tons of oil equivalent (TOE)	Source
Steam coal	ton	0.63	US coefficients in IEA (1997) p.43.

Coking coal	ton	0.709	US coefficients in IEA (1997) p.43.
Crude oil	barrel (bbl)	0.1339	Coefficient for Philippine from ADB (1994) table 11, p. XXIX.
Natural gas	cubic meter (m3)	0.0008645	Gross calorific value for Germany from IEA (1997) p. 36 converted from kcal to TOE
Gasoline	barrel (bbl)	0.1324762	Conversion factor for "all other countries" from IEA (1997) p. 41, converted from liter to bbl
LFO	barrel (bbl)	0.1363651	Conversion factor for "all other countries" from IEA (1997) p. 41, converted from liter to bbl
HFO	ton	0.96	Conversion factor for "all other countries" from IEA (1997) p. 42.
Diesel	barrel (bbl)	0.14127	Conversion factor for "all other countries" from IEA (1997) p. 41, converted from liter to bbl

11.3.2. Price Indices

For exchange rates, we have data for the national currency price of the US dollar, for all 92 countries in the EPD country set. For price indices, our sole data source is the IEA's *Energy Prices and Taxes* (IEA, 2018). This provides national currency price indices for coal, natural gas, oil products, and electricity. We use the single coal price index for the two corresponding EPD commodities (steaming coal, coking coal), and the single oil products price index for the four corresponding EPD commodities (heavy fuel oil, light fuel oil, gasoline, diesel oil). For crude oil we take the index of real crude import costs in national currencies (a questionable procedure).

For each index, we extract data for 1994 to 2016. We extract all available countries; these number 28 to 34, depending on the series. To fill in missing countries, we use the United States price index, adjusted for exchange rate changes. Where exchange rates are lacking, we just use the United States price index.

Of the price series we need to update, some are in national currency units and some in US dollars. From the national currency price indices and exchange rates, we calculate combined price update and exchange conversion factors. For national currency price series, we use the formula

$$P_{ED1} = \frac{1}{E_1}\frac{P_{IN1}}{P_{IN0}}P_{AN0},$$

where P_{ED1} denotes the estimated US dollar price in the later year, P_{AN0} the actual national currency price in the earlier year, P_{IN0} and P_{IN1} national currency price indices in the earlier and later year, and E_1 the exchange rate in the later year. For US dollar price series, we use the formula

$$P_{ED1} = \frac{P_{IN1}/E_1}{P_{IN0}/E_0}P_{AD0},$$

where E_0 denotes the exchange rate in the earlier year, and P_{AD0} the actual US dollar price in the earlier year.

11.3.3. Tax Rates

For taxes as for prices we collect use-specific values, which we arrange in the EPD use classification. We use several sources; where sources overlap, we use the IEA data.

— From the IEA we take tax rates for many commodity-use-country triples for 1978 to 2016. The IEA reports both excise and value added tax, but we take just the excise tax rate.
— From OLADE's SIEE data (OLADE, 2018), we take tax rates for twenty-seven Latin American countries for household, utility and industrial use of gasoline, diesel oil, and electricity for 1988 to 2017.

After taking all available data, estimates are still lacking for many commodity-use-country triples. We note for future reference which rates are known and which are unknown. For the price and tax calculations, wherever a required rate is unknown, we assume a rate of zero.

11.3.4. Basic Prices Taken Directly from Source Data

In a few cases, we have source data for basic prices.

— From the *China Energy Databook*, we take the coking coal and steaming coal prices averaged across months within years in 1996-2006, and basic prices of gasoline and diesel oil in 2005-2008.

We convert and update these to the GTAP 10 reference year US dollar prices per TOE, using the price and physical conversion factors described in sections 11.3.1 and 11.3.2.

11.3.5. Basic Prices Calculated from Import Duty Rates and CIF Import Prices

For 169 commodity-country pairs, we estimate basic prices from import duty rates and CIF import prices. For duty rates, we take *ad valorem* rates from the GTAP protection data set (chapter 10). This provides estimates for 185 of the 244 GTAP countries. The commodity classification is of course standard GTAP; this we expand to the EPDCC by assigning each EPD commodity the rate for the corresponding GTAP commodity. For the missing countries, we set duty rates to zero.

For CIF import prices, we take data from the IEA (2018) and OLADE:

— from the IEA, prices for steaming coal, coking coal, crude oil and natural gas imports, covering 1980-2016 timeframe and a total of 28 countries (data availability differs by years and commodities),
— from OLADE, prices for eleven energy sources imported form 27 countries, covering 1970-2017 timeframe.

We convert these prices from their various original units to US dollars per TOE and rescale from the source year to GTAP 10 reference years. From them and the duty rates we calculate basic prices, according to the formula

$$BPM = \left(1 + \frac{1}{100} MDR\right) CIF, \qquad (1)$$

where *BPM* denotes the basic price of imports, *MDR* the import duty rate (*ad valorem* or *ad valorem* equivalent), and *CIF* the CIF price of imports.

11.3.6. Purchasers' Prices

For purchasers' prices we use an especially wide variety of sources. Following the IEA's *Energy Prices and Taxes*, we record all domestic purchasers' prices as prices for industry, households, or electricity generation, though not all sources use those descriptions. In some cases, we take averages; for example, to obtain prices paid by households and industry for electricity in China, we average prices reported in the *China Energy Databook* across provinces. The commodity descriptions also do not always match exactly — from the IEA export price data, for instance, we apply the gasoil price to light fuel oil, and an average of the low sulfur fuel oil and high sulfur prices to heavy fuel oil. From the IEA's *Energy Prices and Taxes* we extract time series data; from the other sources we extract just the latest available year case-by-case. Further detail is available in Malcolm and Babiker (1998).

We do not attempt to fill all combinations of commodities and use classes; rather, we assume that some combinations, for example household use of heavy fuel oil, or utilities use of light fuel oil, do not occur and require no price data.

We take:

— from the IEA, prices for industrial, household and utility use of steaming coal, coking coal, natural gas, heavy fuel oil, light fuel oil, diesel oil, petroleum products, and electricity for various overlapping sets of up to 34 countries, from 1978 to 2016,

— also from the IEA, prices of exports of crude oil, steaming and coking coal and various oil products for selected energy exporters, from 1960-2016 (timespan varies for different commodities),

— from OLADE, prices for industrial use of steaming coal, coking coal, natural gas, heavy fuel oil, light fuel oil, diesel, and electricity, household use of natural gas, light fuel oil, gasoline, diesel, and electricity, and exports of steaming coal, coking coal, crude oil, natural gas, heavy fuel oil, light fuel oil, diesel and gasoline, for 27 Latin American and Caribbean countries in 1988-2017,

— from the United States Department of Energy, prices for industrial use of crude oil in the United States in 1990-2008, and for industry use of heavy fuel oil, light fuel oil, and diesel oil, and household use of light fuel oil and gasoline, in up to 92 countries in 1995-2002,

— from the *China Energy Databook*, prices for industrial use of steaming coal and coking coal in 1996-2006, heavy fuel oil, and diesel oil in 2005-2008 and household and industrial use of diesel and gasoline in 2005-2008, industrial and household use of electricity in 2008.

As with basic prices, we convert and update these purchasers' prices to GTAP 10 reference year US dollar prices per TOE, using the price and physical conversion factors described in sections 11.3.1 and 11.3.2.

We now fill in missing prices for the three domestic use classes (industrial, household, utilities). We divide countries into four classes, according as their energy prices are above or below average, and as they are net exporters or importers of energy. We find five high-price exporters, 49 high-price importers, 26 low-price exporters, and eight low-price importers. For each of the four country classes, and for each product and use class, we calculate an average price as the simple average of the available prices (table 11.11). We fill in missing values with these average prices.

Table 11.11. Cross-Country Average Purchasers' Prices, by EPD Commodity and Use Class (US$ per TOE), 2014

Commodity	Use class	HX	HM	LX	LM
Steaming coal	Industrial	184	259	277	170
Steaming coal	Household	1009	871	0	0
Steaming coal	Utilities	165	165	96	89
Coking coal	Industrial	244	282	119	281
Crude oil	Industrial	0	0	0	599
Natural gas	Industrial	513	656	124	163
Natural gas	Household	857	1273	265	307
Natural gas	Utilities	402	546	258	220
Heavy fuel oil	Industrial	726	760	382	506
Heavy fuel oil	Utilities	740	555	585	804
Light fuel oil	Industrial	1257	1230	530	790
Light fuel oil	Household	1269	1349	536	804
Gasoline	Household	2152	2220	988	1273
Diesel oil	Industrial	1620	1559	717	910
Diesel oil	Household	1937	1783	814	999
Electricity	Industrial	1472	1746	704	1016
Electricity	Household	2491	2589	814	2135

HX High-price energy exporter
HM High-price energy importer
LX Low-price energy exporter
LM Low-price energy importer
For commodity and use codes, see tables 11.8 and 11.9.

We find price averages for all country groups for all the commodity-use combinations we seek, except that for high-price energy exporters, we find no data for industrial use of crude oil. For this country group therefore we borrow the average calculated for high-price energy importers.

In a few cases, we find that the tax rate exceeds the estimated user price. In such cases, we discard the tax rate, and treat the rate as unknown.

For exports, we use a similar procedure, except that, as data are scarcer for export prices than for domestic uses, we do not separate countries into four groups, but calculate a single average price across all available countries. For products other than diesel oil and electricity, we set the missing values equal to the simple average of the available export prices for each commodity (table 11.12). For diesel oil and electricity, no export prices are available; for these commodities, for each country, we set the export price equal to the industrial price.

Table 11.12. Average export prices (US$ per TOE)

Commodity (code)	Price
Steaming coal	154
Coking coal	299
Crude oil	681
Natural gas	532
Heavy fuel oil	540
Light fuel oil	758
Gasoline	761
Diesel oil	NA
Electricity	NA

11.3.7. Basic Prices Calculated from Tax Rates, Margin Rates, and Purchasers' Prices

Our third method of obtaining basic prices is to calculate them from tax rates, margin rates, and purchasers' prices. Sections 11.3.4 and 11.3.7 relate the derivation of the tax rates and purchasers' prices; we now relate the derivation of the margin rates.

Purchasers' prices and basic prices are related to each other according to the formula

$$PP = (1 + MR)BP + TR, \qquad (2)$$

where *PP* denotes purchasers' price, *MR* the margin rate, *BP* basic price, and *TR* the tax rate (a specific rate or specific rate equivalent). Where basic price estimates are available from source data (section 11.3.5) or import prices (section 11.3.6), we use this equation to calculate the margin rate. If the tax rate is unknown, we assume a rate of zero.

This yields some plausible and some wild estimates. We discard all estimates for which imports represent less than twenty per cent of total supply, or for which the calculation yields a negative margin rate. In all cases where the calculation yields an estimate greater than 5, we substitute a rate of 5. For each product and use class, we then calculate an average rate of margins on imports as the simple cross-country average of the available rates. For household and industrial use of diesel oil, finding no rates available, we use the rate for household use of gasoline. Overriding the average calculation, we fix the rate for household use of natural gas at 2.0 and for industrial use at 1.3.

We also obtain margin rates for the United States and Japan from I-O data sources. Then, for the United States and Japan, we use their own margin rate; for all other countries, we set the margin rate equal to a weighted average of the (cross-country average) import margin rate, the United States rate, and the Japanese rate, with weights of 0.6, 0.2, and 0.2. Thus, all countries except the United States and Japan have the same margin rates; these we report in table 11.13.

Table 17.3. Margin Rates, by Product and Use Class, for Countries Other than the United States and Japan

Commodity	Industrial	Household	Utilities	Export
Steaming coal	0.40	2.82	0.33	0.24
Coking coal	0.29	0.51	0.12	0.41
Crude oil	0.09	N/A	0.10	0.20
Natural gas	0.55	2.00	0.21	0.37
Heavy fuel oil	0.40	N/A	0.28	0.16
Light fuel oil	0.49	0.63	0.27	0.11
Gasoline	0.00	0.65	N/A	0.11
Diesel oil	0.31	0.65	N/A	0.02
Electricity	0.00	0.00	0.00	0.00

At this point all variables in equation (1) are estimated except for the basic price and in some cases the tax rate. We now use the formula to obtain basic prices. If the tax rate is unknown, for purposes of this calculation we use a rate of zero. In this way we obtain estimates of basic prices, indexed not only by EPD commodity and country but also by EPD use class.

11.3.8. Basic Prices: Final Estimates

For each EPD commodity in each EPD country, we now have up to five estimates of the basic price. We may have an estimate extracted from source data or calculated from import prices (in no case do we have both), and we may have up to four estimates calculated from purchasers' prices for the several EPD use classes. Our preferred estimate of the basic price is the estimate extracted from source data or calculated from import prices, if either is available; otherwise, it is a share-weighted average of the available purchasers'-price-based estimates. We use the special-purpose energy volume data (section 11.3.3) to calculate the weights.

We now fill in remaining missing values in two stages. First, for each commodity-use pair, if we have observations for some countries but not all, we fill in the missing countries with the simple average of the available countries' prices. Because of the previous filling in of the purchasers' prices (section 11.3.8), such cases arise only for commodity-use pairs for which no purchasers' prices are available, for example, gasoline usage by industry. In such cases the available observations are either import-price-based (section 11.3.6) or taken directly from source data (section 11.3.5). The only missing observations are now for prices of electricity in usage by utilities; we set them equal to the corresponding prices in usage by industry.

11.3.9. Aggregating from EPD to ESD Commodities

At this point, we have in hand estimates of basic prices, export prices, indexed by EPD commodity and country (the export prices are a slice of the purchasers' price array obtained as described in section 11.3.7; the part of the array relating to domestic uses may now be discarded). We also have estimates of tax rates (section 11.3.4), indexed as the prices but also by EPD use class. We now aggregate the price and taxes from the nine EPD commodities to the five ESD commodities, using share weighted averages, calculated from the special-purpose energy volume data (section 11.3.3).

11.3.10. Mapping from EPD Countries to GTAP Regions

We map energy price and tax data from IEA countries to GTAP regions in two steps. First, we map from IEA countries to standard GTAP countries, then from standard GTAP countries to GTAP regions.

Of the 244 standard GTAP countries, 92 are included in the original price and tax data. For the rest of the countries, we assign proxies, and set their prices and tax rates equal to those for the proxy countries. In the main, the proxy countries match their partners in geographical area and direction of net energy trade (importer or exporter), but some quirks are apparent (for example, the matching of Guinea to Brazil rather than to Ghana, and the matching of Barbados to Brazil rather than to itself). Table 11.14 shows the matching; to save space, we have omitted countries matched to themselves.

Table 11.14. Matching GTAP to EPD Countries: Proxy and Missing Countries

EPD country	GTAP countries
United Arab Emirates	Bahrain, Bahrain, Oman, Yemen,
Australia	Cocos (Keeling) Islands, Christmas Island, Heard Island and McDonald Islands, Norfolk Island, Pitcairn
Azerbaijan	Armenia, Georgia,

Brazil	Aruba, Anguilla, Antigua & Barbuda, Bahamas, Belize, Barbados, Comoros, Cayman Islands, Dominica, Falkland Islands (Malvinas), Guinea, Guadeloupe, Grenada, French Guiana, Guyana, Saint Kitts and Nevis, Saint Lucia, Montserrat, Martinique, Puerto Rico, Suriname, Turks and Caicos, Saint Vincent and the Grenadines, Virgin Islands, British, Virgin Islands, U.S.
Barbados	Netherlands Antilles
Canada	Saint Pierre and Miquelon
Switzerland	Liechtenstein
China	Macau
Denmark	Greenland
Spain	Andorra, Gibraltar
Estonia	Croatia
Finland	Aland Islands
France	Monaco
United Kingdom	Faroe Islands, Guernsey, Isle of Man, British Indian Ocean Territory, Jersey, Macedonia, the former Yugoslav Republic of, South Georgia and the South Sandwich Islands
Ghana	Angola, Burundi, Burkina Faso, Botswana, Central African Republic, Cote d'Ivoire, Cameroon, Congo, the Democratic Republic of the, Congo, Cape Verde, Djibouti, Eritrea, Gambia, Guinea-Bissau, Equatorial Guinea, Kenya, Liberia, Lesotho, Madagascar, Mali, Mozambique, Mauritania, Mauritius, Malawi, Mayotte, Namibia, Niger, Reunion, Rwanda, Sudan, Senegal, Saint Helena, Sierra Leone, Somalia, Sao Tome and Principe, Swaziland, Seychelles, Chad, Togo, Tanzania, United Republic of, Uganda, Zambia, Zimbabwe
Greece	Albania, Bosnia and Herzegovina, Cyprus, Montenegro, Serbia and Montenegro
Indonesia	Timor-Leste
India	Maldives, Myanmar
Iran, Islamic Republic of	Iraq
Israel	Palestinian Territory, Occupied
Italy	San Marino, Holy See
Kazakhstan	Turkmenistan, Uzbekistan
Korea, Republic of	Korea, Democratic People's Republic of
Lebanon	Jordan, Syrian Arab Republic
Libyan Arab Jamahiriya	Benin, Egypt, Ethiopia
Lithuania	Belarus, Moldova, Republic of, Ukraine
Morocco	Western Sahara
Norway	Bouvet Island, Svalbard and Jan Mayen
Romania	Bulgaria
Russian Federation	Tajikistan
Slovenia	Malta

Thailand	Afghanistan, American Samoa, Antarctica, French Southern Territories, Bhutan, Cook Islands, Fiji, Micronesia, Federated States of, Guam, Cambodia, Kiribati, Lao People's Democratic Republic, Marshall Islands, Mongolia, Northern Mariana Islands, New Caledonia, Niue, Nauru, Palau, French Polynesia, Solomon Islands, Tokelau, Tonga, Tuvalu, Vanuatu, Wallis and Futuna, Samoa
United States of America	Bermuda, United States Minor Outlying Islands

We then average across countries to obtain prices and tax rates for GTAP regions. For tax rates and basic prices, we use domestic-absorption-weighted averages, where domestic absorption is calculated as imports plus production less exports, taken from the energy volume data set after mapping to EPD commodities and industries but before aggregating to GTAP regions (that is, as at the end of section 11.2.2).

For export (FOB) prices, we use trade shares, defined by adding exports and imports together; unless no trade data are available for countries belonging to the region, in which case we use simple averages; and unless all countries belong to the region are missing, in which case we use a world average export price. Thus, we ensure a full array of non-zero export prices.

11.4. Combining Price and Volume Data

With energy price and volume data in hand, we can now construct money value estimates for international trade and for I-O flows. In so doing, we find it necessary to make some adjustments to both volumes and prices.

As with the GTAP data base itself, we give priority to the trade data over the I-O data. The reason is the same: we cannot construct a balanced trade data set from the I-O data, so, where they differ, the I-O data must adjust to the trade data. Although the volume data are balanced internationally (section 11.2.4), the money value data will be unbalanced unless import and export prices are mutually consistent; and nothing in the initial construction of the price data (section 11.3) enforces international consistency of prices.

Strictly speaking, the initial price data set of section 11.3, although it draws on import prices, contains no import price data specifically, since the estimated basic prices apply equally to imports and domestic product. But assuming import parity pricing, they do apply to imports; and yet in general, they are liable to be inconsistent with the export prices and any reasonable estimate of international trade margins.

Our first main task therefore is to construct an internally consistent data set covering volumes, prices, and money values in international energy trade. For this we draw both on the unilateral trade volumes in the energy volumes data set, and the bilateral trade money values in the trade data set (chapter 9). The second main task is to construct data sets covering volumes, prices, and money values for I-O flows in the individual regions. As it turns out, the I-O money values as initially constructed fail to meet certain necessary inequalities; this we correct by revising the price data.

Some minor tasks also emerge. For technical reasons relating to I-O table balancing (chapter 15), it is expedient to replace many zero values in the data with small non-zeros, an operation we call data *smearing*. For this purpose, we draw on the (unadjusted) I-O tables (chapter 7). To verify the internal consistency of prices and money values in I-O flows (section 11.4.4), we need production subsidy rates; we draw these mainly from the protection data set (chapter 10), but some energy-specific revisions are necessary. And tax rates must be converted from the specific rates recorded in the energy price data set (section 11.3) to the *ad valorem* rates used in the I-O table balancing.

We proceed in this order:

1. Smear the volumes data.
2. Construct energy trade data.
3. Revise the production subsidy data.
4. Construct initial estimates of I-O money value flows, and adjust prices to ensure internal consistency of the I-O money value flows.
5. Convert tax rates from specific to *ad valorem*.

11.4.1. Energy Volumes: Smearing

We adjust the volumes data to replace zero levels of domestic production with strictly positive levels. This is obviously undesirable in principle, but since the new non-negative values are small, they should cause little harm in practice. The reason for the adjustment is that the `FIT` program used to adjust the regional I-O tables to match the energy data (chapter 15) cannot cope with zero or tiny shares of domestic product in total usage. This remains an area for further work in later GTAP releases.

We make the adjustment in two stages. First, we make very small adjustments to import, production, and usage volumes, using the regional I-O tables. The resulting energy usage structure is a weighted average of the original structure in the energy data and a structure derived from the I-O tables, with a high weight (31/32) given to the original energy data and a low weight (1/32) to the I-O tables. Since domestic usage and production is non-zero for each commodity in each regional I-O table, this procedure ensures that they are non-zero also in the energy data set.

11.4.2. International Energy Trade

We construct a bilateral international energy trade data set from the export and import slices of the energy volume data (sections 11.2, 11.4.1), the energy block of the international trade data set (chapter 9), and the export price data from the energy price data set (section 11.3).

We revise the trade data set so that for energy commodities it is compatible with the energy data. We take the volume of each region's exports and imports of each energy commodity from the energy volume and price data sets. We take bilateral trade matrices of FOB money values for GTAP energy commodities from the trade data set, aggregate from GTAP to EDS commodities, and divide by export prices from the energy data set to create initial estimates of bilateral trade volumes. We replace zero values in the initial estimates with small non-zeros to facilitate rebalancing, then balance these matrices against the energy volume data set's export and import vectors. Finally, we multiply by export prices to construct a bilateral money values, and disaggregate from EDS to standard GTAP commodities using shares from the initial trade data set.

For the balancing, we use the bi-proportional adjustment (*RAS*) method (see, e.g., Schneider and Zenios 1990): each element A_{ij} in the initial matrix, representing the volume of exports of an energy commodity from region I to region j, is replaced by a new value $R_i A_{ij} S_j$, where R_i and S_j are scaling factors endogenously determined so that the adjusted bilateral matrix agrees with the specified regional export and import totals.

Table 11.15 summarizes the resultant changes in the trade data set. As it shows, there are substantial reductions in the total money value of trade in coal and petroleum products.

Table 11.15. Trade in energy (FOB value in US$ billion), 2014

Commodity	Old	New
Coal	152.5	99.1
Oil	1394.1	1272.6
Gas	368.9	324.8
Petroleum products	154.6	103.2
Electricity	60.2	49.4
Gas distribution	26.7	7.9

We also find some considerable differences between the original trade data and the energy volumes data on the pattern of trade. To remove the effect of the country-generic changes in trade values shown in table 11.15, we rescale the original trade arrays to match the commodity sums from the revised arrays. We then identify significant changes between original and revised energy exports (table 11.16) and imports (table 11.17).

Table 11.16. Original and Revised Export Profile, Selected Cases (US$ million CIF), 2014

Country	Commodity	Original exports	Revised exports
United Arab Emirates	oil	19046	90948
Uganda	oil	0	2525
Belgium	gas	7078	28
Malaysia	p_c	26814	5045
Russian Federation	gas	36586	79043

Iran, Islamic Republic of	gdt	17	5569
Singapore	p_c	67220	34062
Iran, Islamic Republic of	p_c	1549	11212
Madagascar	oil	0	1030
United Arab Emirates	p_c	32055	12423
United States of America	gdt	788	8452
Belgium	p_c	34889	14893
Canada	gas	14563	33503
Germany	gas	6504	512
Netherlands	gas	2415	11507
United States of America	gas	8104	22044
Rwanda	oil	0	740
Australia	coa	37301	61628
Spain	gas	2237	10
Malta	p_c	2036	8

Table 11.17. Original and Revised Import Profile, Selected Cases (US$ million CIF), 2014

Country	Commodity	Original imports	Revised imports
Singapore	oil	5151	28934
Singapore	p_c	59880	21010
Belgium	oil	3090	20435
Turkey	gas	3520	21020
Greece	p_c	3641	20749
Germany	oil	35514	65677
Rest of East Asia	p_c	582	7009
China	gas	23737	8444
Rest of Europe	p_c	15284	3904
United States of America	gas	15723	34987
Rest of Western Asia	gas	3987	82
Turkey	oil	2992	13077
Italy	oil	64358	38356
Rest of Western Asia	p_c	7303	20207
Togo	p_c	6129	596
Malta	p_c	6892	877
Panama	oil	2243	12
Malaysia	p_c	29338	14093
Poland	gdt	95	3131
Canada	oil	21623	9514

In general, the differences between the original and revised trade data appear quite considerable. They are especially prevalent for petroleum products and gas exports, and crude oil and petroleum products imports. In several cases, the original trade data show substantial export flows where the energy data set has zero or insignificant exports, for example, gas from Belgium and Spain, or petroleum products from Malta.

In one way, the original and revised data are not comparable. The original data include travelers' expenditures (consumption abroad by non-residents), some US$1228 billion in total for 2014, which we have assigned among GTAP commodities (chapter 9.B). A small fraction, some $17.7 billion, is allocated to electricity; but though small as a fraction of travelers' expenditures, it is large in relation to global electricity trade. A number of points arise:

- In principle, we should use the energy data to revise just the cross-border energy flows, and add in the travelers' expenditures after the revision.
- Small as energy purchasers are in relation to total travelers' expenditures, they should arguably be smaller.
- In most of the electricity trade discrepancies reported in tables 11.16 and 11.17, travelers' expenditures do little to explain the discrepancy; in many cases, they reduce rather than increase the discrepancy.

In general, we leave it to those with more knowledge of the energy sector to determine in each case whether the original trade representation or the energy data set representation of energy trade is more credible.

The original trade data set contains not only FOB value but also CIF value and trade margin estimates. From these we can calculate margin rates in international trade. Combining these with our new FOB money value estimates, we obtain new CIF money value estimates. From the new CIF and FOB money value estimates, and the original modal composition of margins, we obtain new estimates of margin usage; summing these over freight commodity, source of freight, and destination of freight, we obtain new estimates of margin supply. We then have a complete new trade data set, which we use in fitting the I-O tables and assembling the main GTAP data file (chapter 15).

Also, dividing the new CIF values by volumes, we calculate source-specific CIF import price estimates. These together with import duty rates (chapter 10) yield source-specific estimates of basic import prices; averaging these over source countries, we obtain basic import prices indexed by EDS commodity and GTAP region. These we use in constructing I-O money value flows (section 11.4.4).

We note that our final energy import price estimates derive not from the source data for energy import prices, but from data for energy export prices, and from the bilateral trade pattern and margin rates in the merchandise trade data set.

11.4.4. I-O Money Value Flows; Domestic Price Adjustment

At this point, having obtained internally consistent data sets for energy prices and volumes, on a GTAP-compatible basis, we can combine the two to obtain estimates of money values of energy flows. For imports we use the import price estimates from the energy trade data (section 11.4.2), and for domestic production, the initial basic price estimates (section 11.3.11). Where basic price estimates are missing, we using world average prices. From these we calculate source-generic prices which we apply to all domestic absorption. For exports, we use the export price estimates from the energy price data set (section 11.3.11). Combining these with the energy volume data set (section 11.2) we obtain money values of energy I-O flows.

We note that, although our source data for energy import prices do not affect these import price estimates (which instead derive from export price data, as explained in section 11.4.2), they are, for many countries and commodities, the main determinant of our domestic product price estimates (see further sections 11.3.6 and 11.3.9).

We find that our initial money value estimates are liable to violate certain necessary inequalities: that in some instances, the cost of energy inputs into an energy industry exceeds the industry's total costs, as inferred from the value of its output. For example, in Japan, producer revenue from refined petroleum products is US$111.5 billion; under our accounting assumptions, this must be equal to the total cost of production, including the user cost of capital. However, the cost of energy inputs into petroleum refining is US$163.8 billion. Therefore, the cost of non-energy inputs must be minus US$52.3 billion, which is obviously impossible.

We deal with this by adjusting producer revenue. Specifically, we require that for each energy industry in each country, the cost of energy inputs must not exceed 90 per cent of producer revenue; where it does exceed 90 per cent, we increase the price of the industry's output so that the 90 per cent rule is satisfied. For example, for the Japanese petroleum refining industry, to satisfy the 90 per cent rule we need to raise producer revenue to US$182 billion (90 per cent of $182 billion is $163.8 billion, equivalent to energy input costs).

There are two ways in which we can make the required adjustment in producer revenue. One is to increase the market value of output, the other to reduce production taxes or increase production subsidies. Of course we can also use both methods at once, increase the output value and the production subsidy simultaneously. In most cases we just increase the market value of output, but in a few cases—where we believe that there is a large production subsidy, but the energy tax data set provides no estimate—we also adjust the production subsidy. In GTAP 10 we do this for just one case: the Singapore petroleum refining industry, where 50 per cent of the producer revenue adjustment is made through the output price.

But these upward adjustments in output values create sectoral imbalances: the value of output in the adjusted industries exceeds the value of sales of the corresponding commodities. In our example, for refined petroleum products in Germany, output (before subsidy/tax) has been raised to $182 billion, but sales remain at $111.5 billion.

At the same time, we must address the question of consistency between volumes, prices, and money values. When we increase the money value of output, does this entail an increase in output volume or in output price? Since the source data are better for volumes, we maintain the original volume estimates, and adjust the price estimates. By finding new price estimates we remove the sectoral imbalances and the volume-price-value inconsistencies simultaneously.

We cannot however adjust export or import prices country-by-country, since this would create cross-country inconsistencies between export and import money values. Accordingly, we hold export and import prices fixed, and adjust only prices of domestic products absorbed domestically.

In adjusting prices to remove imbalances in one sector we may of course create problems in other sectors. If for example we raise the price of petroleum products, to remove a revenue shortfall in the petroleum refining industry, we may create revenue shortfalls in industries that use refined petroleum. Indeed, since the refining industry itself uses refined petroleum, we may find that the revenue shortfall within that industry is not fully removed; intra-industry usage has a multiplier effect. To prevent this we make the adjustments within an IO price model, in which changes in input prices generate changes in output prices. We then solve simultaneously for all prices in a region, so as to remove all imbalances in the region.

We note that treating as intra-industry usage transfers of EEB products mapped to p_c (section 11.2.2), while creating no imbalance in the data, does strengthen the multiplier effect, and increases the price adjustment needed to satisfy the 90 per cent rule.

To remove the imbalance in the Japanese petroleum refining sector, for example, we may raise the price of refined petroleum, and adjust petroleum sales values accordingly. We use the IO price model to find the price of domestically produced petroleum products that removes the revenue shortfall in the refining industry, taking account of the effect of petroleum products price increases on the prices of other energy commodities.

As described so far, the procedure has an upward bias: since the initial imbalances all involve deficits in sales values compared to output values, their removal entails raising the prices of the corresponding commodities. To reduce this bias, we allow the procedure to remove imbalances not only by raising output prices and but also by lowering input prices. So, for instance in the German petroleum refining industry, the imbalance can be addressed not only by raising the price of refined petroleum but also by lowering the price of inputs such as crude oil. But since the price of imported crude oil is fixed, and Germany produces very little crude domestically, lowering the price of domestically produced crude does little to remove the imbalance. So, the imbalance is removed mostly by raising output prices, and the tendency to raise the general energy price level, though somewhat weakened, remains strong.

After removal of imbalances, aggregate energy output is $10.56 trillion, 6.9 per cent above the initial level of the basic value of output. Depending on the commodity, adjustments are introduced in up to 89 regions (the case of “petroleum and coal products”). Table 11.18 shows some of the more significant adjustments.

Table 11.18. Cost Reconciliation and Price Adjustment, Selected Cases, 2014

Region	Commodity	Output value (US$ billion)		Domestic price (US$/TOE)	
		Initial	Updated	Initial	Updated
est	p_c	69.3	768.5	707.0	10257.7
cri	p_c	11.8	65.4	776.8	4795.8
arg	ely	2257.6	14222.3	207.2	1186.5
ben	ely	12.9	36.7	857.0	2128.3
gin	p_c	3.9	10.6	888.4	2113.6
est	coa	12.8	50.3	761.0	916
brn	ely	295.4	688.0	184.5	1918.8
xws	ely	11256.8	20672.4	762.8	2606.2
xsc	p_c	4.9	10.4	717.8	2085.2
rwa	p_c	5.4	11.6	750.0	1967.7
mwi	p_c	4.1	8.8	1096.2	1964.2
gtm	p_c	59.1	129.0	698.0	1818.5
uga	p_c	18.9	39.6	640.7	1927.5
xcb	ely	2617.5	4730.8	769.3	2375
mdg	p_c	7.9	16.1	1104.2	1878.4
est	gas	48.1	147.3	814.3	929.1
kwt	ely	4552.8	8723.5	491.6	1734.3
mlt	ely	258.5	424.9	784.5	2221.6
brn	p_c	340.7	572.5	1319.2	1678.7
sau	ely	21200.2	38392.1	793.0	1458.3

As table 11.18 shows, the adjustment procedure consistently delivers a final value of output a little higher than the initial cost-based estimate. This reflects the multiplier effect of intra-industry usage. Adjustments to the “petroleum and coal products” and “electricity” sectors are the most frequent. Especially large increases in petroleum products prices are observed for instance in Uganda (176 per cent), Malawi (162 per cent), Costa Rica (517 per cent) and Estonia (1351 per cent), and significant increases in the price of coal in Estonia (396 per cent) and the price of electricity in the Argentina (473 per cent).

11.4.5 Ad Valorem *Tax Rates*

With prices finalized, tax rates are converted from specific-rate (per TOE) to *ad valorem* rates. These, along with missing value flags, are passed to the I-O table balancing module (chapter 15).

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