Chapter 17

An Energy Data Base for GTAP

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17.1 Overview

Over the last decade, modelers have become increasingly reliant on good energy data for use in applied general equilibrium (*AGE*) modeling, in particular, to assess the economic costs of policies to reduce greenhouse gas (*GHG*) emissions[1]. However, the reliability of the energy data in version 3 of the GTAP data base has been questioned, in part because these data depart from the data published by the International Energy Agency (IEA) (Babiker and Rutherford, 1997). With financial support from the United States Department of Energy, the Center for Global Trade Analysis undertook the task of integrating energy data from various sources — mainly the IEA — into its input-output (*I-O*) accounting framework. The challenge of this project is twofold : first, it requires integrating data expressed in physical units, because most GHGs emissions — and carbon dioxide in particular — are related to the energy content of the fossil fuels; second, it requires the identification of acceptable energy price levels across countries of the world, because the existence of energy taxes or subsidies is a major factor in determining the marginal abatement costs of

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1 See Wyant and Hill (1997) or OECD (1999) for a survey of these studies.

emissions. In addition, the project aimed at estimating reliable tax wedges for the different uses of the main fossil fuels.

However, estimating such a balanced set of energy accounts in value and physical unit terms for all countries in the world is far from an easy task. The IEA regularly publishes energy prices and volume balances for the OECD countries. It also has some volume data for certain non-OECD countries. But, by and large, information on energy prices and demands in non-OECD countries is fragmentary and often contradictory across sources. The approach followed here gives preeminence to the data from the IEA over any other data sources, including trade data and the national I-O tables. This implies that the national I-O tables must be adjusted in order to be made compatible with the value flows that can be estimated on the basis of the IEA price and volume data. The approach also emphasizes flexibility in filling information gaps so that new information can be easily introduced as it becomes available.

This chapter provides an overview of the methodology that has been used in establishing a set of balanced energy accounts. The first section describes the data from various sources that have been used as inputs. The second section reviews the main definitions (sector and users classification, price definitions, *etc*.) and the major assumptions and parameters used in calculating the energy flows and filling the information gaps. The third section describes the adjustments that have been made in order to make these energy accounts compatible with the rest of the GTAP data base. The final section assesses the resulting energy price data and compares them with the price and tax data published by the IEA.

The set of programs that handle the energy data (the *energy module*) generates a number of output data sets that are then incorporated into the regional I-O tables as described in Chapter 19. These outputs include:

— quantity of energy usage, by energy commodity and energy usage class,
— basic prices of domestically produced and imported energy, by energy commodity,
— money value of energy usage, by energy commodity and energy usage 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
— where available, powers of taxes on intermediate usage and private consumption of energy commodities, by GTAP commodity and industry.

17.2 Input Data

Inputs to the energy module involve price and quantity data that are regularly published and updated by some national and international administrations. This section reviews these data sources.

17.2.1 Price Data

Most energy price data are provided by the IEA publication *Energy Prices and Taxes*. This publication provides end-use prices and taxes (in national currencies and United States dollars) for eight energy products (see below) and three user categories (industries, electricity, and households). The published data cover the OECD countries only though some non-OECD data are available in electronic form. For non-OECD countries, these data have been complemented with data from various sources, including :

— the Organizacion Latino Americana De Energia (*OLADE*)

— the Asian Development Bank's (*ADB*) energy data time-series for eighteen developing member countries from Southeast Asia, South Asia, North Asia (including China), the Pacific Islands and Asian Newly Industrialized Economies, published in *Energy Indicators of Developing Member Countries of ADB*

— the United States Department of Energy (*DOE*)

— the China Energy Databook published by the Ernest Orlando Lawrence Berkeley National Laboratory (J.E. Sinton ed.)

— the World Bank survey of Asia's Energy Prices (Malhotra *et al*., 1994)

Where data sources overlap, priority has been given to the IEA data to the extent that they are available.

17.2.2 Quantity Data

The volume data are from the IEA energy balances data bases. These data are available on diskettes or CD-ROM [2]. They come from four IEA data bases : the energy statistics and energy balances for 29 OECD countries for the years 1960 to 1999; the energy statistics and balances for more than a hundred non-OECD countries for the years 1971 to 1999. The diskettes should be used in conjunction with the following publications: *Energy Statistics of OECD Countries 1998-1999; Energy Balances of OECD Countries 1998-1999; Energy Statistics of Non-OECD Countries 1998-1999; and Energy Balances of Non-OECD countries 1998-1999.* These publications provide

[2] See http://www.iea.org/stats/files/weddisk.htm

complete definitions, methodology, and notes relating to individual countries. Some preliminary aggregation and reallocation of these volume data are needed in order to make them more compatible with the GTAP sectoral definition (see Complainville and van der Mensbrugghe, 1998). The resulting data base identifies 135 countries, seven energy products and 32 different types of energy usage, as described in the following section.

17.3 Basic Definitions and Assumptions

17.3.1 Product Mapping

Table 17.1 shows the different product definitions between the GTAP 5 data base and the various IEA data bases. The IEA energy prices and taxes data have a somewhat higher sectoral breakdown and the price aggregation is done by using the corresponding volume balances for the OECD countries. Caution is needed in interpreting the transition from the IEA volume balances and the GTAP 5 data base. For electricity, the IEA data provide balances for electricity and a number of

Table 17.1 Product Mapping

GTAP 5 Sector	GTAP 5 Code	IEA Volume Data Standardized	IEA Energy Balances in OECD and Non-OECD Countries	IEA Energy Prices and Taxes	IEA Detailed Energy Balances (DEB)
Coal	col	1) coal	coal	steam coal	brown coal bituminous coal sub-bituminous coal
				coking coal	coking coal
Oil	oil	2) oil	crude oil	*n.a.*	crude oil
Gas	gas	3) gas	gas	natural gas	natural gas
Petroleum products	p_c	4) p_c	petroleum products	heavy fuel oil light fuel oil automotive diesel gasoline	heavy fuel oil gas/diesel oil gas/diesel oil motor gasoline
Electricity	ely	5) ely 6) heat	electricity heat	electricity	electricity
Not included[a]	- -	7) renew	hydro geothermal, solar, wind, tide, combustible renewables and waste nuclear		

[a] Renewables in GTAP are part of electricity.

energy sources that are used almost exclusively to generate electricity (nuclear, hydro, geothermal, solar, wind, tide and other renewable energies). The latter are not aggregated into the GTAP electricity sector in order to avoid double counting. In that sense, the GTAP sectors are best considered as a subset of the IEA sectors.

17.3.2 Country Mapping

Table 17.2 shows the concordance between the 66 countries and regions of the GTAP 5 data base and the countries identified in the IEA energy balances data base.

Table 17.2 Concordance between GTAP Version Regions and the Regions in the IEA Energy Balances

	GTAP code	GTAP name	IEA code	IEA name
1	AUS	Australia	AUS	Australia
2	NZL	New Zealand	NZL	New Zealand
3	CHN	China	CHN	China
4	HKG	Hong Kong	HKG	Hong Kong
5	JPN	Japan	JPN	Japan
6	KOR	Korea	KOR	Korea
7	TWN	Taiwan	TWN	Taiwan
8	IDN	Indonesia	IDN	Indonesia
9	MYS	Malaysia	MYS	Malaysia
10	PHL	Philippines	PHL	Philippines
11	SGP	Singapore	SGP	Singapore
12	THA	Thailand	THA	Thailand
13	VNM	Vietnam	VNM	Vietnam
14	BGD	Bangladesh	RAS_BGD	Bangladesh
15	IND	India	IND	India
16	LKA	Sri Lanka	LKA	Sri Lanka
17	XSA	Rest of South Asia	RAS_NPL RAS_PAK BTN in OTHERASIA MDV in OTHERAFRIC	Nepal Pakistan Bhutan Maldives
18	CAN	Canada	CAN	Canada
19	USA	United States of America	USA	United States of America
20	MEX	Mexico	MEX	Mexico

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Table 17.2 Concordance between GTAP Version 5 Regions and the Regions in the IEA Energy Balances (Continued)

GTAP code	GTAP name	IEA code	IEA name
21 XCM	Central America and the Caribbean		*Anguila*
		ATG in OTHERLATIN	Antigua & Barbuda
			Aruba
		BHS in OTHERLATIN	Bahamas
		BRB in OTHERLATIN	Barbados
			Belize
			Cayman Islands
		CAM_CRI	Costa Rica
		CAM_CUB	Cuba
		DMA in OTHERLATIN	Dominica
		CAM_DOM	Dominican Republic
		CAM_SLV	El Salvador
		GRN in OTHERLATIN	Grenada
		CAM_GTM	Guatemala
		CAM_HTI	Haiti
		CAM_HND	Honduras
		CAM_JAM	Jamaica
		CAM_ANT	Netherlands Antilles
		CAM_NIC	Nicaragua
		CAM_PAN	Panama
		KNA in OTHERLATIN	Saint Kitts and Nevis
		LCA in OTHERLATIN	Saint Lucia
		VCT in OTHERLATIN	Saint Vincent and the Grenadines
		CAM_TTO	Trinidad and Tobago
			Virgin Islands, British
22 COL	Colombia	COL	Colombia
23 PER	Peru	RAP_PER	Peru
24 VEN	Venezuela	VEN	Venezuela
25 XAP	Rest of Andean Pact	RAP_BOL	Bolivia
		RAP_ECU	Ecuador
26 ARG	Argentina	ARG	Argentina
27 BRA	Brazil	BRA	Brazil
28 CHL	Chile	CHL	Chile
29 URY	Uruguay	URY	Uruguay
30 XSM	Rest of South America	GUY in OTHERLATIN	Guyana
		RSM_PRY	Paraguay
		SUR in OTHERLATIN	Suriname
31 AUT	Austria	REU_AUT	Austria
32 BEL	Belgium	REU_BEL	Belgium
33 DNK	Denmark	DNK	Denmark
34 FIN	Finland	FIN	Finland
35 FRA	France	REU_FRA	France
			French Guiana
			Martinique
			Reunion

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Table 17.2 Concordance between GTAP Version 5 Regions and the Regions in the IEA Energy Balances (Continued)

GTAP code	GTAP name	IEA code	IEA name
36 DEU	Germany	DEU	Germany
37 GBR	United Kingdom	GBR	United Kingdom
38 GRC	Greece	REU_GRC	Greece
39 IRL	Ireland	REU_IRL	Ireland
40 ITA	Italy	REU_ITA	Italy
41 LUX	Luxembourg	REU_LUX	Luxembourg
42 NLD	Netherlands	REU_NLD	Netherlands
43 PRT	Portugal	REU_PRT	Portugal
44 ESP	Spain	REU_ESP	Spain
45 SWE	Sweden	SWE	Sweden
46 CHE	Switzerland	EFT_CHE	Switzerland
47 XEF	Rest of EFTA	EFT_ISL	Iceland
			Leichtenstein
		EFTt_NOR	Norway
48 HUN	Hungary	CEA_HUN	Hungary
49 POL	Poland	CEA_POL	Poland
50 XCE	Rest of Central European Associates	CEA_BGR	Bulgaria
		CEA_CZE	Czech Republic
		CEA_ROM	Romania
		CEA_SVK	Slovakia
		CEA_SVN	Slovenia
51 XSU	Former Soviet Union	FSU_ARM	Armenia
		FSU_AZE	Azerbaijan
		FSU_BLR	Belarus
		FSU_EST	Estonia
		FSU_GEO	Georgia
		FSU_KAZ	Kazakhstan
		FSU_KGZ	Kyrgyzstan
		FSU_LVA	Latvia
		FSU_LTU	Lithuania
		FSU_MDA	Moldova, Republic of
		FSU_RUS	Russian Federation
		FSU_TJK	Tajikistan
		FSU_TKM	Turkmenistan
		FSU_UKR	Ukraine
		FSU_UZB	Uzbekistan
52 TUR	Turkey	TUR	Turkey

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Table 17.2 Concordance between GTAP Version 5 Regions and the Regions in the IEA Energy Balances (Continued)

	GTAP code	GTAP name	IEA code	IEA name
53	XME	Rest of Middle East	RME_BHR	Bahrain
			RME_IRN	Iran, Islamic Republic of
			RME_IRQ	Iraq
			RME_ISR	Israel
			RME_JOR	Jordan
			RME_KWT	Kuwait
			RME_LBN	Lebanon
			RME_OMN	Oman
			RME_QAT	Qatar
			RME_SAU	Saudi Arabia
			RME_SYR	Syrian Arab Republic
			RME_ARE	United Arab Emirates
			RME_YEM	Yemen
54	MAR	Morocco	MAR	Morocco
55	XNF	Rest of North Africa	RNF_DZA	Algeria
			RNF_EGY	Egypt
			RNF_LBY	Libyan Arab Jamahiriya
			RNF_TUN	Tunisia
56	BWA	Botswana	BWA in OTHERAFRIC	Botswana
57	XSC	Rest of South African Customs Union	LSO in OTHERAFRIC	Lesotho
			NAM in OTHERAFRIC	Namibia
			SAF	South Africa
			SWZ in OTHERAFRIC	Swaziland
58	MWI	Malawi	MWI in OTHERAFRIC	Malawi
59	MOZ	Mozambique	RSA_MOZ	Mozambique
60	TZA	Tanzania	RSA_TZA	Tanzania, United Republic of
61	ZMB	Zambia	RSA_ZMB	Zambia
62	ZWE	Zimbabwe	RSA_ZWE	Zimbabwe
63	XSF	Other Southern Africa	RSA_AGO	Angola
			MUS in OTHERAFRIC	Mauritius
65	XSS	Rest of Sub-Saharan Africa	RSS_BEN	Benin
			BFA in OTHERAFRIC	Burkina Faso
			BDI in OTHERAFRIC	Burundi
			RSS_CMR	Cameroon
			CPV in OTHERAFRIC	Cape Verde
			CAF in OTHERAFRIC	Central African Republic
			TCD in OTHERAFRIC	Chad
			COM in OTHERAFRIC	Comoros
			RSS_COG	Congo
			RSS_CIV	Cote d'Ivoire
			DJI in OTHERAFRIC	Djibouti
			GNQ in OTHERAFRIC	Equatorial Guinea
			ERI in OTHERAFRIC	Eritrea
			RSS_ETH	Ethiopia
			RSS_GAB	Gabon

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Table 17.2 Concordance between GTAP Version 5 Regions and the Regions in the IEA Energy Balances (Continued)

	GTAP code	GTAP name	IEA code	IEA name
			GMB in OTHERAFRIC	Gambia
			RSS_GHA	Ghana
			GIN in OTHERAFRIC	Guinea
			GNB in OTHERAFRIC	Guinea-Bissau
			RSS_KEN	Kenya
			LBR in OTHERAFRIC	Liberia
			MDG in OTHERAFRIC	Madagascar
			MLI in OTHERAFRIC	Mali
			MRT in OTHERAFRIC	Mauritania
				Mayotte
			NER in OTHERAFRIC	Niger
			RSS_NGA	Nigeria
			RWA in OTHERAFRIC	Rwanda
			STP in OTHERAFRIC	Sao Tome and Principe
			RSS_SEN	Senegal
			SYC in OTHERAFRIC	Seychelles
			SLE in OTHERAFRIC	Sierra Leone
			SOM in OTHERAFRIC	Somalia
			RSS_SDN	Sudan
			TGO in OTHERAFRIC	Togo
			RSS_ZAR	Zaire
66	XRW	Rest of World	AFG in OTHERASIA	Afghanistan
			ROW_ALB	Albania
				Andorra
				Bermuda
			ROW_BIH	Bosnia and Herzegovina
			ROW_BRN	Brunei
			KHM in OTHERASIA	Cambodia
			ROW_HRV	Croatia
			ROW_CYP	Cyprus
				Faroe Islands
			FJI in OTHERASIA	Fiji
				French Polynesia
			REU_GIB	Gibraltar
				Greenland
				Guadeloupe
			KIR in OTHERASIA	Kiribati
			LAO in OTHERASIA	Lao People's Democratic Republic
				Macau
			ROW_MKD	Macedonia, the former Yugoslav Republic of
			ROW_MLT	Malta
				Marshall Islands
				Micronesia, Federated States of
				Monaco
			MNG in OTHERASIA	Mongolia
			ROW_MMR	Myanmar

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Table 17.2 Concordance between GTAP Version 5 Regions and the Regions in the IEA Energy Balances (Continued)

GTAP code	GTAP name	IEA code	IEA name
		NRU in OTHERASIA	Nauru
			New Caledonia
		ROW_PRK	Korea, Democratic People's Republic of
		PNG in OTHERASIA	
			Papua New Guinea
		SLB in OTHERASIA	*San Marino*
		TON in OTHERASIA	Solomon Islands
			Tonga
		VUT in OTHERASIA	*Tuvalu*
		WSM in OTHERASIA	Vanuatu
		ROW_SER	Western Samoa
			Yugoslavia

17.3.3 Users Mapping

For each energy source, the IEA energy balances identify the amount available for domestic demand and how this domestic demand is allocated between intermediate and end-use sectors. *Total primary energy supply* (*TPES*) is indigenous production plus imports less exports less consumption by international marine bunkers, adjusted for changes in stocks. This total supply is allocated between 17 energy transformation sectors and 27 end-use sectors. The aggregation of the IEA flows into the GTAP sectors involves two stages. First, the original IEA flows are aggregated and sometimes reallocated to an intermediate level of aggregation referred to as the GTAP flows. This process is described in Complainville and van der Mensbrugghe (1998) and table 17.3 illustrates the correspondences. Second, these flows are further allocated between the various intermediate and final demands corresponding to the version 5 sectoral breakdown, as shown on table 17.4. Both allocation processes involve a number of arbitrary rules about how some IEA flows — *e.g.*, the use of petroleum products for road transportation — is allocated to the GTAP intermediate usage of petroleum products by the transportation sector or to the household demand of petroleum products.

Table 17.3 IEA Flow Aggregation

IEA Flow Codes	GTAP Flow Codes	Description
INDPROD	PROD	Indigenous production
IMPORTS	IMP	Imports
EXPORTS	EXP	Exports
BUNKERS	NONROAD	International marine bunkers
STOCKCHA	split over PROD, IMP, and ELY	Stock changes
Energy Transformation		
TRANSFER	P_C	Transfers
STATDIFF	DIFF	Statistical differences
PUBELEC	ELY	Public electricity plants
AUTOELEC	ELY	Autoproducer electricity plants
PUBCHP	ELY	Public CHP plants
AUTOCHP	ELY	Autoproducer CHP plants
PUBHEAT	ELY	Public heat plants
AUTOHEAT	ELY	Autoproducer heat plants
THEAT	ELY	heat pumps
TBOILER	ELY	Electric boilers
TGASWKS	P_C	Gas Works
TREFINER	P_C	Petroleum refineries
COALTRAN	OWNUSE[a]	Coal transformation
LIQUEFAC	P_C	Liquefaction
TNONSPEC	P_C	Other transformation
OWNUSE	OWNUSE	Own use
DISTLOSS	OWNUSE	Distribution losses
Industry Consumption		
IRONSTL	I_S	Iron and steel
CHEMICAL	CRP	Chemical petrochemical
NONFERR	NFM	Non-ferrous metals
NONMET	NMM	Non-metalic minerals
TRANSEQ	TRN	Transport equipment
MACHINE	OME	Machinery
MINING	MIN	Mining and Quarrying
FOODPRO	FPR	food and tobacco
PAPERPRO	PPP	Paper, pulp and printing
WOODPRO	LUM	Wood and wood products
CONSTRUC	CNS	Construction
TEXTILES	TWL	Textiles and leather
INONSPEC	OMF	Non-specified industry
Transport Consumption		
INTCIAV	NONROAD	International civil aviation
AIR	NONROAD	Air transport
ROAD	ROAD	Road
RAIL	NONROAD	Rail
PIPELINE	NONROAD	Pipeline transport
INLWATER	NONROAD	Internal navigation
TRNONSPEC	NONROAD	Non-specified transport

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Table 17.3 IEA Flow Aggregation (Continued)

IEA Flow Codes	GTAP Flow Codes	Description
Other Sectors Consumption		
AGRICULT	AGR	Agriculture
COMMPUB	SER	Commercial and public services
RESIDENT	DWE	Residential
ONONSPEC	split over AGR, SER DW	Non-specified other
Non-Energy Use		
NEINTREN	CRP	In industry/transf/energy
NETRANS	NETRANS	In transport
NEOTHER	AGR	In other services

Note: The sub-total (TPES, TFC, TOTIND, TOTRANS, TOTOTHER, and NONENUSE) available in IEA energy balance are not shown.

[a] OWNUSE corresponds to the diagonal in the input-output table.

Table 17.4 Main Assumptions in Allocating GTAP Usage Flows

GTAP Usage Flows (as defined in Table 17.3)	GTAP Input-output Flows
All energy uses, except petroleum products, by ROAD, NONROAD and NETRANS	Intermediate energy inputs of T_T[a]
Half of the use of petroleum products by ROAD plus NONROAD and NETRANS	Intermediate input of P_C in T_T
OWNUSE in coal	Input of COL to P_C
OWNUSE crude oil	Input of OIL toP_C
Half of OWNUSE in gas	Input of GAS to ELY
All energy uses - except petroleum product - in DWE	Final energy demands by households
Petroleum products used in DWE	Final demand of petroleum products by households
Half of the use of petroleum products by ROAD	Final energy demands by household

[a] T_T - Trade and transportation

17.3.4 Price Typology

Figure 17.1 illustrates the price relationships that underlie the estimation of the energy flow balances. First, the procedure identifies a basic price, in 1997 US dollars per tonnes of oil equivalent (*TOE*). By assumption, the basic price prevailing on the domestic market is set equal to the corresponding *cif* import price plus import tariffs:

$$BP_{xxx} = IPRC_{xxx} \cdot \left(1 + \frac{IDUT_{xxx}}{100} \right), \tag{1}$$

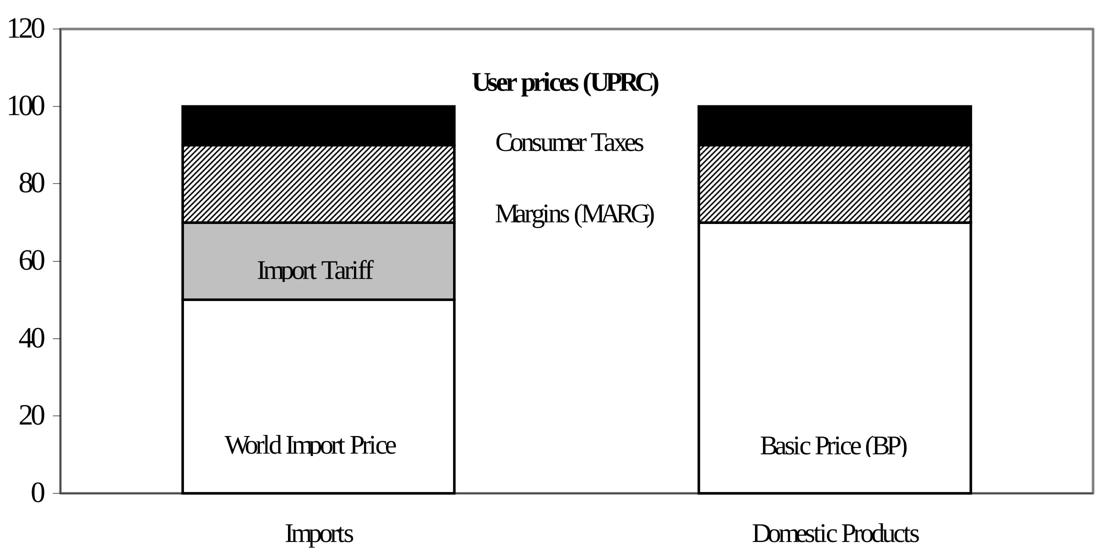
where BP_{xxx} is the country-specific basic price for user category *xxx*, $IPRC_{xxx}$ the corresponding *cif* import price, and $IDUT_{xxx}$ the import duty rate. Basic prices are initially identified for four categories of users: industries (*I*), electricity (*U*), households (*H*) and exports (*X*). A weighted average basic price (BP) is also calculated.

Thus, in each country market, import prices including import tariffs are equal to domestic basic prices[3]. Moving next to the end-user price levels *UPRC* requires adding up margins, *MARG*, and user-specific taxes, *UTAX*. End-user prices are not differentiated between domestic and imported products, so neither are margins or user taxes (see Figure 17.1).

$$UPRC_{xxx} = \left(1 + MARG_{xxx}\right) \cdot BP_{xxx} + UTAX_{xxx} \tag{2}$$

In general, data sources provide information for import prices (at *cif* values), *IPRC*, import duty rates, *IDUT*, end-user prices, *UPRC*, and taxes, *UTAX*. When information is missing, it is imputed using methods that are described in section 17.3.6. The price procedure yields estimations of user-specific and average basic prices.

Figure 17.1 Price Typology in Energy Data Calculations



[3] Consistent with the assumption that domestic and imported energy products are perfect substitutes.

17.3.5 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 17.5 contains the conversion factors used in this version of the data base.

Table 17.5 Conversion Factors

	Unit	Tons of oil equivalents (toe)	Source
Steam coal	1 ton	0.63	US coefficients in IEA, Energy Prices and Taxes, p.43.
Coking coal	1 ton	0.709	US coefficients in IEA, Energy Prices and Taxes, p.43.
Crude oil	1 barrel (bbl)	0.1339	Coefficient for Philippine from ADB Table 11, p.XXIX.
Natural gas	1 cubic meter (m3)	0.0008645	Gross calorific value for Germany from IEA, Energy Prices and Taxes, p.36 converted into toe
Gasoline	1 barrel (bbl)	0.1327014	Conversion factor for "all other countries" from IEA, Energy Prices and Taxes, p.41 applied to conversion factor from bbl to liters
LFO	1 barrel (bbl)	0.1365969	Conversion factor for "all other countries" from IEA, Energy Prices and Taxes, p.41 applied to conversion factor from bbl to liters
HFO	1 ton	0.94	Conversion factor for "all other countries" from IEA, Energy Prices and Taxes, p.42.
Diesel	1 barrel (bbl)	0.14151	Conversion factor for "all other countries" from IEA, Energy Prices and Taxes, p.41 applied to conversion factor from bbl to liters

17.3.6 Price and Other Imputations

End-user Prices

To the extent possible, all available information about the end-user prices have been incorporated. There are however many instances where this information is not available. Two cases must be considered :

- — Chronological price data are available for years before 1997. The latest available data is then extrapolated by using exchange rates and energy price indices time-series.
- — No user price is available for any date (from 1990 onwards). Then missing prices are imputed by taking average prices in “similar” countries. Four country aggregates are identified : i) net energy exporting countries with higher (than average) energy prices; ii) net energy exporting countries with lower (than average) energy prices; iii) net energy importing countries with higher (than average) energy prices; and, iv) net energy exporting countries with lower (than average) energy prices. Missing prices are assumed equal to the average price in the corresponding country category. Missing export prices are assumed equal to the corresponding average export price in other countries or to industry prices net of any user taxes.

End-user Taxes

Missing end-user taxes are assumed to be equal to zero.

Margins

Combining price relationships (1) and (2) allows us to derive margins for different users :

$$MARG_{xxx} = \frac{UPRC_{xxx} - UTAX_{xxx}}{IPRC_{xxx} \cdot \left(1 + \frac{IDUT_{xxx}}{100}\right)} - 1 \tag{3}$$

To the extent that end-user prices and taxes are available, equation (3) allows us to estimate margins for all users. Then, the remaining missing margins are imputed by using the following rules:

- — United States margins are estimated using the 1992 I-O table, Lawson, 1997 Survey of Current Business and from information from the Department of Commerce
- — Margins in Japan are estimated from the Japanese I-O data.
- — All remaining missing margins are calculated as weighted averages using the formula

$$\begin{aligned} MARG_U = {} & (0.2 \cdot JPNMARG_U) + (0.2 \cdot USAMARG_U) \\ & + (0.6 \cdot AVMARG_U), \end{aligned} \tag{4}$$

where *JPNMARG* is the Japanese margin, *USAMARG* is the United States margin, and *AVMARG* is the world average margin calculated over the countries where information relevant to equation (3) is available.

Basic prices

Basic prices are estimated either by using equation (2) where end-user prices and taxes are available or by using equation (1) where end-user prices and taxes are not available.

Finally, an important assumption is that basic prices are *not* differentiated across users. This is implemented by calculating an average basic price over all users and by assuming that this average price applies to all users. Accordingly, margins need to be re-estimated using an equation similar to equation (3) :

$$MARG_{xxx} = \left(\frac{UPRC_{xxx} - UTAX_{xxx}}{AVBP} \right) - 1, \tag{3'}$$

where *AVBP* is the common average basic price for all users.

17.4 Data Adjustments

After the initial construction of the energy data set, we make several adjustments to it and to other key data sets. The purpose of these adjustments is to remove certain internal inconsistencies from the energy data set, to introduce certain refinements into the energy tax data, and to adjust the other data sets to reconcile them with the energy data. In this section we cover the internal adjustments to the energy data set, the refinements to the energy tax data, and adjustments to the trade data set (chapter 15) and the protection data set (chapter 16). Adjustments to the I-O data to make them consistent with the energy data are covered elsewhere, along with other adjustments to the I-O tables (chapter 19).

These operations need to be ordered with care, to avoid introducing new inconsistencies into the data sets. We discuss them here in the order in which we perform them in the energy module: adjust the volumes data, revise the trade data set (and, implicitly, energy trade prices), refine and revise the energy tax data, revise the domestic price data, and convert energy taxes from specific rates to *ad valorem* equivalents.

In reconciling the energy data set with other key data sets, we need to deal with a difference in sectoral classification. The commodity “gas” in the energy data set corresponds to two sectors in the standard GTAP sectoral classification: “gas” (or “natural gas”) covers only primary gas production, while “gas distribution” covers the manufacture of town gas (a very minor source of gas) and the distribution of gas to end users. So in reconciling the various data sets, we adjust the totals for “gas” and “gas distribution” in the non-energy data sets against “gas” in the energy data set.

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. The initial non-zeros are quite small, $210 thousand in total. 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. Naturally, these balancing adjustments are also quite small.

We further 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 tiny, it 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 19) cannot cope with zero or very 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 of each commodity is non-zero in the regional I-O tables, this procedure ensures that they are non-zero also in the energy data set. Nevertheless, it sometimes happens that the domestic production share is still too close to zero for `FIT`; in such cases we make a second adjustment, shifting a tiny fraction of imports (2^{-19}) to domestic production.

It may at first seem surprising that we first replace non-zero values with zeros, and then zeros with non-zeros. But there is good reason for it. The non-zeros that we eliminate satisfy no sanity checks and are relatively large. The non-zeros that we introduce, being based on I-O tables that have already been screened for anomalies, do satisfy sanity checks; and furthermore, they are relatively small. So the new non-zeros are much less harmful than the old ones.

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 use the trade data set and energy price estimates to create an initial estimate of the bilateral trade volume matrix. We replace zero with small non-zero values in the bilateral trade matrices from the trade data set. We then balance the bilateral trade matrix against the regional export and import totals. Finally, we construct a trade matrix in money values, using the price data from the energy data set, and disaggregate from the energy commodity classification to the standard GTAP commodity classification using shares from the initial trade data set.

In the initial replacement of zero by non-zero values, we introduce some small level of intra-region trade in energy commodities, even for the single-country regions. The trade data set of course already recognizes intra-region trade for multi-country regions, such as the Former Soviet Union or the "Rest of Middle East". The total trade introduced for single-country regions amounts to some \$240 million on an fob basis, out of world total energy trade of \$440 billion. Improving this method is an area for work in future releases.

For the subsequent balancing, we use the biproportional 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 $R_iA_{ij}S_j$, 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 17.5 summarizes the resultant changes in the trade data set. As it shows, there are small changes in the total money value of trade in coal, crude oil, natural gas, and petroleum products, and larger changes for electricity and gas distribution.There are also consequential changes in the international margins usage and supply data.

Table 17.5 Trade in Energy (fob value in US$ billion)

GTAP Energy Sectors		Old	New
`col`	Coal	20.191	20.003
`oil`	Oil	230.453	230.860
`gas`	Gas	45.479	47.117
`p-c`	Petroleum products	129.731	101.256
`ely`	Electricity	13.955	22.688
`gdt`	Gas distribution	4.390	2.452

We make some adjustments to the production tax rates in the protection data set. The problem is that for energy industries, these are inherited from the I-O tables; but for some regions, the I-O tables record commodity taxes as though they were production taxes. If we set commodity tax rates for energy according to the IEA data, but left the production taxes unchanged, then we would double-count the taxes. At the same time, some other changes were made inadvertently, apparently replacing production tax rates inherited from current versions of the I-O tables with those from earlier versions; this remains an area for work in future releases. The regions affected by these inadvertent changes include (but are not limited to) Vietnam, Sri Lanka, Switzerland, and Uganda.

We assume that there is no taxation of energy usage by energy industries, except for the electricity industry. For most energy commodities, we adjust the tax rates paid by non-energy industries upward so that the total tax payment on each energy commodity in each region remains the same. However we make no adjustment for crude oil; since most crude oil is used by the petroleum refining industry, the adjustment to tax rates paid by other industries would have to be very drastic to keep the total tax payment constant. Since we exclude in one way or another the major uses of energy commodities in energy sectors — crude oil inputs into petroleum refining, and energy inputs into electricity generation — the remaining price adjustments are generally small.

Combining the volumes, tax, and price data, we have implicit estimates for money values of energy usage and production both at market prices and at agents' prices. However these estimates may contain latent inconsistencies: it is possible for the cost of energy inputs into an energy industry to exceed the industry's total costs, as inferred from the value of its output. For example, in Germany, producer revenue from refined petroleum products is US$13.0 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$14.3 billion. Therefore the cost of non-energy inputs must be minus US$1.3 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 percent of producer revenue; where it does exceed 90 percent, we increase the price of the industry's output so that the 90 percent rule is satisfied. For example, for the German petroleum refining industry, to satisfy the 90 percent rule we need to raise producer revenue to US$15.8 billion (90 percent of $15.8 billion is $14.3 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 price 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 price and the production subsidy simultaneously. In most cases we just increase the market price 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 fact we do this for just two cases: the Singapore petroleum refining industry, where 50 percent of the producer revenue adjustment is made through the output price, and 50 percent through the production subsidy; and the Former Soviet Union electricity industry, where 25 percent of the adjustment is made through the price, and 75 percent through the subsidy.

However this initial calculation ignores simultaneities. For example, the petroleum refining industry may use petroleum products as an input, or may use other energy commodities whose prices are subject to adjustment. We therefore do a further calculation, taking account of these simultaneities. In the case of German petroleum refining, we set a final producer revenue level of US$16.0 billion; this satisfies the 90 percent rule even after allowing for changes in energy input costs.

This completes the price adjustment. The next and final step is to rework the tax data. We convert the specific tax rates on energy commodities into *ad valorem* equivalents to obtain powers of output and commodity taxes, and translate them from the energy sectoral classifications into the GTAP sectoral classification.

17.5 Energy Data Evaluation

This section provides a summary overview of the energy price levels in the version 5 data base. It helps the reader to form a synthetic view on how the energy prices differ across countries. Comparison is also made with the energy price levels in the previous version 4-E (the GTAP data base that supports the GTAP-E model) so as to provide the reader with an evaluation of the changes and corrections that have been incorporated in the version 5 data base. A more detailed evaluation of the version 5 energy prices, including a comparison with the price levels published by the International Energy Agency (IEA) will become available soon.

17.5.1 Coal

Figures 17.2 and 17.3 report the average coal prices - in USD per ton of oil equivalent (toe) - at the disaggregated region level in version 4.E and 5 respectively. These prices are shown in comparison with the US price (horizontal line) used as a proxy for the world price. Both versions agree on pointing out China (CHN), India (IND) and some South African countries - the South African Customs Union (SAF) in version 4-E and Zimbabwe (ZWE) and the Rest of Sub-Saharan Africa (XSS) in version 5 - as lower-price countries. The Former Soviet Union is much closer to the world price level in version 5 (XSU) than in version 4-E , possibly reflecting the impact of market reforms. In both versions, the Rest of North Africa (RNF, XNF) appears as a relatively high-price region. Both versions report higher coal prices in a number of European countries (Finland(FIN), Netherlands (NLD), Ireland (IRL) in version 5; Sweden (SWE) and the EFTA region (EFT) in version 4-E) but the price divergences relatively to the US price is much lower in version 5 compared with version 4-E. The Rest of South Asia region (RAS) is out of range in version 4-E with a coal price three times the US price, most likely reflecting some error. This is no longer the case in the version 5.

Figure 17.2 Average Coal Prices in Version 4-E

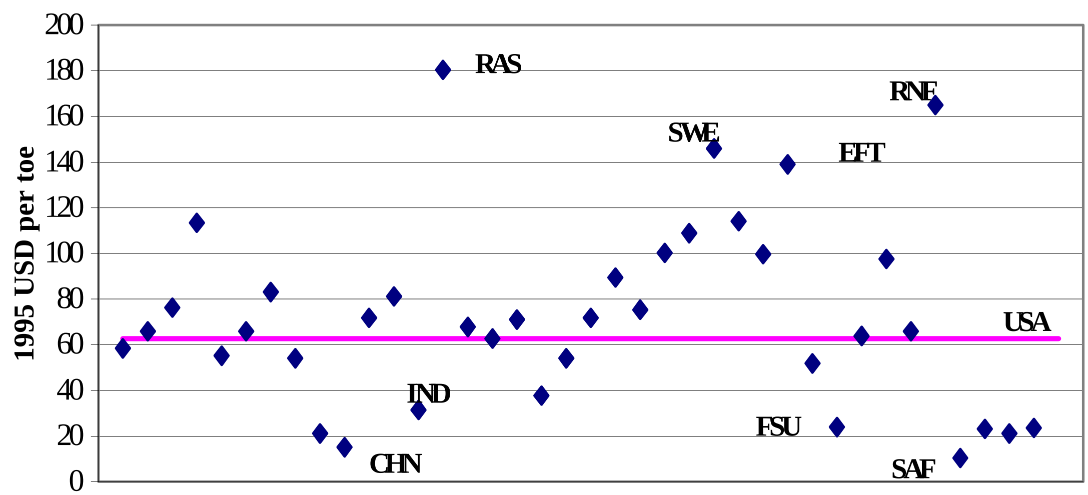
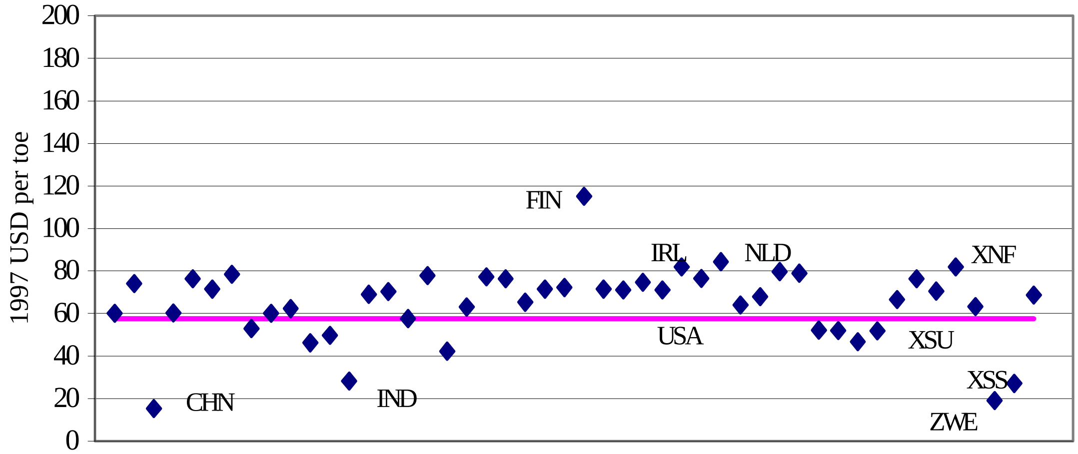


Figure 17.3 Average Coal Prices in Version 5



17.5.2 Petroleum Products

Figure 17.5 shows the profile of the average prices of petroleum products across regions in the version 5 data base. Most European countries (France (FRA), United Kingdom (GBR), Netherlands (NLD), Rest of EFTA (XEF), Germany (DEU)) have petroleum product prices as much as three times higher than in the US. In contrast, petroleum prices in oil exporting countries, such as Venezuela, are at the lower end. In comparison, the corresponding price profile in version 4-E looks very odd (see Figure 17.4). The average petroleum price in Germany (DEU) is equal to almost 3000 1995 USD per toe or 15 times higher than the corresponding US price. In the rest of European Union region (REU), the average price amounts to 2290 1995 USD per toe. Petroleum prices were also unrealistically high in version 4-E for Uruguay (URY), Turkey (TUR) and the Rest of the World Region (ROW). Besides errors in the process of estimating energy prices, the major explanation for these discrepancies relates to the fact that, for a number of reasons, the targets calculated by the energy module could not be effectively enforced in the adjustment process for regional I-O tables (as operated by the FIT program). Figure 17.5 shows that these problems have been fixed in version 5.

Figure 17.4 Average Prices of Petroleum Products in Version 4-E

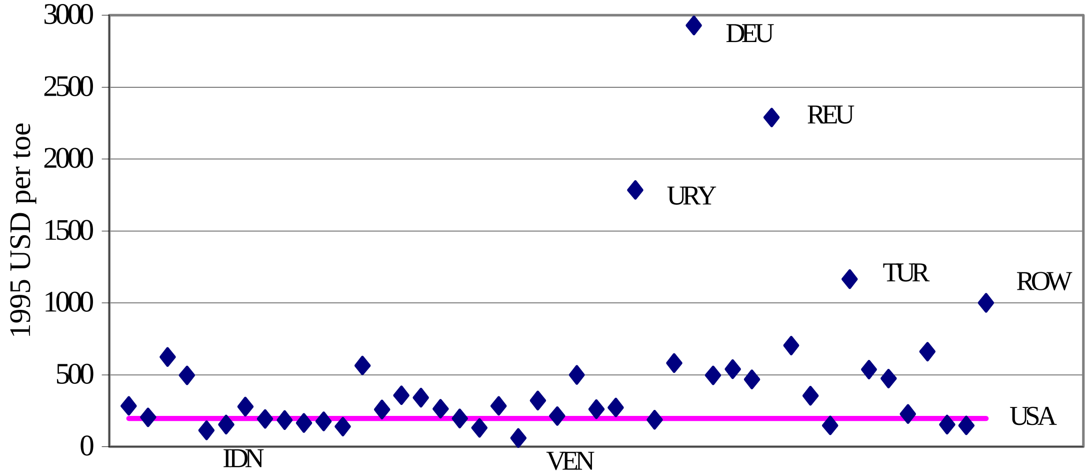
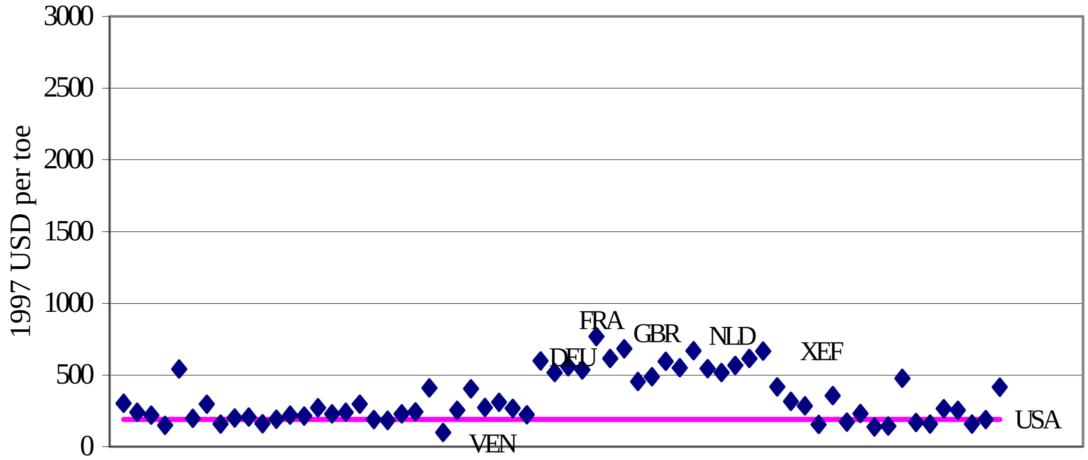


Figure 17.5 Average Prices of Petroleum Products in Version 5



17.5.3 Gas

The pattern of gas prices in version 5 is shown on Figure 17.7. Gas prices average around 100 USD per toe in the US. As expected, prices are higher in most European countries - Italy (ITA), Germany (DEU), Denmark (DNK), France (FRA) - and in Japan (JPN). Lower prices are reported in Venezuela (VEN), Chile (CHL), the Central America and the Caribbean region (XCM) and China (CHN). As for petroleum products, the corresponding price pattern in version 4-E raises suspicion, to say the least. First, there is a huge price dispersion (the reader will notice that the scale of the vertical axis in Figure 17.6 is ten times greater than in Figure 17.7). Second, gas prices in some regions are excessively high compared with US levels, such as in the South African Customs Union (SAF) where the average gas price is more than ten times higher than in the US, Korea (KOR), Central America and the Caribbean (CAM), Taiwan (TWN) and the Rest of the World region (ROW).

Figure 17.6 Average Prices of Gas in Version 4-E

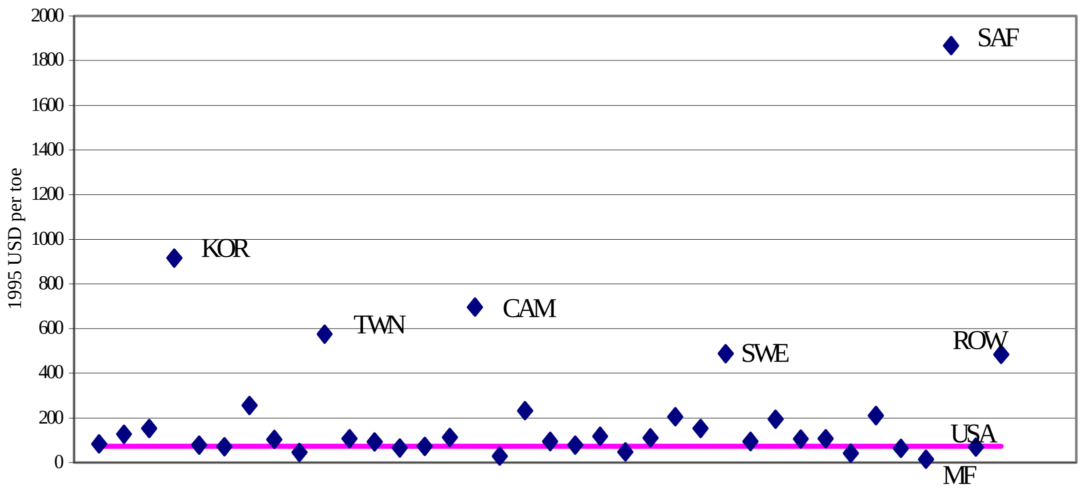
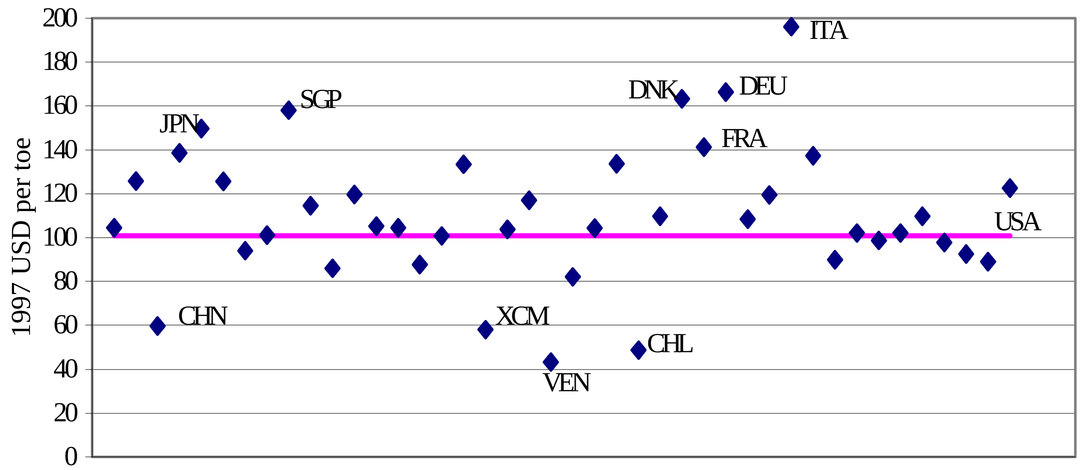


Figure 17.7 Average Prices of Gas in Version 5



17.5.5 *Electricity*

The divergence between version 4-E and version 5 is smaller for electricity than for the other fuel (see figures 17.8 and 17.9), though errors in estimating fossil fuel prices clearly have implications for the electricity price. Both versions however agree in recording higher electricity prices in Japan (JPN) and in Germany (DEU) and lower prices in China (CHN) and the Former Soviet Union (FSU in version 4-E; XSU in version 5). Altogether, the electricity price dispersion in version 5 is smaller than in version 4-E, an outcome that logically results from the lower dispersion of the fossil fuel prices across regions.

Figure 17.8 Average Prices of Electricity in Version 4-E

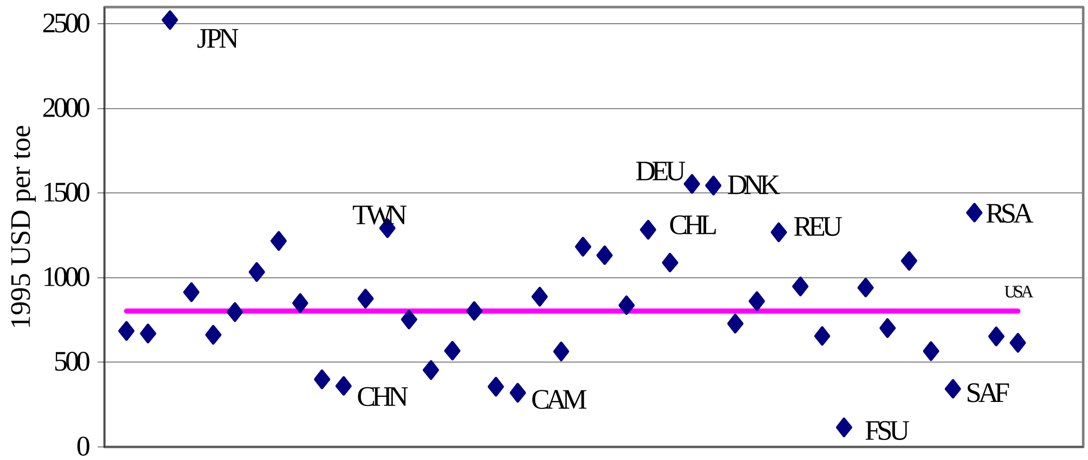
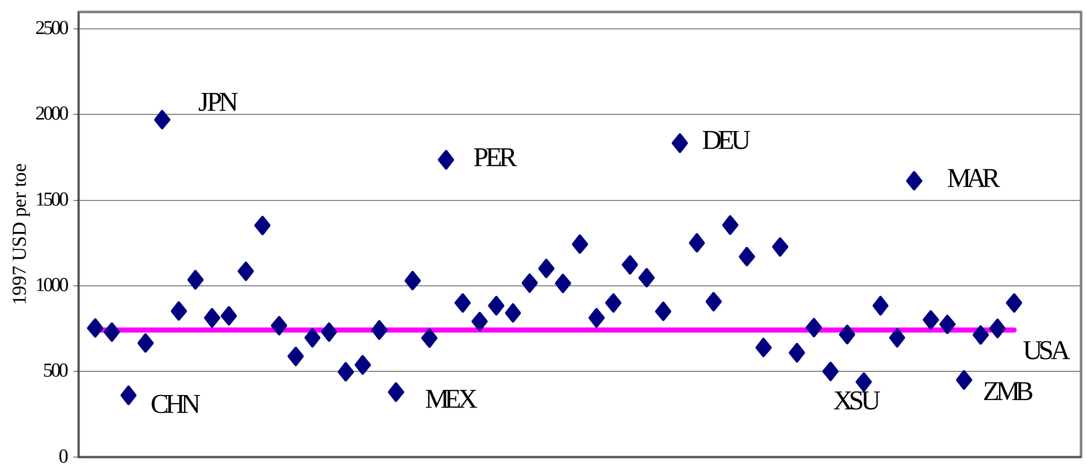


Figure 17.9 Average Prices of Electricity in Version 5



17.5.6 Concluding Remarks

Primary energy sources can be considered as relatively homogenous commodities. Therefore, the price divergences for these commodities across regions mainly reflect: i) regulations on domestic energy markets that distort energy prices; ii) market imperfections such as monopoly rents; and iii) errors in estimating regional energy prices[4]. As far as the last component is concerned, there has been a substantial improvement in the version 5 data base compared with the version 4-E data base. As the above comparison highlights, some energy prices - in particular for petroleum products in Europe - were obviously out of the range in version 4-E. This no longer the case in version 5.

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[4] Many of these errors originate from estimating distribution margins.