GTAP-E Model and the 'new' CO2 Emissions Data in the GTAP/EPA Integrated Data Base – Some Comparative Results

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Abstract

Growing research demands for integrated assessment of GHGs issues have motivated the construction of a data base of land use and GHG emissions for use with CGE models. The EPA sponsored GTAP project (hereafter, GTAP/EPA project) aims to develop such a data base. In this paper, we utilize the availability of the CO2 emission data in this 'new' integrated data base to carry out some illustrative experiments using the GTAP-E model. We first report on the differences between the 'new' CO2 emission 'coefficients' as implied in the 'new' data base and the previously employed aggregate coefficients used in GTAP-E experiments (Burniaux and Truong, 2002). Overall, the new (implied) coefficients are slightly higher than the previously employed aggregate coefficients. However, there are some cases where the reverse is true. We then use the GTAP-E model to run some experiments with the new data base; first, without any modification to the GTAP-E model structure, and then, with some modifications, to take into account the fact that the new data base contains a richer set of information regarding CO2 emissions at a more disaggregate level, and also because of the fact that the new level of CO2 emissions are generally higher than the old levels. The results of these experiments show that the new data base can give significantly different results, and more research are needed to throw light on the issues concerning the implications of these differences in emission levels across different data bases.

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INTRODUCTION

Growing research demands for integrated assessment of green house gases (GHGs) issues have motivated the construction of a data base of land use and GHG emissions for use with CGE models. The EPA sponsored GTAP project (hereafter, GTAP/EPA project) aims to develop such a data base. As a first step in the construction of such a data base, estimates of the levels of Carbon dioxide (CO_2) emissions are carried out and put in a format compatible with the GTAP configuration (Lee, 2002). Carbon dioxide is by far the most important and significant of all green house gases. It accounts for about 60 per cent of the increase in radiative forcing since preindustrial times (IPCC, 1992). By far the largest source of CO_2 emissions is from the oxidation of carbon when fossil fuels are burned, which accounts for 70-90 per cent of total anthropogenic CO_2 emissions. The 'new' data base give estimates of the level of CO_2 emissions based on the level of fossil fuel flows (volume and value) implied in the latest GTAP data base. It gives a more accurate assessment of the level of CO_2 emissions from fossil fuel flows than previous approaches because it utilizes more detailed information about the carbon and energy content of fuels at a sectoral as well as regional/country level.

In this paper, we want to utilize this new data base to test how significant the use of such a more accurate data base can significantly influence the result of some Kyoto-type experiments. We use a version of the GTAP-E model developed by Burniaux and Truong (2002) for this purpose. We first explore the new data base to see how significantly different it is from the 'conventional' approach to estimating the level of CO2 emissions as previously adopted in some GTAP-E simulations. We then carry out some illustrative experiments using both new data base and the conventional approach to explore the differences in the results. We also note that to utilise the more detailed information in the new data base, the structure of the model may also need to be altered, to allow for the differences in the level of emissions from different sources within a country (sectors of the economy) as well as across different countries/regions to be reflected in the model structure.

THE NEW AND THE OLD DATA BASES COMPARED

First we compare the 'new' CO2 emissions data base with the 'old' data base as implied or used by previous CO2 emission experiments. In the 'traditional' approach, used, for example, in the GTAP-E simulations (Burniaux and Truong, 2002), each fuel is given an average CO2 emission coefficient which is often assumed to be constant across all sectors of the economy as well as across different regions. For example, the coefficients used in Burniaux and Truong (2002) were: 24.69, 13.47, and 18.52 Million Tons of Carbon per Exajoule (Mt of C/EJ) for Coal, Gas, and Petroleum and Coal Products (Oil_Pcts) respectively. To compare different data bases, it is best that we compare the effective CO2 emission coefficients implied across these different data bases. To compute these implied CO2 emission coefficients for the new data base, we simply divide the total level of CO2 emissions for each particular sector (emitter) by the total level of fuels used by that sector. These implied or 'effective' CO2 emission coefficients of the new data base are then compared with the (explicit) emission coefficients used in the 'old' approaches (as given above), and the *ratio* of the new and the old coefficients can give us an indication of how different the two data bases are. This method of comparison is preferable to a direct comparison of the *absolute* levels of the emissions in the two data bases, because the 'base' level of energy usage might in some cases have changed.

Table 1 reports on the ratio of the 'new' to the 'old' emission coefficients for the various (aggregated) sectors and regions as defined in the GTAP-E experiments of Burniaux and Truong (2002). From Table 1, it can be seen that the ratios are quite stable across different regions as well as different sectors (Agriculture, Coal, Electricity, and Other Industry and Services ('Oth_Ind_Ser')), even though they can vary significantly across different fuels (for example, comparing Gas with Coal). Secondly, it is noted that the 'new' emission coefficients as implied in the 'new' data base are consistently *higher* than the 'old' ones (the ratio in Table 1 being greater than 1), and this despite the fact that the absolute levels of energy usage in both of these data bases are quite similar[‡]. For example, the emission coefficient for Coal is about 2.4 percent

[‡] They are in fact almost identical because both are derived from the GTAP energy volume data base.

higher in the new data base as compared to the old one, across these sectors for all regions. For Gas, however, this can be as high as 13 percent higher (Table 1). When we move to the Energy Intensive Industries (En_Int_Ind) or the Gas sector (Tables 2 and 3), the picture can change significantly. First of all, there is no longer a uniform picture across all regions (see the columns for Gas and Oil_Pcts in Tables 2 and 3), and that is to be expected. Some regions display a higher emission coefficient in the new data base as compared to the old coefficients (the ratio being greater than 1), and other regions display the reverse (the ratios are less than 1). Thus, the Energy Intensive Industries sector in the USA, for example, has an emission coefficient for Gas, which is higher in the 'new' GTAP/EPA data base as compared to the 'old' data base (the ratio = 1.13). For the European Union (EU) and the Eastern Europe and Former Soviet Union (EEFSU), the reverse is true: the ratios are 0.875 and 0.524 respectively (the 'new' emission coefficients for Gas in these regions are 12.5 percent and 48.6 percent lower respectively, as compared to 'old' emission coefficients). When it comes to oil products (Oil_Pcts), the figures are substantially lower across all regions, ranging from 0.102 (90 percent lower) for the USA, to 0.886 (11 percent lower) for the EEFSU. Similar variations across fuels and across regions are also observed in Table 3 for the 'Gas' sector. In this case, it is the emission coefficients for Gas (used in the Gas sector) which display a consistently lower level in the new data base as compared to the old data base. Some of these significant variations can perhaps be explained by the fact that the absolute levels of energy flows (and therefore C02 emissions) are quite small in some regions (such as Japan (JPN)) and therefore, when we divide a small number into another small number, their ratios can display significant variations. However, other variations can only be explained as having come from the actual differences in these emission coefficients when they are measured at a disaggregate level. This illustrates the important differences between the so-called bottom-up approach (as used in the new data base) with the traditional top-down approach as used in most previous experiments. Finally, Tables 4-6 shows the difference in the absolute levels of C02 emissions for different fuels and for different regions between the 'new' and the 'old' data bases. It is observed here that the absolute levels of CO_2 emissions are consistently higher in the new data base as compared to the old data base, and this is true for all fuels as well as for all regions, with the exception of oil and coal products (Oil_Pcts). This fact is also consistent with the picture given above regarding the higher levels of emission *coefficients* as implied in the new data base as compared to those coefficients used in the old data base.

SOME ILLUSTRATIVE EXPERIMENTS

Having observed the significant differences in the absolute levels of CO2 emissions as well as in the level of emission coefficients in the two data bases, it is important to know if these differences will make any significant impacts on the simulation results of a particular experiment. To answer this question, we carry out some simulations using the GTAP-E model as described in Burniaux and Truong (2002), and using both the 'old' data base employed previously as well as the 'new' data base[§]. The experiments we carry out can be said to consist of the following: (1) Kyoto with worldwide trading of carbon emissions without any restriction, (2) Kyoto with no worldwide trading, and (3) Kyoto with only Annex 1 countries trading[**]. We first use the same GTAP-E model ('old' model) as described in Burniaux and Truong (2002) and with the same aggregate approach to C02 emissions calculations as was employed therein ('old data'). Next, we use the GTAP/EPA CO2 emission data ('new data') to replace the 'old' CO2 emissions data used in the GTAP-E model previously, while keeping the model structure the same ('old model'). Finally, we also make some 'minor' changes to the model structure (as described in the Appendix A) to allow us to make use of the more detailed sectoral information on C02 emissions levels in the new data base, and this is called the 'new model'). The results for these three different data-model situations are reported as columns (1), (2) and (3) in Tables 7-9 for the three different types of experiments.

[§] By 'new' and 'old' data bases, we mean the same GTAP version 5 data base, but one with the CO2 emission levels generated using the GTAP/EPA integrated data base ('new'), and one with these emission levels calculated using the 'old' aggregate CO2 emission coefficients for fossil fuels (assumed to be the same for all regions and also the same for all sectors of an economy).

[**] For more details on these experiments, see Burniaux and Truong (2002).

RESULTS

From Table 7, we can observe that using the new data but keeping the same model structure for the GTAP-E model as previously used (i.e. 'new data' but 'old model') will result in a generally *lower* level of marginal cost of CO2 emissions reduction (see the columns marked with the label '(2)' in Tables 7-9). This can be explained as follows. Since the 'new' data contains essentially the same energy flow data as in the old data, but with the level of CO2 emissions generally being higher (see Table 6), this implies the emission coefficients are also generally higher (as discussed in previous sections, and also see Tables 1-3). As a result of this, the results reported under columns labelled '(2)' in Tables 7-9 are equivalent to an experiment which assumes implicitly that the 'effective' CO2 emission coefficients in these experiments have been raised to a higher level. Such an experiment which uses a higher level of CO2 emission per unit of energy used is also equivalent to a situation when the absolute level of CO2 emissions have been 'inflated' and therefore, the 'real' cost (or value) of CO2 emissions (and therefore of CO2 emission reductions) would also have declined if the 'nominal' cost stays the same. This is the situation as reported in the columns '(2)' of Tables 7-9. Here, it is noted that the 'nominal' targets of CO2 emission reductions have stayed the same between experiments (see the first three columns of Table 7, for example). As a result, when we use a data base which has a higher absolute level of CO2 emissions (the 'new' data base') as compared to the one which has a lower absolute level (the 'old' data base) CO2 emissions have been 'inflated', and as a result, the (real) costs of achieving these target reductions are now lower (comparing column (2) with column (1) under the 'Marginal Cost' heading).

If we judge that the actual levels of CO2 emissions coefficients are closer to the ones implied by the 'new' data base rather than the 'old' data base (old coefficients), then the results in columns (2) of Tables 7-9 would suggest to us that the actual level of marginal abatement costs for CO2 emissions in reality would also be lower than the values suggested to us by experiments using the 'old' data base (i.e. old approaches to CO2 emission calculations using the 'old' aggregated coefficients). If, however, we believe that perhaps this 'inflated' level of CO2 emission levels in the new data base (as compared to the old one) are due, not to a higher level of emission coefficients generally, but simply due to an 'incorrect' or 'inexact' integration of the CO2 emission data base with the energy flow data base[††], then it would be desirable to fnd a way of automatically 'correcting ' for this inexact integration, so that the results of the simulation would not be affected by this general 'inflation' problem. In other words, the question is how to filter out the 'inflationary' aspect of CO2 emissions measurement when this is based simply on energy flow data (which may come from a different time period, for example).

One way of doing this within the GTAP-E model can be suggested as follows. First, we note that currently, CO2 emissions (levels and growth rates) are used to 'drive' a model such as GTAP-E by being inked to the levels of energy flows (read in, as well as being updated internally within the model) and the latter are then linked to the levels of economic activities (domestic production, import, export) calculated within the model. The linkages are essentially 'inflation' proof because by assumption, all data are 'calibrated' to the same base year. Suppose now that one particular set of variables (energy) are not entirely 'calibrated' to the same reference level as another (CO2 emissions) due to a variety of reasons. This will result in a general 'inflation' of one set of variables in the data base relative to another. To avoid incorporating and perpetuating this 'inflationary' aspect (of CO2 emission levels relative to energy usage level) into the model, we can establish a different kind of 'links'. For example, instead of linking CO2 emissions *growth* to the *levels* of energy flow on one side of equation, and then linking energy flow levels to the percentage growth of real economic activities on the other side of the equation, which means any inflationary aspects appearing in the CO2 emission variable will affect only one side of the equation but not the other side, we should now link the energy flow levels to the CO2 emission growth variables on *both* sides of the equation. This approach is more balanced i.e. any 'inflationary ' aspect, if it appears within one particular variable (such as CO2 emissions levels relative to energy flow levels, or vice versa) will affect *both* sides of the equation rather than just one side, and therefore, will cancel each other out. This is what we have done to the 'new' GTAP-E model (detailed modifications described in Appendix A) and we use the

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[††] Which should reveal to us variations in CO2 coefficients between different sources of emissions but not between two different data bases in general.

‘new’ model to run with the ‘new’ set of CO2 emissions data. The results are reported in column ‘(3)’ of Tables 7-9. It can be observed from these Tables that the results are now closer to the ‘original’ results of the GTAP-E simulations (old model, old data base) than are those which utilise the ‘new’ data base but without any modifications to the ‘old’ model structure.

CONCLUSIONS

In this paper we have examined the ‘new’ CO2 emission data contained in the GTAP/EPA Integrated Data Base and using this data base, together with the GTAP energy volume data, to estimate the (implied) CO2 emission coefficients for various fuel types, industry sectors and regions. We then compare these implied coefficients with the aggregate or ‘top-down’ CO2 emission coefficients often assumed in previous GTAP-E experiments. We have found that in general, the new implied coefficients are higher than the ‘old’ aggregate coefficients, and this is true for several fuel types, across many regions, and across many sectors. This brings up certain important issues to consider. Firstly, there is the question of whether the higher implicit levels of CO2 emission coefficients in the ‘new’ data base are ‘real’ rather than just ‘inflationary’ (i.e. arising from an indexing problem or a calibration issue). If it is the former, then future experiments using this new disaggregate data base will tend to give accurate results than are compared with the ‘old’ approach using only highly aggregate emission coefficients from a top-down point of view to measure the actual level of emissions. If it is the latter, however, then there is the issue of how to handle this problem, perhaps internally within a model structure, rather than relying on the elimination of this problem within the data base itself (which certainly is a more effective approach, but perhaps also a more costly and difficult one to follow). In this paper, we have suggested a way for the GTAP-E model to follow which can handle this particular issue and illustrated the effectiveness of this method by comparing the results of various experiments using firstly, the ‘old’ model and old data approach, and then the ‘new’ model with the ‘new’ data base.

REFERENCES

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Table 1 Ratio of the ‘New’ to ‘Old’ CO_2 Emission Coefficients for the ‘Agriculture’, ‘Coal’, ‘Oil’, ‘Electricity’, and ‘Oth_ind_ser’ sectors.

	Fuel Type			
Regions	Coal	Oil	Gas	Oil_Pcts
USA	1.024	1.069	1.130	1.079
EU	1.024	1.069	1.130	1.079
EEFSU	1.024	1.069	1.130	1.079
JPN	1.024	1.069	1.130	1.079
RoA1	1.024	1.069	1.130	1.079
EEx	1.024	1.069	1.130	1.079
CHIND	1.024	1.069	1.130	1.079
RoW	1.024	1.069	1.130	1.079

Note: ‘New’ Co2 emission coefficients are those implied, or arrived at, by dividing the CO2 emission levels in the GTAP/EPA data base by the energy volume flow the GTAP energy-volume data base. The ‘Old’ emission coefficients are those used previously in Burniaux and Truong (2002).

Table 2 Ratio of the ‘New’ to ‘Old’ CO_2 Emission Coefficients for the Energy Intensive Industry (En_Int_Ind) Sector

	Fuel Type			
Regions	Coal	Oil	Gas	Oil_Pcts
USA	1.024	1.069	1.130	0.102
EU	1.024	1.069	0.875	0.282
EEFSU	1.024	1.069	0.524	0.886
JPN	1.024	1.069	1.130	0.220
RoA1	1.024	1.069	0.835	0.287
EEx	1.024	1.069	0.373	0.707
CHIND	1.024	1.069	0.879	0.459
RoW	1.024	1.069	0.798	0.523

See Notes to Table 1.

Table 3 Ratio of the ‘New’ to ‘Old’ CO_2 Emission Coefficients for the Gas Sector

	Fuel Type			
Regions	Coal	Oil	Gas	Oil_Pcts
USA	1.024	1.069	0.073	1.079
EU	1.024	1.069	0.133	1.079
EEFSU	1.024	1.069	0.001	1.079
JPN	1.024	1.069	0.000	1.079
RoA1	1.024	1.069	0.348	1.079
EEx	1.024	1.069	0.671	1.079
CHIND	1.024	1.069	0.567	1.079
RoW	1.024	1.069	0.190	1.079

See Notes to Table 1.

Table 4 The Level of CO2 Emissions (M tons of C) in the 'New' data base.

	Fuel Type			
Regions	Coal	Oil	Gas	Oil_Pcts
USA	544.9	0.2	386.7	637.9
EU	237.8	1.0	207.6	483.6
EEFSU	307.4	3.4	319.9	197.8
JPN	92.0	12.0	38.7	185.3
RoA1	78.0	0.3	66.1	119.7
Eex	68.1	14.6	215.5	433.7
CHIND	862.0	3.0	25.2	198.4
RoW	209.2	1.4	53.4	366.3

Table 5 The Level of CO2 Emissions (M tons of C) in the 'Old' data base.

	Fuel Type			
Regions	Coal	Oil	Gas	Oil_Pcts
USA	532.0	0.2	287.3	680.2
EU	232.2	0.9	172.1	506.1
EEFSU	300.1	3.2	286.2	187.5
JPN	89.8	11.2	33.0	203.1
RoA1	76.2	0.3	55.8	125.3
Eex	66.5	13.7	184.5	418.3
CHIND	841.7	2.8	22.2	214.5
RoW	204.3	1.3	44.9	372.7

Table 6 Ratio of the New to the Old Levels of CO2 Emissions in the two data bases

	Fuel Type			
Regions	Coal	Oil	Gas	Oil_Pcts
USA	1.024	1.072	1.346	0.938
EU	1.024	1.066	1.207	0.956
EEFSU	1.024	1.069	1.118	1.055
JPN	1.024	1.069	1.171	0.912
RoA1	1.024	1.069	1.183	0.956
EEx	1.024	1.069	1.168	1.037
CHIND	1.024	1.069	1.138	0.925
RoW	1.024	1.069	1.189	0.983

Table 7 Kyoto with Worldwide Trade

Regions	% reduction of emissions (1) Old Data Old Model	(2) New Data Old Model	(3) New Data New Model	Marginal Cost (1997 USD per ton of Carbon) (1) Old Data Old Model	(2) New Data Old Model	(3) New Data New Model	Terms of Trade (1) Old Data Old Model	(2) New Data Old Model	(3) New Data New Model	Per capita utility from aggregate household expenditure (1) Old Data Old Model	(2) New Data Old Model	(3) New Data New Model
USA	-12.7	-13.0	-13.3	29.6	26.6	29.7	0.18	0.15	0.17	-0.16	-0.14	-0.16
EU	-5.8	-6.0	-6.1	29.6	26.5	29.7	0.12	0.11	0.12	-0.06	-0.05	-0.05
EEFSU	-13.0	-13.1	-13.4	29.5	26.5	29.5	0.05	0.06	0.07	0.66	0.59	0.65
JPN	-6.2	-5.9	-6.4	29.6	26.5	29.6	0.43	0.39	0.43	-0.07	-0.06	-0.07
RoA1	-9.3	-9.5	-9.8	29.7	26.6	29.8	-0.40	-0.37	-0.41	-0.42	-0.38	-0.43
EEx	-7.3	-7.8	-8.3	29.8	26.7	29.8	-1.47	-1.28	-1.42	-0.53	-0.46	-0.51
CHIND	-31.8	-31.1	-29.7	29.4	26.3	29.4	0.80	0.69	0.75	0.44	0.37	0.29
RoW	-8.6	-8.2	-8.5	29.6	26.5	29.6	0.32	0.28	0.31	0.10	0.08	0.09

Notes: 'New Data' means GTAP/EPA data base, 'New Model' means GTAP-E with some modifications as described in Appendix A; 'Old Model' means GTAP-E model as described in Burniaux and Truong (2002); 'Old Data' means the approach to calculating CO2 emissions using aggregate coefficients.

Table 8 Kyoto with No emission Trade

Regions	% reduction of emissions (1) Old Data Old Model	(2) New Data Old Model	(3) New Data New Model	Marginal Cost (1997 USD per ton of Carbon) (1) Old Data Old Model	(2) New Data Old Model	(3) New Data New Model	Terms of Trade (1) Old Data Old Model	(2) New Data Old Model	(3) New Data New Model	Per capita utility from aggregate household expenditure (1) Old Data Old Model	(2) New Data Old Model	(3) New Data New Model
USA	-35.6	-35.6	-35.6	126	108	140	0.96	0.84	1.01	-0.25	-0.21	-0.45
EU	-22.4	-22.4	-22.4	147	126	158	0.33	0.29	0.35	-0.48	-0.41	-0.58
EEFSU	4.0	3.8	6.5	0	0	0	-0.87	-0.79	-0.89	-0.41	-0.38	-0.45
JPN	-31.8	-31.8	-31.8	230	228	295	1.34	1.24	1.53	-0.61	-0.59	-0.93
RoA1	-35.7	-35.7	-35.7	178	156	206	-0.65	-0.61	-0.70	-1.30	-1.16	-1.81
EEx	2.6	2.1	3.5	0	0	0	-3.02	-2.63	-3.20	-1.00	-0.88	-1.07
CHIND	-0.9	-1.1	1.8	0	0	0	0.03	-0.01	-0.04	0.08	0.06	0.07
RoW	4.4	3.9	5.1	0	0	0	0.26	0.21	0.24	0.16	0.13	0.16

See Notes to Table 7

Table 9 Kyoto with Annex 1 Trading

Regions	% reduction of emissions			Marginal Cost (1997 USD per ton of Carbon)			Terms of Trade			Per capita utility from aggregate household expenditure		
	(1) Old Data	(2) New Data	(3) New Data	(1) Old Data	(2) New Data	(3) New Data	(1) Old Data	(2) New Data	(3) New Data	(1) Old Data	(2) New Data	(3) New Data
	Old Model	Old Model	New Model	Old Model	Old Model	New Model	Old Model	Old Model	New Model	Old Model	Old Model	New Model
USA	-26.6	-26.7	-26.5	77.9	67.8	80.1	0.54	0.47	0.53	-0.26	-0.23	-0.32
EU	-13.9	-13.9	-14.1	77.9	67.8	80.0	0.20	0.18	0.21	-0.27	-0.23	-0.29
EEFSU	-26.6	-26.8	-26.7	76.4	66.6	78.4	0.92	0.83	0.96	2.75	2.39	2.60
JPN	-15.2	-14.2	-14.8	78.0	67.8	80.1	0.66	0.57	0.66	-0.27	-0.23	-0.27
RoA1	-20.9	-20.8	-20.9	78.3	68.1	80.5	-0.56	-0.52	-0.59	-0.86	-0.75	-0.91
EEx	2.0	1.6	2.5	0.0	0.0	0.0	-2.19	-1.87	-2.16	-0.73	-0.62	-0.72
CHIND	-0.5	-0.6	1.1	0.0	0.0	0.0	-0.01	-0.02	-0.03	0.05	0.04	0.05
RoW	3.7	3.2	3.9	0.0	0.0	0.0	0.22	0.18	0.21	0.13	0.11	0.13

See Notes to Table 7

APPENDIX A

Differences between the 'old' GTAP-E model (Burniaux and Truong (2002) and the 'new' GTAP-E model structure as used in this paper:

<u>'OLD' GTAP-E:</u>

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EQUATION CEMISSIONS # emission growth by fuels (except crude oil)#
    (all,r,REG)(all,i,EGYCOM2)
  DCVOL(r,i)*gco2(r,i) = (DVOL(r,i)*qo(i,r)) + (MVOL(r,i)*qim(i,r))
      - (XVOL(r,i)*qxw(i,r));

!   emissions from crude oil, excluding sales to refined oil products        !
!  Here we consider the domestic demand of crude oil as the sum of all   !
!  sales, except sales to refineries (thus there is no VOL data in this       !
! equation.                                                                   !

COEFFICIENT (all,r,REG)(all,i,OILS)              OILSALES(r,i)
  !  total sales of crude oil (DOM.+IMPORTED) excl. sales to ref.oil pcts  !;

FORMULA (all,r,REG)(all,i,OILS)
  OILSALES(r,i) = sum(j,PROD_COMM,VFA(i,j,r)) - sum(j,OIL_PCS,VFA(i,j,r))
          + VPA(i,r) + VGA(i,r);

EQUATION OILEMISSIONS # emission growth from crude oil #
    (all,r,REG)(all,i,OILS)
  OILSALES(r,i)*gco2(r,i) = sum(j,PROD_COMM,VFA(i,j,r)*qf(i,j,r))
                - sum(j,OIL_PCS,VFA(i,j,r)*qf(i,j,r))
                + (VPA(i,r)*qp(i,r))
                + (VGA(i,r)*qg(i,r));
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'NEW' GTAP-E:

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!< modified by TRUONG & Huey-Lin 1/2003 >!
set GHGS (CO2, CH4, NOX);
set SRC (dom,imp);
set household (HouseH);
set redundant (Redun);
set allemitter1 = trad_comm union household;
set allemitters = allemitter1 union redundant;
COEFFICIENT (ALL,g,GHGS) (all,i,EGYCOM)(All,s,SRC)
   (All,j,allemitters) (All,r,REG)                          EGHG(g,i,s,j,r)
   ! Carbon emissions in base year in Gg of CO2 for all emitters ! ;
Read EGHG FROM FILE GTAPDATA HEADER "EGHG" ;
formula (initial) (all,i,EGYCOM)(All,r,REG)
   ! Carbon emissions in base year in M tons of C !
 CO2(r,i) = sum(s,SRC, sum(j,ALLEMITTERS,
            {[(12/44)*1000]/1000000}*EGHG("CO2",i,s,j,r)));
UPDATE (all,r,REG)(all,i,EGYCOM)   CO2(r,i) = gco2(r,i);
!<  total carbon emissions >!
VARIABLE (all,r,REG)                                         gco2t(r)
   # growth of emissions  by region #  ;
COEFFICIENT (ALL,r,REG)                                      CO2T (r)
   ! Total carbon emissions  in base year in M tons of C! ;
UPDATE (all,r,REG)   CO2T (r) = gco2t(r);
Read CO2T  FROM FILE GTAPDATA HEADER "CO2T"  ;
!<  country/region emissions quotas  >!
VARIABLE (all,r,REG)                                         gco2q(r)
   # growth of emissions quota by region #  ;
COEFFICIENT (ALL,r,REG)                                      CO2Q(r)
   ! Total carbon emissions quotas in M tons of C!  ;
UPDATE (all,r,REG)   CO2Q (r) = gco2q(r);
Read CO2Q  FROM FILE GTAPDATA HEADER "CO2Q" ;
UPDATE (all,i,EGYCOM)(All,j,TRAD_COMM)(All,r,REG)
   EVF (i,j,r) = qf(i,j,r) ;
UPDATE (all,i,EGYCOM)(All,r,REG)
   EVH(i,r) = qp(i,r) ;
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VARIABLE (all,r,REG)(all,i,EGYCOM)(all,j,TRAD_COMM)          gco2j(r,i,j)
   # growth of emissions by fuel #  ;
COEFFICIENT (ALL,r,REG)(all,i,EGYCOM)(all,j,TRAD_COMM)     CO2j(r,i,j)
   !  Carbon emissions in base year in M tons of C!  ;
formula (initial) (all,r,REG)(all,i,EGYCOM)(all,j,TRAD_COMM)
 CO2j(r,i,j) = sum(s,SRC, EGHG("CO2",i,s,j,r)) *
             {[(12/44)*1000]/1000000};
UPDATE (all,r,REG)(all,i,EGYCOM)(all,j,TRAD_COMM)
   CO2j(r,i,j) = gco2j(r,i,j);
EQUATION CEMISSIONS_j # emission growth by fuels (except crude oil)#
      (all,r,REG)(all,i,EGYCOM)(all,j,TRAD_COMM)
    gco2j(r,i,j) = qf(i,j,r);
VARIABLE (all,r,REG)(all,i,EGYCOM)                                   gco2h(r,i)
   # growth of emissions by fuel #  ;
COEFFICIENT (ALL,r,REG)(all,i,EGYCOM)                                CO2h(r,i)
   !  Carbon emissions in base year in M tons of C!  ;
formula (initial) (all,r,REG)(all,i,EGYCOM)
 CO2h(r,i) = sum(s,SRC, sum(j,Household, EGHG("CO2",i,s,j,r))) *
             {[(12/44)*1000]/1000000};
UPDATE (all,r,REG)(all,i,EGYCOM)
   CO2h(r,i) = gco2h(r,i);
EQUATION CEMISSIONS_h # emission growth by fuels (except crude oil)#
     (all,r,REG)(all,i,EGYCOM)
    gco2h(r,i) = qp(i,r);
EQUATION CEMISSIONS # emission growth by fuels (except crude oil)#
    (all,r,REG)(all,i,EGYCOM2)
    DCVOL(r,i)*gco2(r,i) = sum(j,TRAD_COMM, EVF(i,j,r)*gco2j(r,i,j)) +
                               + EVH(i,r)*gco2h(r,i);
EQUATION OILEMISSIONS # emission growth from crude oil #
     (all,r,REG)(all,i,OILS )
     CO2(r,i)*gco2(r,i) = sum(j,TRAD_COMM, EVF(i,j,r)*qf(i,j,r))
                          - sum(j,OIL_PCS, EVF(i,j,r)*qf(i,j,r))
                          + (EVH(i,r)*qp(i,r));
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