5. Implementation & Results

Methodology & Data Sources

In the context of the negotiations for apportionment of emissions reduction during 2012-2016 post Kyoto regime, issues of equity and fairness have been considered. While certain fundamental paradigms are enunciated in the Kyoto protocol itself in the form of 'common but differentiated responsibility' principle, these need elaboration as well as demonstration. The present analysis generates a model highlighting this perspective taking into account the energy entitlements and differentiated responsibilities, to apportion the emission reduction targets. Mitigation capacity and differentiated emission responsibilities are the criteria selected for apportionment. This chapter examines the impacts of these equitable principles on emission reduction commitments on various stakeholders. The proposed methodology would also take care of the emission trading mechanisms by appropriately modifying the quantitative entitlements to account for the same for future apportionment.

The historical emissions, GDP and population data have been sourced from the Centre for Monitoring Indian Economy (CMIE). For business as usual (BAU) future projection of this data, trends in the baseline scenarios of the *Emission Scenario Database prepared for IPCC Special Report on Emission Scenarios* (Tsuneyuki Morita, 1999) has been adopted[21]. For computing the

[21]BAU Scenarios: CO2 :– CMIE data projected based on trends in Source ID 235 Baseline Scenario from the year 2005
GDP :– CMIE data projected based on trends in Source ID 235 Baseline Scenario from the year 2005
Population :– Source ID 235 Baseline Scenario

emission reduction, the difference between the projections of Business as Usual scenarios and the projected post-mitigation emissions of the respective country/region has been taken.

Several scenarios involving target emission and corresponding apportionment profiles have been explored. Some sample results are discussed below:

(i) *Scenario I: Reduction of Global emissions to the current levels by 2030.*

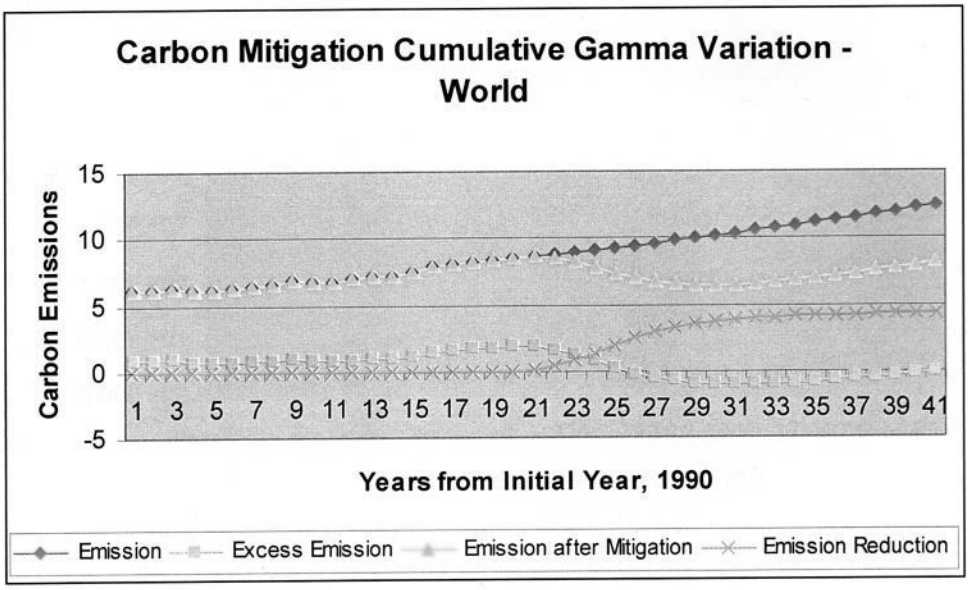
Table 5 shows the emission apportionment obtained by the cumulative gamma and parabolic mitigation strategies. It is seen that the results are more or less identical irrespective of the trajectory of mitigation. The methodologies would converge, if the iterative solutions are fine-tuned to identical points in the feasibility region by appropriately choosing the iteration accuracy. Since the apportionment of reduction takes into account entitlements and the capacity for mitigation, Africa and India have negligible reduction targets. This is in tune with the development goals in these economies. Brazil has a little higher commitment on account of lower entitlements due to lower population. As could be anticipated, bulk of the reduction commitments would fall on USA (30%) and the EU (26%) countries. China, though having high population, gets a moderate target (5.3%) due to higher emissions and higher GDP.

Table 5. Apportionment for Emission Reduction to current levels by 2030

Region/Mode of mitigation	Cumulative Gamma Mitigation		Parabolic Mitigation	
	Target Emission Reduction, Final Year (GtC/year)	Cumulative Emission Reduction (GtC)	Target Emission Reduction, Final Year (GtC/year)	Cumulative Emission Reduction (GtC)
World	4.2810	66.3708	4.2810	66.2995
OECD	3.0655	48.4004	3.0397	47.9521
Non-OECD	1.2157	17.8359	1.2415	18.2296
Annex I	3.2608	51.2226	3.2254	50.6511
Non Annex I	1.0205	15.0137	1.0558	15.5306
USA	1.2860	19.9667	1.2689	19.6888
China	0.2568	3.52312	0.2585	3.5738
India	0.0360	0.46042	0.0476	0.6429
Brazil	0.0987	1.29519	0.1004	1.3198
EU	1.0766	17.2746	1.0734	17.2142
Africa	0.0525	0.79084	0.0636	0.9490

Variations of some of the parameters (actual and projected) from the base year (1990) and during the mitigation period are shown in Charts 7(1) to 7(9) (All carbon emissions are in Gigatons of Carbon). Variations of parameters are shown both for cumulative gamma and parabolic mitigation to enable comparison. The charts show that there is no substantive variation on account of the mode of mitigation and the apportionment would remain the same if the methodologies are fine tuned. The variations appear to capture the differentiated mitigation responsibility based on the equity approach suggested.

Figure 7(1a) Cumulative Gamma (1b) Parabolic Mitigation: Variation of carbon emission (before and after mitigation), excess emission and emission reduction



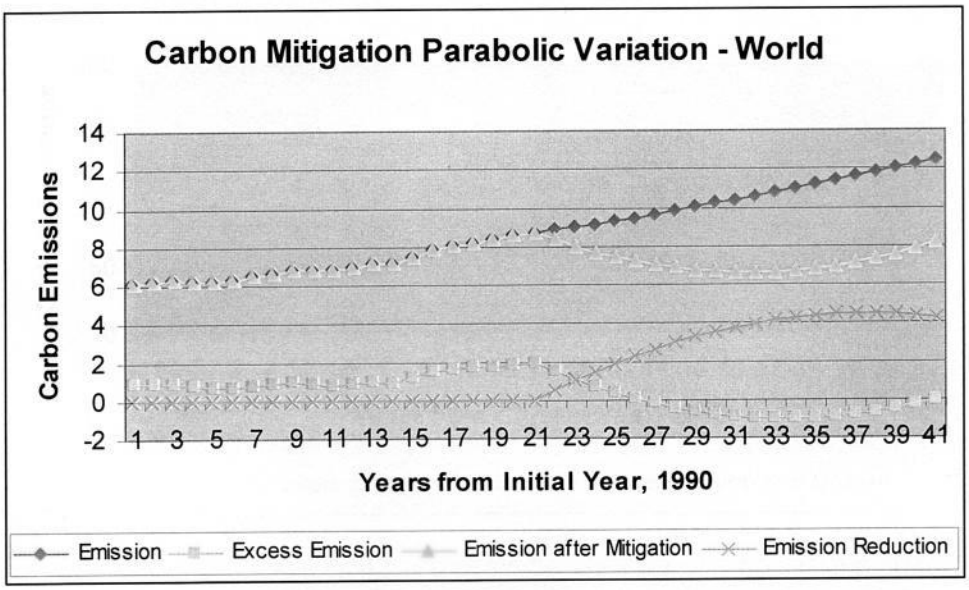
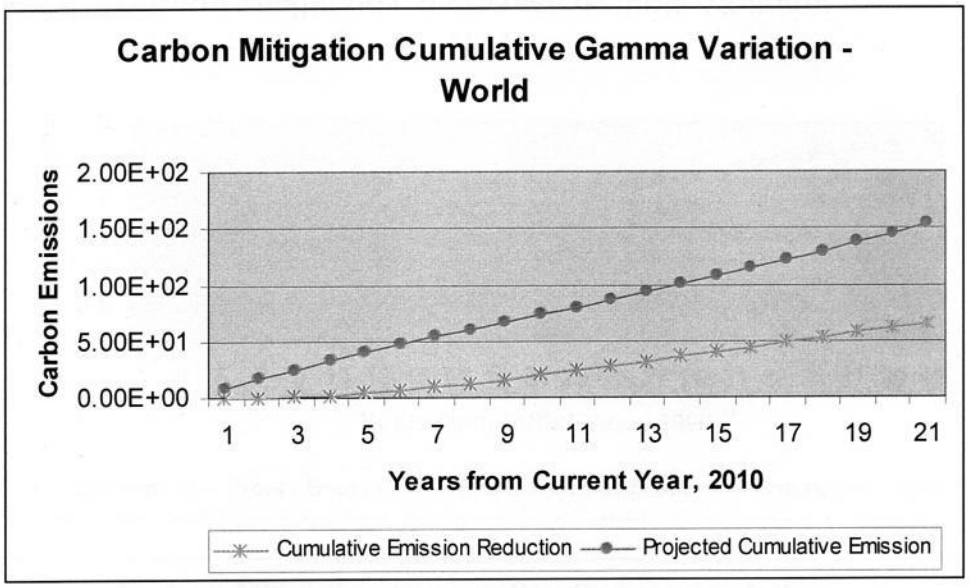


Figure 7(2a) Cumulative Gamma (2b) Parabolic Mitigation: Variation of projected cumulative emission reduction and cumulative emission after mitigation



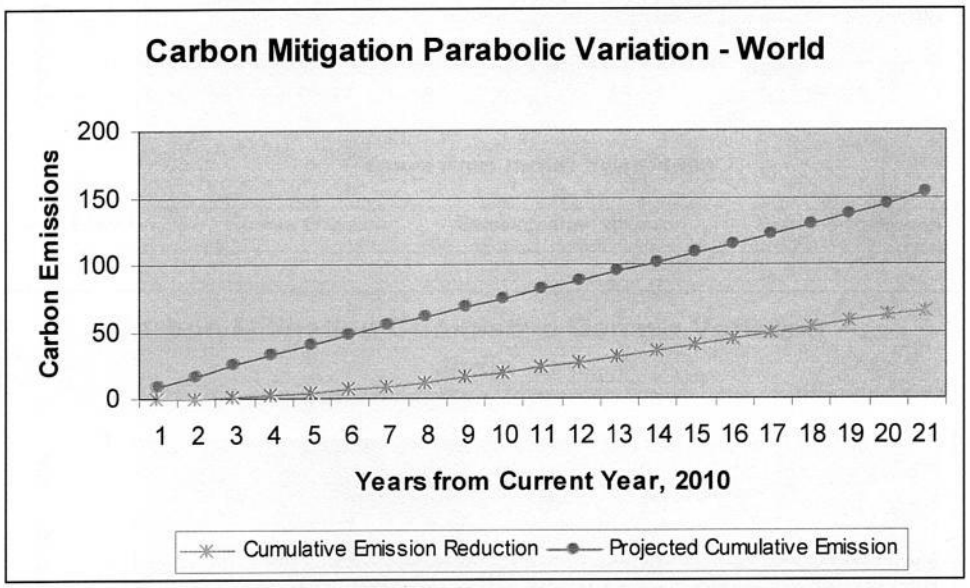
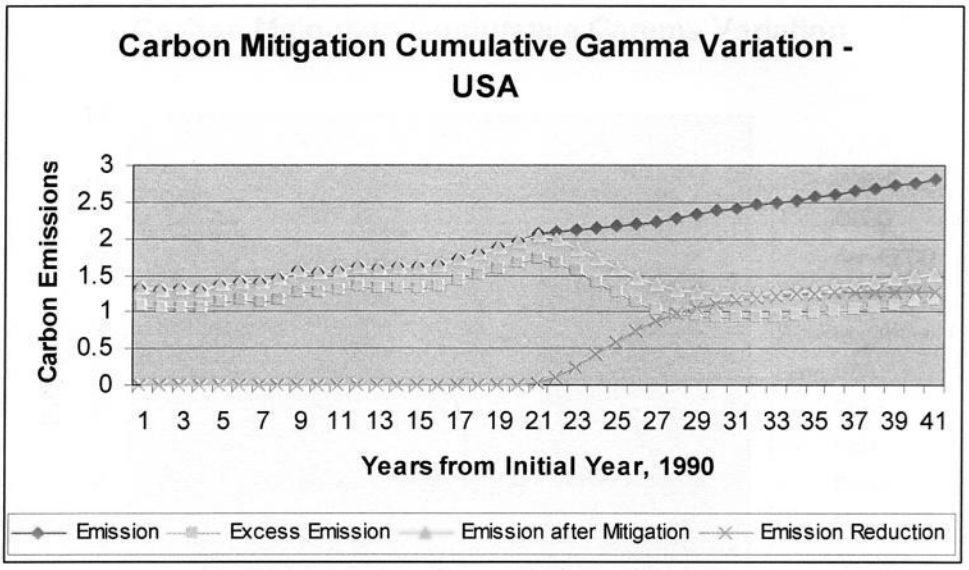
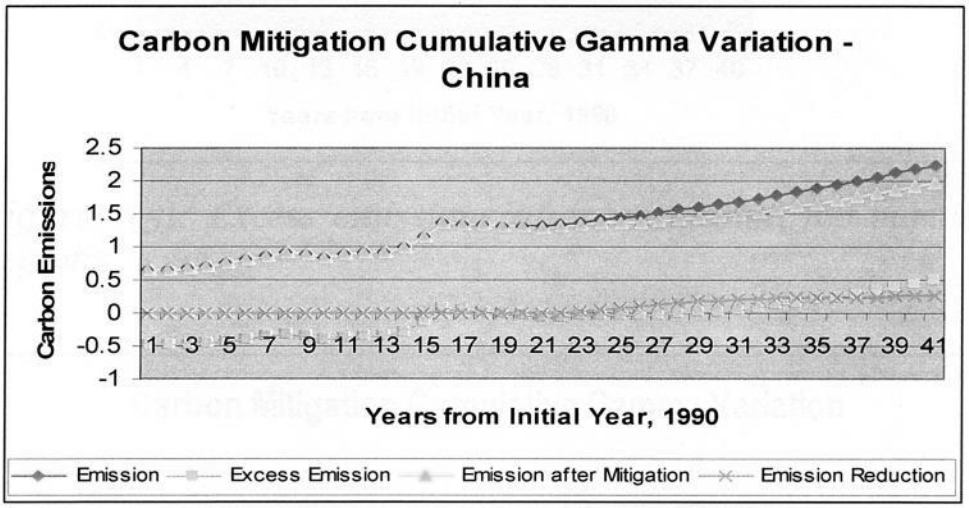


Figure 7(3): Variations of parameters for (a) USA (b) China (c) India





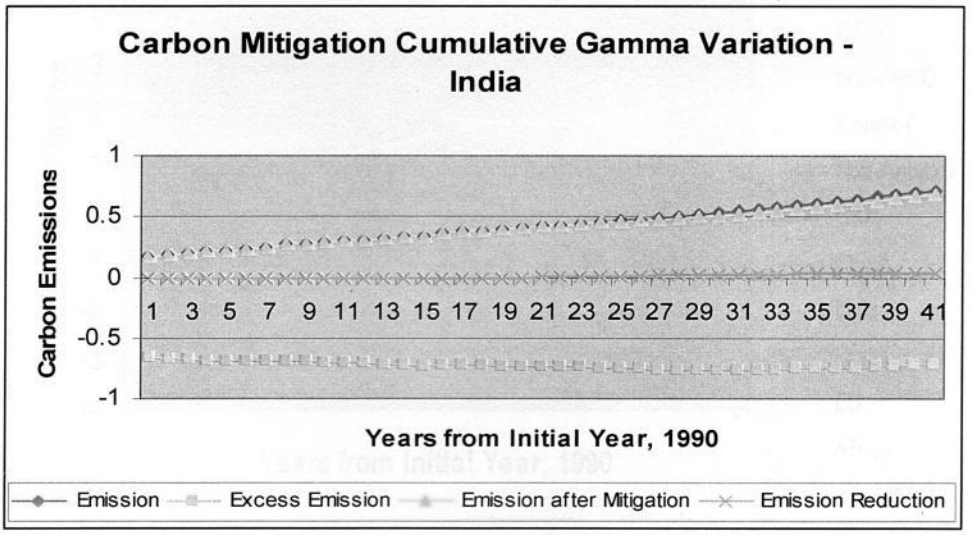


Figure 7(4): Actual and projected emissions for various regions without mitigation

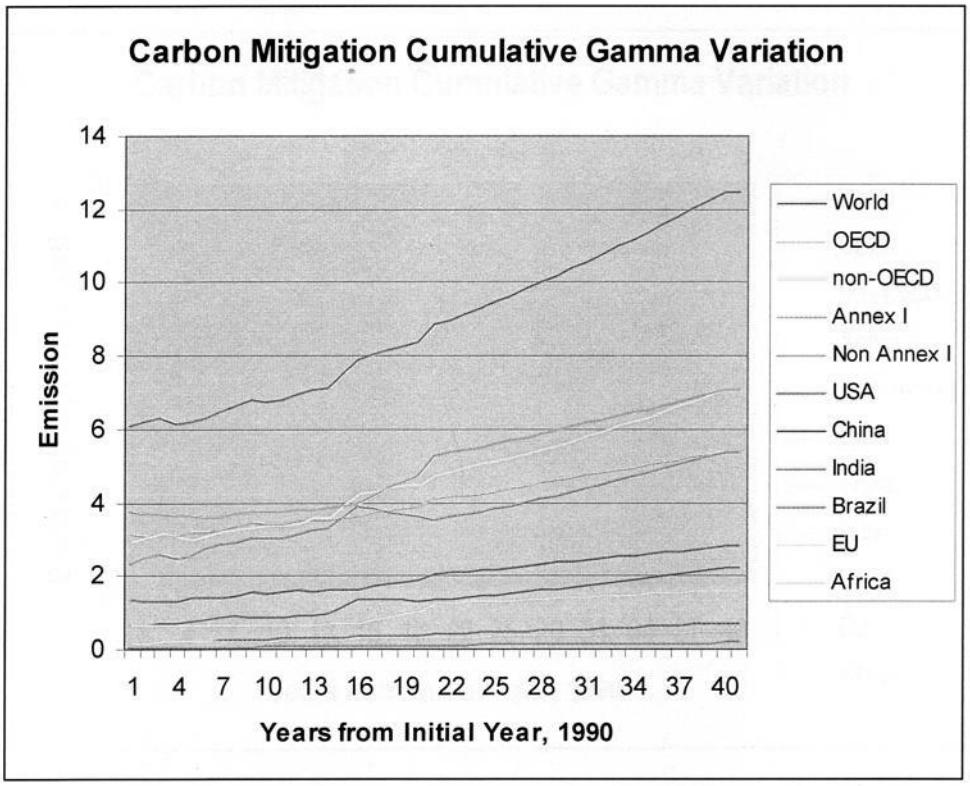


Figure 7(5): Excess emissions after mitigation for various regions

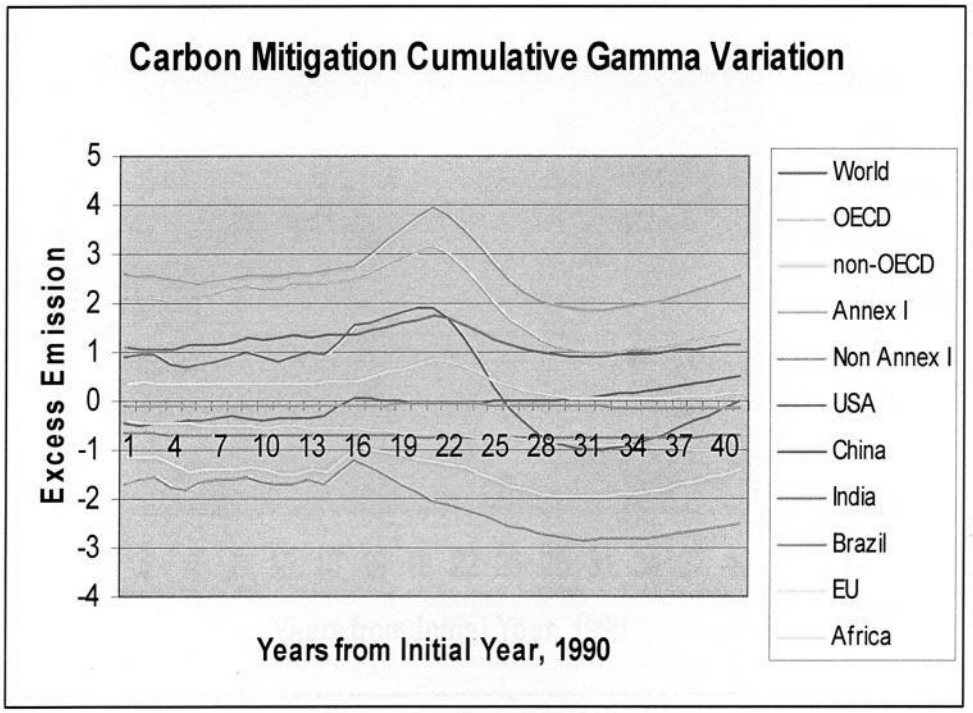
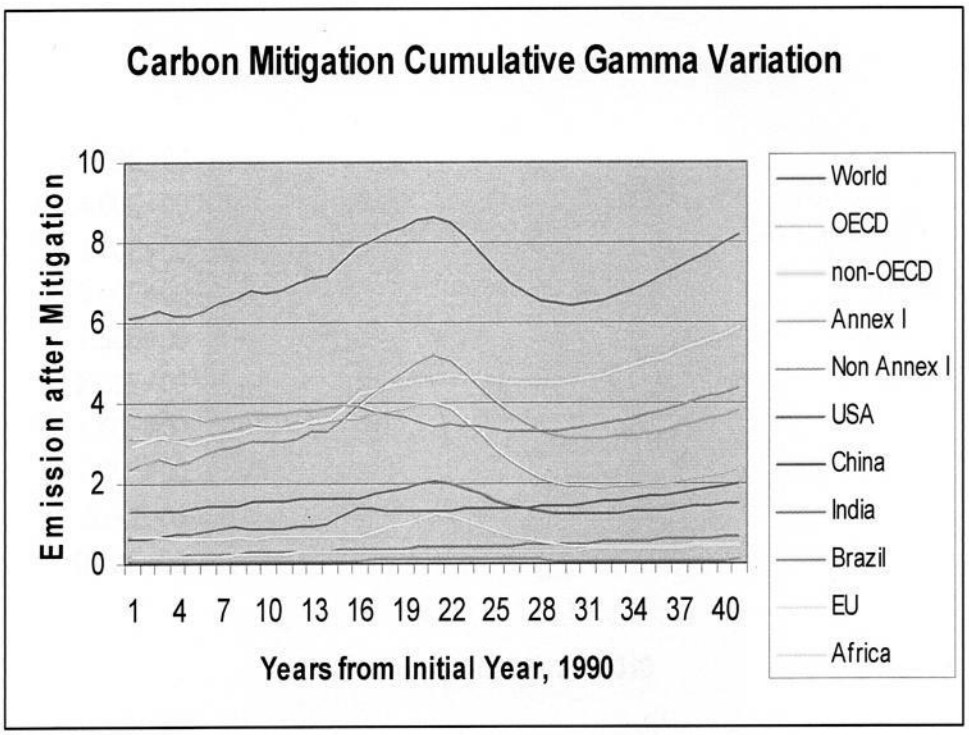


Figure 7(6a) Cumulative Gamma (6b) Parabolic Mitigation: Emission after mitigation for various regions



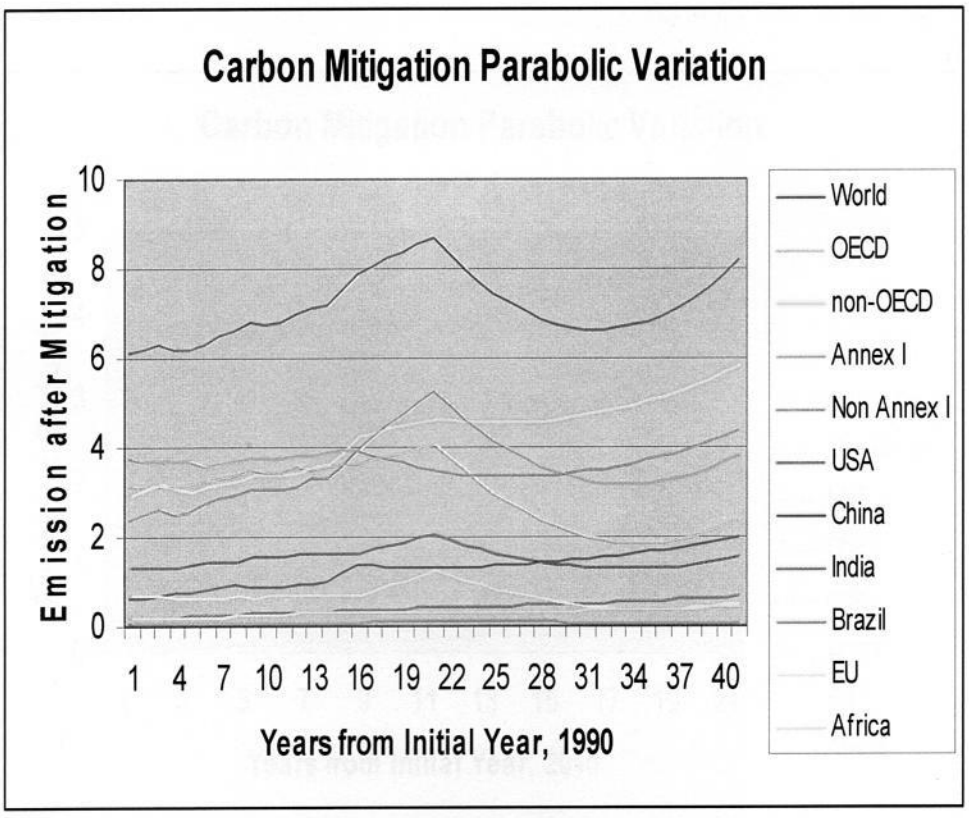
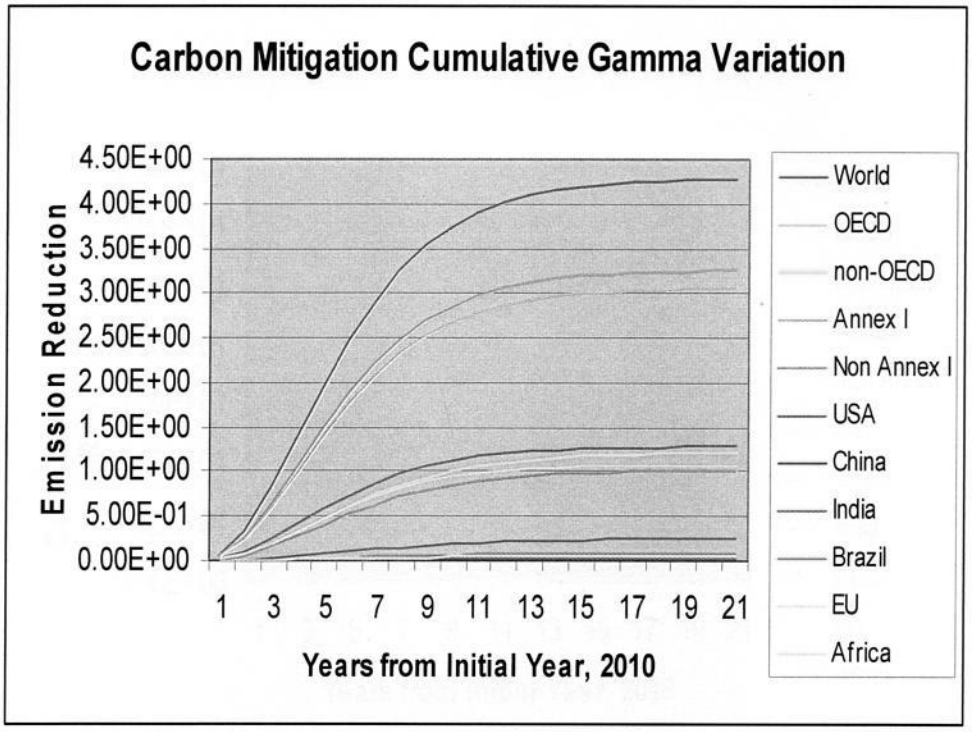


Figure 7(7a) Cumulative Gamma (7b) Parabolic Mitigation: Variation of Emission Reduction after mitigation



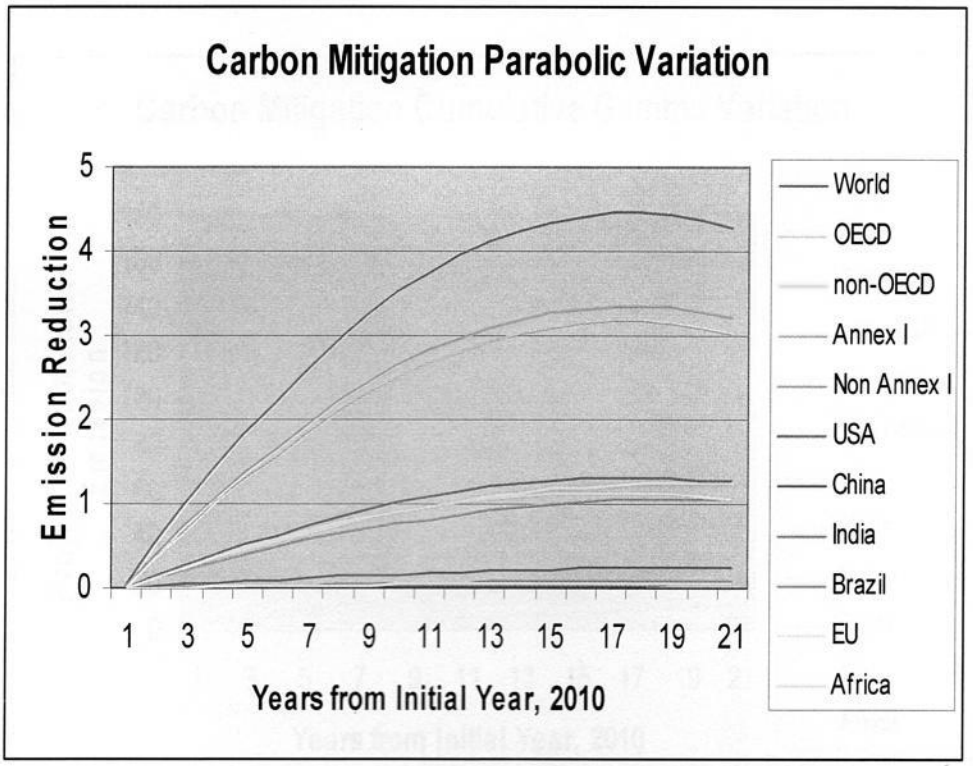


Figure 7(8): Variation of Cumulative Emission Reduction after Mitigation

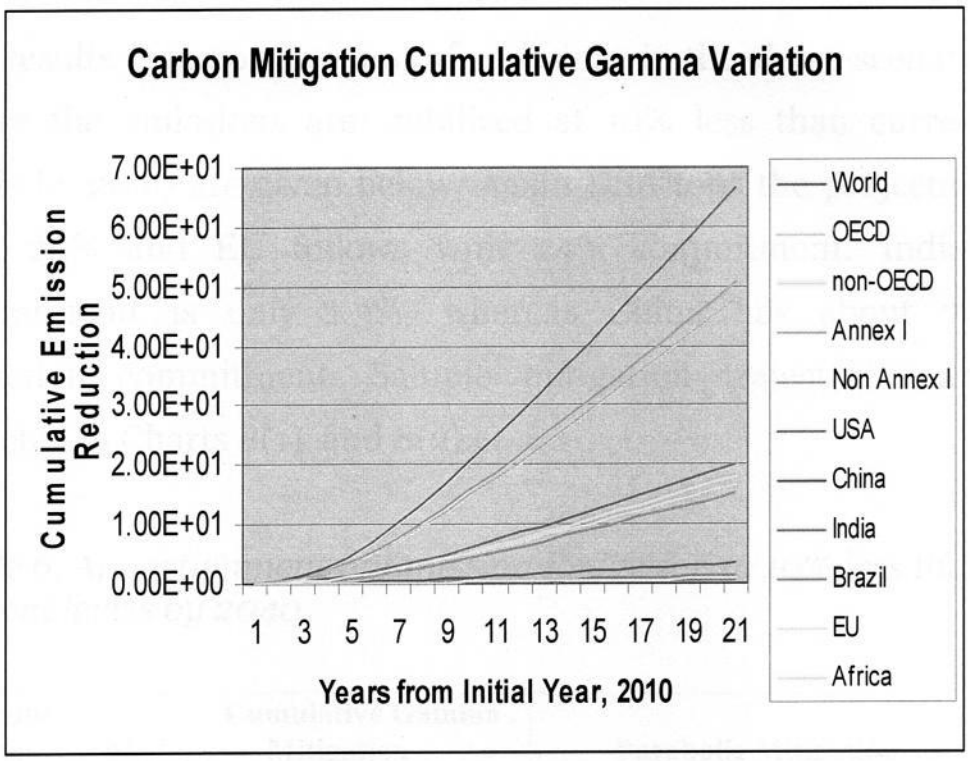
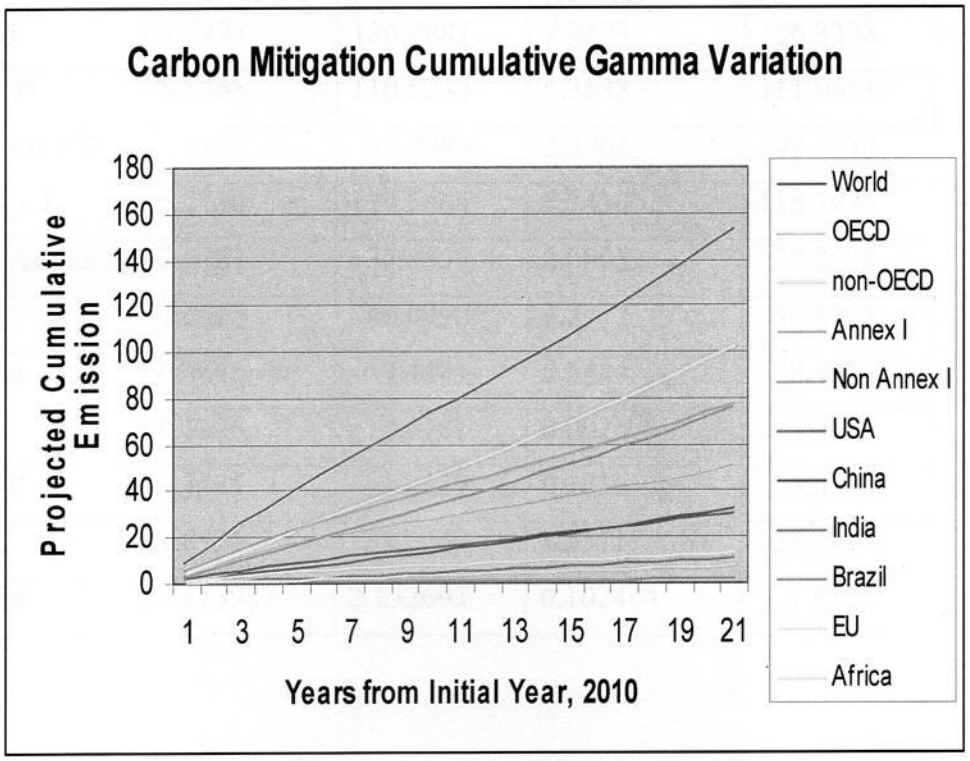


Figure 7(9): Variation of Cumulative Emission after mitigation



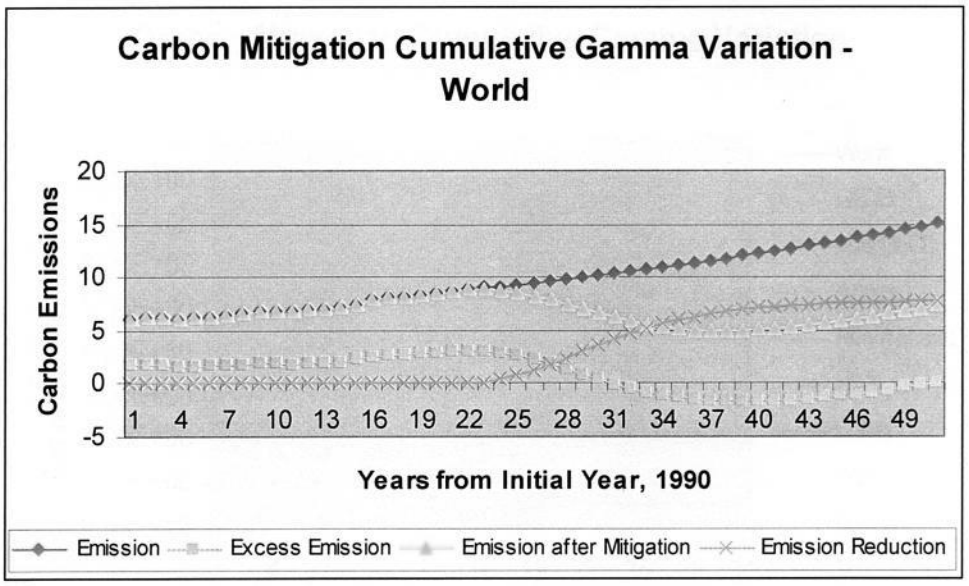
(ii) Scenario II: Reduction of Global emissions to 10% less than current levels by 2040

The results of apportionment of emissions in the above scenario where the emissions are stabilized at 10% less than current levels by 2040 are given below. Again USA tops the projection with 29% and EU follows with 24% commitment. India's commitment is only 1.3%, whereas China has about 7% reduction commitment. Sample mitigation trajectories are depicted in Charts 8(1) and 8(2).

Table 6. Apportionment of Emission Reduction to 10% less than current levels by 2040

Region/ Mode of mitigation	Cumulative Gamma Mitigation		Parabolic Mitigation	
	Target Emission Reduction, Final Year (GtC/year)	Cumulative Emission Reduction (GtC)	Target Emission Reduction, Final Year (GtC/year)	Cumulative Emission Reduction (GtC)
World	7.7473	156.2881	7.7473	156.3328
OECD	5.3365	110.5234	5.3532	111.0651
Non-OECD	2.4132	44.8989	2.3964	44.5373
Annex I	5.7130	117.5664	5.7430	118.3425
Non Annex I	2.0367	37.8559	2.0065	37.2599
USA	2.2628	46.0990	2.2777	46.4773
China	0.5446	9.4401	0.5484	9.4599
India	0.1026	1.5781	0.0926	1.3515
Brazil	0.1835	3.0529	0.1816	3.0173
EU	1.8521	38.9560	1.8511	38.9892
Africa	0.113987	2.132697	0.102464	1.9141

Figure 8(1): Variation of carbon emissions (before and after mitigation), excess emissions and emission reduction during 1990-2040(a) Cumulative Gamma pdf (b) Parabolic Variation



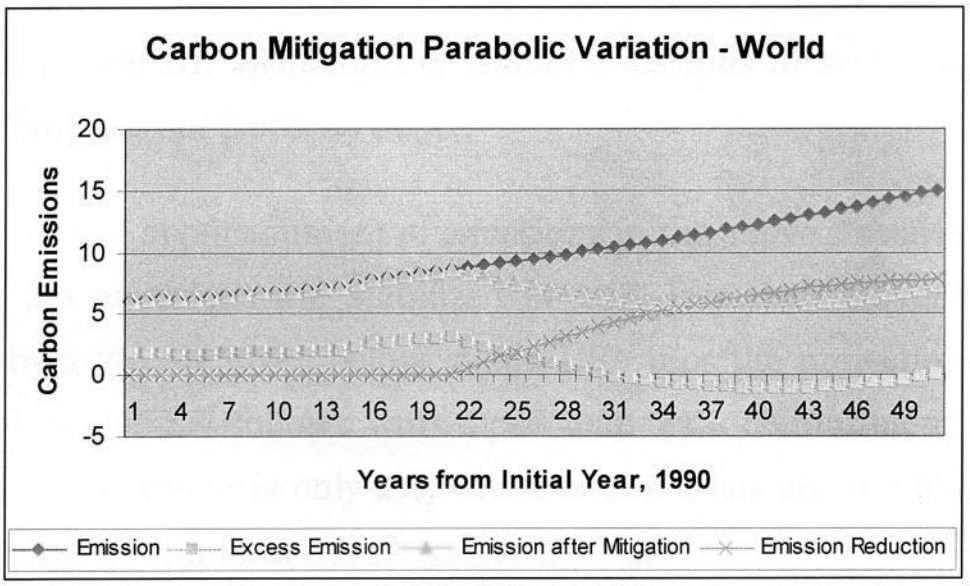
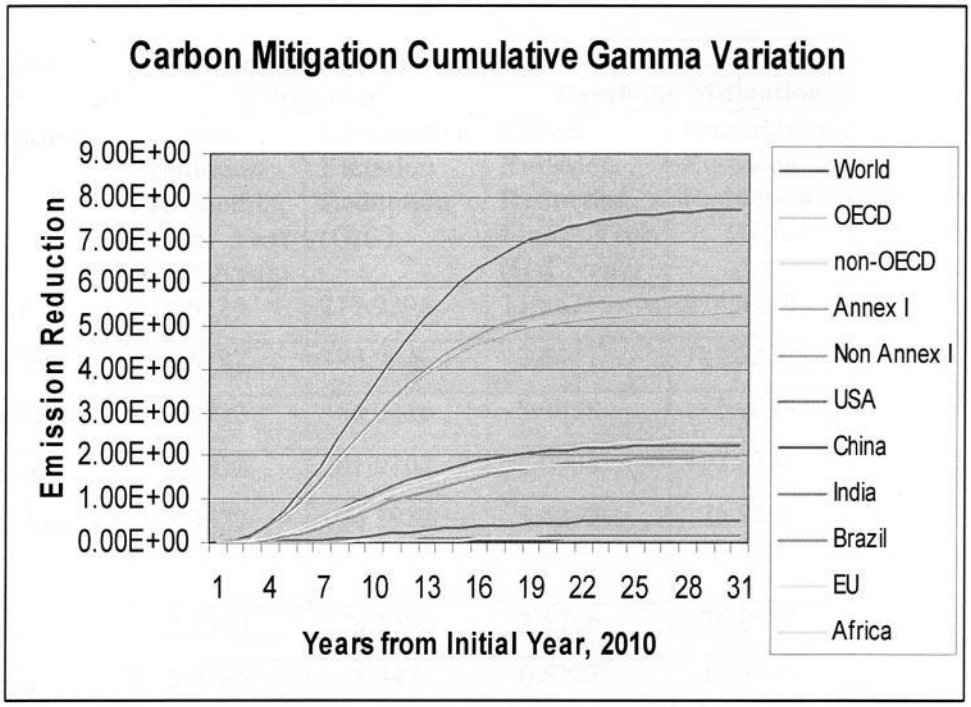


Figure 8(2): Variation of Emission Reduction after Mitigation



(iii) Scenario III: Reduction of Global emissions to 20% less than current levels by 2050

The results of apportionment of emissions in the above scenario where the emissions are stabilized at 20% less than current levels by 2050 are given below. Again USA tops the projection with 28% and EU follows with more than 23% commitment. India's commitment is only 2%, whereas China has about 7.6% reduction commitment.

Table 7. Apportionment of Emission Reduction to 20% less than current levels by 2050

Region/ Mode of mitigation	Cumulative Gamma Mitigation		Parabolic Mitigation	
	Target Emission Reduction, Final Year (GtC/year)	Cumulative Emission Reduction (GtC)	Target Emission Reduction, Final Year (GtC/year)	Cumulative Emission Reduction (GtC)
World	11.5525	277.7296	11.5525	274.3438
OECD	7.6787	190.0646	7.6447	187.3224
Non-OECD	3.8772	86.0446	3.9078	86.9099
Annex I	8.1932	201.9104	8.0708	197.2731
Non Annex I	3.3627	74.1988	3.4817	76.9591
USA	3.2399	79.1598	3.1766	76.8923
China	0.8785	18.3451	0.8282	17.5766
India	0.2319	4.5840	0.2725	5.7777
Brazil	0.2877	5.7025	0.2991	5.9329
EU	2.6791	67.1645	2.7080	67.3194
Africa	0.2287	5.1991	0.2872	6.5189

(iv) *Scenario IV: Reduction of Global emissions to limit temperature increase to 2 °C by 2050*

(v) *Scenario V: Reduction of Global emissions to limit temperature increase to 2.5 °C by 2050*

The results of apportionment of emissions in the above scenarios are given in Tables 8 and 9 respectively:

Table 8. Apportionment of Emission Reduction to limit temperature increase to 2 °C by 2050

Region/ Mode of mitigation	Cumulative Gamma Mitigation		Parabolic Mitigation	
	Target Emission Reduction,2050 (GtC/year)	Cumulative Emission Reduction (GtC)	Target Emission Reduction, 2050 (GtC/year)	Cumulative Emission Reduction (GtC)
World	15.8229	380.3939	15.8229	375.2849
OECD	10.3290	255.3777	10.4645	256.0815
Non-OECD	5.4970	123.1876	5.3585	119.2034
Annex I	10.9763	270.4174	11.0319	269.3674
Non Annex I	4.8496	108.1478	4.7910	105.9175
USA	4.3247	105.5353	4.3392	104.9088
China	1.2072	25.7816	1.1254	23.9370
India	0.3892	8.2607	0.3808	8.1321
Brazil	0.4027	8.0403	0.4117	8.1685
EU	3.6292	90.9363	3.7144	92.2382
Africa	0.3957	9.0411	0.4041	9.1694

Table 9. Apportionment of Emission Reduction to limit temperature increase to 2.5 °C by 2050

Region/ Mode of mitigation	Cumulative Gamma Mitigation		Parabolic Mitigation	
	Target Emission Reduction, 2050 (GtC/year)	Cumulative Emission Reduction (GtC)	Target Emission Reduction, 2050 (GtC/year)	Cumulative Emission Reduction (GtC)
World	15.0142	360.9526	15.0142	356.1048
OECD	9.8224	242.8841	9.9296	242.9936
Non-OECD	5.1949	116.2892	5.0846	113.1111
Annex I	10.4432	257.2889	10.4681	255.6005
Non Annex I	4.5742	101.8844	4.5461	100.5043
USA	4.1165	100.4674	4.1174	99.5471
China	1.1451	24.3898	1.0678	22.7136
India	0.3612	7.6147	0.3613	7.7165
Brazil	0.3811	7.6035	0.3907	7.7510
EU	3.4483	86.4079	3.5246	87.5240
Africa	0.3661	8.3623	0.3835	8.7008

Comparison with Princeton Proposal

The following table compares the results of simulations obtained by the Princeton proposal (Chakravarty et al., 2009) and the dual principle approach for various countries/regions for the scenario of emission reduction to current levels (30GtCO$_2$/year) by 2030. The percentages indicated are the percentage reduction of each country/region compared to the global emission reduction required in the year 2030 from the business as usual (BAU) scenario.

Table 10. Comparison of Apportionment Approaches

Country	Princeton Proposal (percentage share of emission reduction in 2030)	Dual Principle approach (percentage share of emission reduction in 2030)
OECD	50.4	71.6
Non-OECD	49.6	28.4
USA	34.1	30
China	22.5	6
India	≈0	0.8
Brazil	≈0	2.3
Africa	3.1	1.2

It is seen that the share of OECD increases under the dual principle approach compared to the Princeton proposal. While India's share is almost identical in both regimes, China and Africa gets a higher commitment under the Princeton proposal. The share of USA remains comparable under both evaluations.

The Princeton proposal basically considers only income distribution of various countries and doesn't take into account the

emission intensity of GDP or the historical emissions. The dual principle approach takes into account the dynamic nature of emission and GDP profile along the trajectory and also emission entitlements based on a convergence approach. It is the entitlement and historical emission factors that keep the share of the non-OECD lower in the dual principle approach. The apportionment arrived at in the dual principle approach is relatively more stable and well-distributed. These outcomes are on account of the fact that the distributions are arrived at based on two separate variables representing two logical principles related to apportionment, for which independent data are available.