Tables and Figures (I)

Roll the DICE Again: The Economics of Global Warming

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Table 3-1. Regional Details of the RICE-98 Model

	Industrial CO2 Emissions	Gross Domestic Product [1990 U.S. dollars, market exchange rates]		Population	CO2-GDP Ratio
	[1000 tons, carbon weight]	(billions)	GDP growth rate [percent per year]		[kg per $1000]
	1995	1995	1970-95	1995	1995
United States	1,407,257	6175.79	2.6%	263,119,008	227.9
China	871,311	654.29	8.5%	1,200,241,024	1,331.7
Japan	307,520	3419.59	3.6%	125,213,000	89.9
EU	847,682	6,871.55	2.4%	380,113,900	123.4
Germany	227,920	1787.01	2.3%	81,869,000	127.5
United Kingdom	147,964	891.62	2.1%	58,533,000	165.9
Italy	118,927	997.59	2.6%	57,204,000	119.2
France	92,818	1188.59	2.5%	58,060,000	78.1
Spain	63,211	405.98	2.9%	39,199,000	155.7
Netherlands	37,093	303.47	2.4%	15,460,000	122.2
Belgium	28,334	188.84	2.3%	10,145,900	150.0
Greece	20,820	59.53	2.5%	10,467,000	349.8
Norway	19,774	125.25	3.5%	4,354,000	157.9
Austria	16,179	165.25	2.7%	5,110,000	97.9
Denmark	14,975	131.58	2.1%	5,220,000	113.8
Portugal	14,172	58.21	3.3%	9,927,000	243.5
Finland	13,923	106.87	2.4%	5,110,000	130.3
Sweden	12,170	195.29	1.6%	8,830,000	62.3
Switzerland	10,604	213.10	1.4%	7,039,000	49.8
Ireland	8,798	53.36	4.2%	3,586,000	164.9
Luxembourg	2,528	[na]	[na]	[na]	[na]
Iceland	492	[na]	[na]	[na]	[na]
Greenland	137	[na]	[na]	[na]	[na]
Liechtenstein	[na]	[na]	[na]	31,000	[na]
Russia	496,182	334.48	1.2%	148,195,008	1,483.4
India	248,017	447.09	4.4%	929,358,016	554.7
Other high income	235,531	997.25	3.4%	59,768,500	236.2
Canada	118,927	541.37	3.2%	29,606,000	219.7
Australia	79,096	295.38	3.1%	18,054,000	267.8
Singapore	17,377	45.52	8.1%	2,986,500	381.8
Israel	12,642	66.00	5.0%	5,521,000	191.6
Hong Kong	8,459	83.53	7.4%	6,189,800	101.3
New Zealand	7,489	48.99	2.2%	3,601,000	152.9
Virgin Islands (U.S.)	3,121	[na]	[na]	[na]	[na]
Guam	1,129	[na]	[na]	[na]	[na]
Aruba	491	[na]	[na]	[na]	[na]
Bahamas	466	[na]	[na]	[na]	[na]
Faeroe Islands	169	[na]	[na]	45,000	[na]
Bermuda	124	[na]	[na]	[na]	[na]
British Virgin Islands	14	[na]	[na]	[na]	[na]
Andorra	[na]	[na]	[na]	[na]	[na]
Monaco	[na]	[na]	[na]	34,000	[na]
San Marino	[na]	[na]	[na]	[na]	[na]

High-income OPEC	80,146	107.68	1.1%	24,386,000	744.3
Saudi Arabia	69,392	107.68	3.7%	18,979,000	644.4
United Arab Emirates	18,642	[na]	[na]	[na]	[na]
Kuwait	13,297	[na]	[na]	[na]	[na]
Libya	10,754	[na]	[na]	5,407,000	[na]
Qatar	7,920	[na]	[na]	[na]	[na]
Bahrain	4,048	[na]	[na]	[na]	[na]
Oman	3,116	[na]	[na]	[na]	[na]
Brunei	2,247	[na]	[na]	[na]	[na]
Eastern Europe	347,363	290.20	5.4%	169,591,000	1,197.0
Ukraine	119,599	33.68	1.0%	51,550,000	3,551.4
Poland	92,818	74.43	[na]	38,612,000	1,247.0
Romania	33,049	34.91	[na]	22,692,000	946.7
Czech Republic	30,581	37.04	10.9%	10,332,000	825.6
Belarus	16,185	20.00	1.2%	10,339,000	809.2
Bulgaria	15,474	24.82	[na]	8,409,000	623.4
Hungary	15,250	27.05	2.2%	10,229,000	563.9
Slovakia	10,381	18.58	10.7%	5,369,000	558.8
Croatia	4,644	[na]	#VALUE!	4,778,000	#VALUE!
Estonia	4,488	4.35	0.7%	1,484,000	1,030.9
Lithuania	4,043	7.92	1.0%	3,715,000	510.2
Slovenia	3,197	[na]	[na]	[na]	[na]
Moldova	2,952	1.91	-0.9%	4,344,000	1,544.1
Macedonia, F.Y.R.	2,934	[na]	[na]	[na]	[na]
Latvia	2,543	5.50	0.6%	2,516,000	462.2
Bosnia and Hercegovina	503	[na]	[na]	4,383,000	[na]
Serbia and Montenegro	[na]	[na]	[na]	[na]	[na]
Middle income	238,644	877.70	4.6%	262,595,000	271.9
Korea, Rep.	101,963	287.79	8.8%	44,851,000	354.3
Brazil	68,012	370.01	4.5%	159,222,000	183.8
Argentina	35,334	148.97	1.8%	34,665,000	237.2
Malaysia	29,095	70.92	7.3%	20,140,000	410.2
Trinidad and Tobago	4,670	[na]	[na]	[na]	[na]
Puerto Rico	4,240	[na]	[na]	3,717,000	[na]
Netherlands Antilles	1,762	[na]	[na]	[na]	#VALUE!
Cyprus	1,413	[na]	[na]	[na]	[na]
Gabon	967	[na]	[na]	[na]	#VALUE!
Suriname	587	[na]	[na]	[na]	[na]
Martinique	556	[na]	[na]	[na]	[na]
Malta	471	[na]	[na]	[na]	[na]
New Caledonia	468	[na]	[na]	[na]	[na]
Reunion	424	[na]	[na]	[na]	[na]
Macao	336	[na]	[na]	[na]	[na]
Barbados	225	[na]	[na]	[na]	[na]
French Polynesia	153	[na]	[na]	[na]	[na]
Antigua and Barbuda	88	[na]	[na]	[na]	[na]
Gibraltar	62	[na]	[na]	[na]	[na]
St. Lucia	52	[na]	[na]	[na]	[na]
Seychelles	44	[na]	[na]	[na]	[na]
Nauru	38	[na]	[na]	[na]	[na]
St. Kitts and Nevis	26	[na]	[na]	[na]	[na]
St. Pierre and Miquelon	19	[na]	[na]	[na]	[na]
Montserrat	12	[na]	[na]	[na]	[na]
Isle of Man	[na]	[na]	[na]	[na]	[na]
Northern Mariana Islands	[na]	[na]	[na]	69,000	[na]
Turks and Caicos Islands	[na]	[na]	[na]	[na]	[na]
Anguilla	[na]	[na]	[na]	[na]	[na]
Taiwan	[na]	[na]	[na]	[na]	[na]

Lower-middle income	541,912	883.78	3.6%	540,517,000	613.2
Mexico	97,662	179.33	3.4%	91,831,000	544.6
South Africa	83,462	101.68	2.1%	41,457,000	820.8
Iran, Islamic Rep.	71,987	[na]	[na]	64,120,000	[na]
Venezuela	49,193	65.01	2.0%	21,671,000	756.7
Turkey	47,773	129.03	4.3%	61,058,000	370.2
Thailand	47,773	121.64	7.5%	58,242,000	392.7
Kazakhstan	37,093	18.17	1.6%	16,606,000	2,041.4
Algeria	24,909	75.67	3.4%	27,959,000	[na]
Colombia	18,429	57.45	4.5%	36,813,000	320.8
Syrian Arab Rep.	12,561	20.26	6.2%	14,112,000	620.0
Chile	12,037	16.14	5.2%	14,225,000	745.7
Peru	8,341	27.88	2.2%	23,819,000	299.1
Morocco	7,995	26.21	3.9%	26,562,000	305.0
Cuba	7,933	[na]	[na]	11,011,000	[na]
Turkmenistan	7,733	1.30	3.6%	4,508,000	5,959.5
Ecuador	6,177	7.43	4.5%	11,477,000	831.8
Tunisia	4,178	14.62	5.1%		285.8
Dominican Rep.	3,212	7.43	4.5%	7,822,000	432.5
Jamaica	2,470	[na]	[na]	[na]	[na]
Panama	1,882	[na]	[na]	[na]	[na]
Uruguay	1,468	10.05	1.8%	3,184,000	146.0
Costa Rica	1,428	7.31	4.1%	3,399,000	195.3
El Salvador	1,416	6.52	1.9%	5,623,000	217.1
Paraguay	1,036	5.74	5.2%	4,828,000	180.5
Papua New Guinea	677	5.16	3.1%	4,302,000	131.1
Guadeloupe	416	[na]	[na]	[na]	[na]
Mauritius	407	[na]	[na]	[na]	[na]
French Guiana	238	[na]	[na]	[na]	[na]
Fiji	201	[na]	[na]	[na]	[na]
Belize	113	[na]	[na]	[na]	[na]
Cayman Islands	84	[na]	[na]	[na]	[na]
American Samoa	75	[na]	[na]	[na]	[na]
Pacific Islands	65	[na]	[na]	[na]	[na]
Grenada	46	[na]	[na]	[na]	[na]
St. Vincent and the Grenadines	34	[na]	[na]	[na]	[na]
Tonga	28	[na]	[na]	[na]	[na]
Dominica	22	[na]	[na]	[na]	[na]
Vanuatu	17	[na]	[na]	[na]	[na]
Cook Islands	6	[na]	[na]	[na]	[na]
Niue	1	[na]	[na]	[na]	[na]
Namibia	0	[na]	[na]	[na]	[na]
Micronesia	0	[na]	[na]	[na]	[na]
Marshall Islands	0	[na]	[na]	[na]	[na]
Wallis and Futuna	0	[na]	[na]	[na]	[na]

Africa	39,152	154.64	3.2%	454,460,000	253.2
Nigeria	24,759	44.81	2.9%	111,273,000	[na]
Cote d'Ivoire	2,828	11.59	2.6%	13,978,000	243.9
Zimbabwe	2,657	7.54	2.9%	11,011,000	352.3
Kenya	1,824	11.34	5.2%	26,688,000	160.9
Angola	1,256	7.83	[na]	10,772,000	160.5
Cameroon	1,131	10.94	3.3%	13,288,000	103.4
Ghana	1,104	8.12	1.9%	17,075,000	136.0
Ethiopia	962	9.85	[na]	56,404,000	97.7
Sudan	955	[na]	[na]	26,707,000	[na]
Mauritania	837	[na]	[na]	[na]	[na]
Senegal	836	6.35	2.5%	8,468,000	131.7
Tanzania	666	5.20	[na]	29,646,000	128.1
Zambia	656	2.62	0.9%	8,978,000	250.8
Botswana	612	[na]	[na]	[na]	[na]
Zaire	573	[na]	[na]	43,848,000	[na]
Congo	346	[na]	[na]	[na]	[na]
Madagascar	307	3.07	0.5%	13,651,000	99.9
Niger	305	2.81	0.3%	9,028,000	108.6
Guinea	295	3.02	[na]	6,591,000	97.7
Uganda	285	12.09	[na]	19,168,000	23.6
Mozambique	271	2.43	[na]	16,168,000	111.3
Burkina Faso	261	3.04	3.6%	10,377,000	85.9
Togo	203	1.51	2.0%	4,085,000	134.1
Malawi	198	1.62	3.7%	9,757,000	122.5
Benin	173	[na]	[na]	5,475,000	[na]
Rwanda	134	1.43	0.8%	6,400,000	93.4
Mali	127	2.84	3.0%	9,788,000	44.7
Swaziland	124	[na]	[na]	[na]	[na]
Sierra Leone	121	0.81	0.8%	4,195,000	149.3
Djibouti	101	[na]	[na]	[na]	[na]
Liberia	87	[na]	[na]	[na]	[na]
Central African Rep.	64	1.33	1.4%	3,275,000	48.3
Guinea-Bissau	63	[na]	[na]	[na]	[na]
Gambia, The	59	[na]	[na]	[na]	[na]
Burundi	58	1.29	2.8%	6,264,000	44.9
Equatorial Guinea	36	[na]	[na]	[na]	[na]
Cape Verde	31	[na]	[na]	[na]	[na]
Chad	26	1.30	1.9%	6,448,000	19.9
Comoros	18	[na]	[na]	[na]	[na]
Somalia	3	[na]	[na]	9,491,000	[na]
Lesotho	[na]	[na]	[na]	[na]	[na]

Low income	320,649	482.42	4.1%	895,036,222	664.7
Indonesia	80,822	157.56	7.1%	193,276,992	513.0
Korea, Dem. Rep.	70,138	[na]	[na]	23,867,000	[na]
Iraq	27,020	[na]	[na]	20,097,000	[na]
Uzbekistan	26,986	15.23	3.3%	22,771,000	1,771.4
Egypt, Arab Rep.	25,023	47.56	5.4%	57,800,000	[na]
Pakistan	23,296	56.03	5.3%	129,905,000	[na]
Philippines	16,692	48.94	3.4%	68,595,000	341.1
Azerbaijan	11,620	3.31	-0.2%	7,510,000	3,515.7
Viet Nam	8,654	67.91	[na]	73,475,000	127.4
Bangladesh	5,713	27.38	3.3%	57,800,000	208.7
Yemen	3,933	[na]	[na]	15,272,000	[na]
Lebanon	3,641	[na]	[na]	4,005,000	[na]
Jordan	3,632	[na]	[na]	4,212,000	[na]
Bolivia	2,859	6.64	2.5%	57,800,000	430.7
Mongolia	2,308	[na]	[na]	[na]	[na]
Georgia	2,114	2.64	-3.4%	5,400,000	800.0
Guatemala	1,962	10.81	3.4%	10,621,230	181.5
Myanmar	1,919	[na]	[na]	45,106,000	[na]
Sri Lanka	1,607	10.50	4.5%	18,114,000	153.1
Kyrgyzstan	1,491	1.26	2.4%	4,515,000	1,184.8
Honduras	1,052	6.07	3.8%	5,924,000	173.3
Tajikistan	1,021	1.68	3.4%	5,836,000	607.8
Armenia	996	1.20	-0.1%	3,760,000	828.5
Nicaragua	737	4.04	-0.2%	4,375,000	182.2
Albania	504	3.27	[na]	3,260,000	153.9
Nepal	418	5.00	3.7%	21,456,000	83.6
Afghanistan	338	[na]	[na]	23,481,000	[na]
Guyana	255	[na]	[na]	[na]	[na]
Haiti	174	1.87	0.4%	7,168,000	92.9
Cambodia	136	1.50	[na]	10,024,000	90.4
Lao, PDR	84	2.01	[na]	4,882,000	41.8
Bhutan	65	[na]	[na]	[na]	[na]
Western Sahara	57	[na]	[na]	[na]	[na]
Maldives	50	[na]	[na]	[na]	[na]
Solomon Islands	44	[na]	[na]	[na]	[na]
Western Samoa	36	[na]	[na]	[na]	[na]
Sao Tome and Principe	21	[na]	[na]	[na]	[na]
Kiribati	6	[na]	[na]	[na]	[na]
West Bank	[na]	[na]	[na]	[na]	[na]
Gaza Strip	[na]	[na]	[na]	[na]	[na]
Tuvalu	[na]	[na]	[na]	[na]	[na]
Tokelau	[na]	[na]	[na]	[na]	[na]

Table 3-2. Major Regional Aggregates in RICE-98 Regions

	Industrial CO2 Emissions	Gross Domestic Product [1990 U.S. dollars, market exchange rates]			Population	CO2-GDP Ratio
	[million metric tons, carbon weight]	[billions]	Growth rate of real GDP [% per year]	GDP per capita	[millions]	[kg per $100
	1995	1995	1970-95	1995	1995	1995
United States	1,407.3	6175.79	2.6%	23,471	263.1	227.9
China	871.3	654.29	8.5%	545	1,200.2	1,331.7
EU	847.7	6,871.55	2.4%	18,078	380.1	123.4
Lower-middle income	541.9	883.78	3.6%	1,635	540.5	613.2
Russia	496.2	334.48	1.2%	2,257	148.2	1,483.4
Eastern Europe	347.4	290.20	5.4%	1,711	169.6	1,197.0
Low income	320.6	482.42	4.1%	539	895.0	664.7
Japan	307.5	3419.59	3.6%	27,310	125.2	89.9
India	248.0	447.09	4.4%	481	929.4	554.7
Middle income	238.6	877.70	4.6%	3,342	262.6	271.9
Other high income	235.5	997.25	3.4%	16,685	59.8	236.2
High-income OPEC	80.1	107.68	1.1%	4,416	24.4	744.3
Africa	39.2	154.64	3.2%	340	454.5	253.2

Notes on sources of data for Tables 3-1 through 3-5.

Underlying data in Tables 3-1 through 3-5 were taken from the following. Most output data were from *World Development Indicators 1997*, CD-ROM. Energy data for 1995 were from United Nations, *1995 Energy Statistics Yearbook*, United Nations, New York 1997. Energy data for 1970 were from United Nations, *World Energy Supplies, 1970-1973*, United Nations, Department of Economic and Social Affairs Statistical Office, New York, 1975. Other years were from World Bank, *World Development Indicators*, 1997. Data on carbon-dioxide emissions were from the web page of the Carbon Dioxide Information Analysis Center (http: //cdiac.esd.ornl.gov /cdp/95_emis_1998/top95.tot). The cited source at that page was Gregg Marland et al. Conversion factors were taken from National Academy of Sciences, *Policy Implications of Greenhouse Warming: Mitigation, Adaptation, and the Science Base*, National Academy Press, 1992, pp. 847-848. Multiple adjustments were made for countries, particularly those of the former Soviet Union.

Notes on units.

Carbon is measured in metric tons.

Output and consumption is measured using country price weights and converted into U.S. dollars at 1990 market exchange rates.

Source: tables for rice paper 102698.xls

Table 3-3.

GDP PER CAPITA GROWTH RATES

Regional Aggregates

	1970-75	1975-80	1980-85	1985-90	1990-95	1970-95
United States	1.10%	2.08%	1.60%	1.83%	1.29%	1.58%
China	3.34%	4.89%	8.72%	6.30%	11.08%	6.83%
Japan	3.06%	3.46%	2.67%	4.17%	1.01%	2.87%
EU	2.32%	2.70%	1.37%	2.74%	0.95%	2.01%
Russia	5.67%	3.78%	2.40%	1.14%	-9.07%	0.65%
India	0.60%	0.79%	3.12%	4.13%	2.55%	2.23%
Other high income	2.72%	2.21%	1.74%	1.50%	1.20%	1.87%
High-income OPEC	0.11%	3.24%	-11.29%	-6.86%	-1.58%	-3.42%
Eastern Europe	11.14%	15.01%	3.18%	0.90%	-4.35%	4.94%
Middle income	5.22%	3.77%	-0.13%	2.31%	2.53%	2.73%
Lower-middle income	2.46%	2.31%	0.13%	0.92%	0.75%	1.31%
Africa	1.68%	1.33%	1.87%	0.32%	-3.55%	0.31%
Low income	3.07%	4.82%	1.14%	-0.05%	-0.28%	1.72%
World	2.18%	2.96%	0.37%	1.91%	0.62%	1.60%

Table 3-4.

ENERGY/GDP GROWTH RATES

Regional Aggregates

	1970-75	1975-80	1980-85	1985-90	1990-95	1970-95
United States	0.03%	-1.32%	-2.86%	-1.10%	-1.67%	-1.39%
China	-1.62%	-0.62%	-5.12%	-2.85%	-8.15%	-3.71%
Japan	1.98%	-1.90%	-2.43%	-0.98%	-1.93%	-1.07%
EU	1.43%	-0.81%	-1.19%	-1.74%	-2.95%	-1.06%
Russia	0.53%	0.17%	0.40%	-2.19%	3.60%	0.48%
India	0.69%	1.10%	1.30%	0.80%	0.57%	0.89%
Other high income	1.70%	-0.54%	-2.44%	-0.22%	-2.10%	-0.73%
High-income OPEC	15.37%	14.83%	15.12%	7.20%	0.19%	10.37%
Eastern Europe	-11.53%	-11.30%	4.17%	-1.91%	-3.24%	-4.95%
Middle income	2.48%	-0.10%	0.74%	1.75%	-0.48%	0.87%
Lower-middle income	9.70%	-0.57%	3.97%	-1.71%	-2.35%	1.71%
Africa	5.42%	3.89%	-3.10%	0.05%	-3.20%	0.55%
Low income	-4.94%	-1.16%	5.89%	1.14%	0.45%	0.21%
World	0.78%	-0.69%	-0.02%	-1.39%	-2.38%	-0.75%

Table 3-5

CO2/GDP GROWTH RATES

Regional Aggregates

	1970-75	1975-80	1980-85	1985-90	1990-95	1970-95
United States	-1.88%	-1.75%	-3.23%	-0.70%	-1.41%	-1.80%
China	2.39%	-0.99%	-4.09%	-3.43%	-5.93%	-2.45%
Japan	-1.54%	-2.48%	-3.30%	-1.57%	-0.44%	-1.87%
EU	-2.03%	-1.32%	-3.18%	-2.68%	-1.94%	-2.23%
Russia	-1.35%	-1.45%	-0.80%	-2.11%	5.88%	-0.01%
India	2.37%	3.47%	1.60%	0.18%	1.62%	1.84%
Other high income	-1.40%	-0.74%	-2.89%	-0.84%	-0.67%	-1.31%
High-income OPEC	0.06%	3.99%	11.17%	8.70%	0.66%	4.83%
Eastern Europe	-6.96%	-11.25%	-2.64%	-3.37%	-1.86%	-5.28%
Middle income	-0.51%	0.92%	-0.44%	0.71%	3.00%	0.73%
Lower-middle income	0.10%	-0.05%	0.25%	-0.43%	-0.51%	-0.13%
Africa	5.50%	1.54%	-4.51%	0.18%	2.44%	0.98%
Low income	1.17%	-2.50%	0.03%	1.88%	2.24%	0.55%
World	-0.65%	-1.02%	-1.47%	-1.45%	-0.77%	-1.07%

Source: tables for rice paper 102698.xls

Table 3-6

Projected and Actual Real Return on Capital by Region

[Average percent per year]

	Historical	---------- Projected ----------			
Year		***1995***	***2005***	***2015***	***2025***
Japan	5.0	4.4%	3.9%	3.7%	3.5%
USA	6.0	5.1%	3.9%	3.3%	3.1%
European Union	6.0	5.4%	4.2%	3.6%	3.4%
Other High Income	7.0	5.7%	4.3%	3.6%	3.4%
High Income Opec	3.0	2.3%	3.4%	3.7%	3.7%
Middle Income	8.0	7.2%	5.4%	4.6%	4.2%
Russia	8.0	6.8%	5.4%	4.7%	4.4%
Lower Middle Income	8.0	7.3%	5.7%	5.0%	4.6%
Eastern Europe	8.0	6.6%	5.4%	4.9%	4.6%
Low Income	9.0	8.0%	5.9%	4.9%	4.5%
China	9.0	7.4%	6.3%	5.7%	5.3%
India	9.0	7.7%	6.2%	5.4%	5.0%
Africa	9.0	8.0%	5.6%	4.6%	4.1%

Source: growth sheet121598.xls

Table 3-7
Comparison of RICE with Maddison Projections
[Annual average growth rates of per capita GDP]

		----- Historical estimates -----		----------Projections----------		
Maddison region	***RICE region***	***RICE*** 1970-95	***Maddison*** 1973-95	***RICE*** 1995-2015	***Maddison*** 1995-2015	***Difference***
Western Europe	**European Union**	2.01	1.72	1.26	1.30	-0.04
Other Europe	**Eastern Europe**	4.94	0.48	2.92	2.68	0.24
Former USSR	**Russia**	0.65	-2.35	2.73	2.50	0.23
USA	**USA**	1.58	1.55	1.27	1.30	-0.03
Other Americas	**Middle Income**	2.73	0.68	2.46	1.33	1.13
China	**China**	6.83	5.37	3.83	4.50	-0.67
India	**India**	2.23	2.81	3.46	3.50	-0.04
Japan	**Japan**	2.87	2.53	1.20	1.30	-0.10
Other Asia	**Low Income**	1.72	2.17	2.85	2.86	-0.01
Africa	**Africa**	0.31	-0.33	2.51	1.00	1.51
Weighted average*		3.15	2.35	2.89	2.81	0.08

* Weighted by 1995 population
Source: Maddison [1998] and RICE-98 model.

***1995 population weights**

Source: Maddison [1994] and RICE-98 model.

Source: Maddison growth forecasts and compare 121498.xls

Table 3-8. Growth in Per Capita Output in RICE-98 Regions: Historical Rates, Target Rates, and Projections

Region	Growth rate of per capita output							Per capita output [1990 U.S. prices]	
	Actual	Target	RICE-98 Model Calculations			Average			
	1970-95		1995-2005	2005-2015	2015-2025	1995-2045	2045-2095	1995	2100
Japan	2.87%	2.00%	1.30%	1.10%	0.99%	1.04%	0.70%	$24,883	$61,065
USA	1.58%	1.60%	1.49%	1.04%	0.85%	0.97%	0.65%	$22,904	$52,796
European Union	2.01%	2.00%	1.48%	1.04%	0.83%	0.98%	0.64%	$18,788	$43,239
Other High Income	1.87%	2.20%	1.55%	1.07%	0.87%	1.00%	0.66%	$18,999	$44,741
High Income Opec	-3.42%	0.80%	0.75%	1.12%	1.22%	1.10%	0.98%	$7,819	$22,909
Middle Income	2.73%	3.00%	2.80%	2.11%	1.78%	1.94%	1.17%	$4,801	$23,592
Russia	0.65%	3.00%	3.07%	2.39%	2.06%	2.22%	1.46%	$2,250	$14,871
Lower Middle Income	1.31%	3.20%	2.95%	2.33%	2.00%	2.15%	1.35%	$2,039	$12,174
Eastern Europe	4.94%	3.30%	3.24%	2.60%	2.26%	2.41%	1.60%	$1,994	$15,562
Low Income	1.72%	3.50%	3.26%	2.43%	2.04%	2.25%	1.43%	$578	$3,800
China	6.83%	4.50%	4.19%	3.47%	3.03%	3.18%	2.02%	$489	$6,919
India	2.23%	4.00%	3.82%	3.09%	2.68%	2.85%	1.82%	$360	$3,898
Africa	0.31%	3.00%	2.94%	2.07%	1.69%	1.92%	1.21%	$310	$1,545

Note: The estimates of output levels and growth rates use market exchange rates. The levels of output are calculated to be substantially higher for low-income countries and lower for Japan and Europe using purchasing power parity exchange rates.

Source: growth sheet121598.xls

Table 3-9
Comparison of RICE with IIASA Scenario B

Comparison of IIASA Scenario B and RICE Model

	2020		2050	
	IIASA	RICE	IIASA	RICE
Population (billions)	7.92	7.60	10.06	9.24
World Output (trillions, 1990 prices)	40.2	38.49	72.8	58.93
Carbon emissions (GtC)	8.91	8.56	10.76	10.92
Carbon intensity (GtC per billion $)	222	222	148	185

Source: Maddison growth forecasts and compare 121598.xls

Table 3-10. Estimated Impact from IPCC Report, 1996

	$2xCO_2$				
	Cline (2.5°C)	Fankhauser (2.5°C)[1]	Nordhaus (3°C)[3]	Titus (4°C)	Tol (2.5°C)[2]
Agriculture	17.5	8.4	1.1	1.2	10.0
Forest Loss	3.3	0.7	small	43.6	-
Species Loss	4.0 + a[3]	8.4	[4]	-	5.0
Sea Level Rise	7.0	9.0	12.2	5.7	8.5
Electricity	11.2	7.9	1.1	5.6	-
Non-El. Heating	- 1.3	-		-	-
Human Amenity	+ b[3]	-		-	12.0
Human Morbidity	+ c[3]	-		-	-
Mortality	5.8	11.4		9.4	37.4
Migration	0.5	0.6		-	1.0
Hurricanes	0.8	0.2		-	0.3
Construction	± d[3]	-		-	-
Leisure Activities	1.7	-		-	-
Water Supply					
availability	7.0	15.6		11.4	-
pollution	-	-		32.6	-
Urban Infrastruc.	0.1	-		-	-
Air Pollution		7.3			-
tropos. Ozone	3.5			27.2	
other	+ e[3]			-	
Mobile Air Cond.	-	-		2.5	-
Total	61.1 +a+b+c±d+e	69.5	55.5	139.2	74.2
(% of GDP)	(1.1)	(1.3)	(1.0)	(2.5)	(1.5)[2]

[1] transformed to 1990 base
[2] USA and Canada, base year 1988
[3] identified, but not estimated
[4] not assessed categories, estimated at 0.75% of GDP

Sources: Cline (1992a); Fankhauser (1995a); Nordhaus (1991); Titus (1992); Tol (1995)

Source: IPCC III [1996].

Table 3-11. Regional Mean Temperatures, 1990

Region	*Regional Mean Temperature* [Annual average, degrees C]	
	Area weight	*Population weight*
Russia	**-5.0**	**3.1**
Eastern Europe	**7.9**	**8.9**
Western Europe	**9.1**	**10.5**
Other high income	**6.6**	**12.5**
Japan	**8.9**	**12.6**
United States	**7.8**	**13.4**
China	**4.6**	**13.8**
Lower-middle income	**19.2**	**19.0**
Middle income	**21.7**	**21.3**
Low income	**21.2**	**22.6**
High-income OPEC	**23.3**	**24.0**
Africa	**24.3**	**24.2**
India	**22.4**	**25.7**

Source: Nordhaus [1998c]

Table 3-12

Summary of Impacts in Different Sectors

Impact of 2.5 degree warming on different sectors:

[Positive numbers are damages; negative numbers are benefits; impacts measured as percent of market incomes]

	TOTAL [2.5 degree]	Agriculture	Other vul-nerable mkt	Coastal	Health	Non-market time use	Settlements	Catastrophic impact [2.5 degree]	[6 degrees]
United States	***0.45%***	0.06%	0.00%	0.11%	0.02%	-0.28%	0.10%	0.44%	2.97%
China	***0.22%***	-0.37%	0.13%	0.07%	0.09%	-0.26%	0.05%	0.52%	3.51%
Japan	***0.50%***	-0.46%	0.00%	0.56%	0.02%	-0.31%	0.25%	0.45%	3.04%
EU	***2.83%***	0.49%	0.00%	0.60%	0.02%	-0.43%	0.25%	1.91%	13.00%
Russia	***-0.65%***	-0.69%	-0.37%	0.09%	0.02%	-0.75%	0.05%	0.99%	6.74%
India	***4.93%***	1.08%	0.40%	0.09%	0.69%	0.30%	0.10%	2.27%	15.41%
Other high income	***-0.39%***	-0.95%	-0.31%	0.16%	0.02%	-0.35%	0.10%	0.94%	6.39%
High-income OPEC	***1.95%***	0.00%	0.91%	0.06%	0.23%	0.24%	0.05%	0.46%	3.14%
Eastern Europe	***0.71%***	0.46%	0.00%	0.01%	0.02%	-0.36%	0.10%	0.47%	3.23%
Middle income	***2.44%***	1.13%	0.41%	0.04%	0.32%	-0.04%	0.10%	0.47%	3.21%
Lower-middle income	***1.81%***	0.04%	0.29%	0.09%	0.32%	-0.04%	0.10%	1.01%	6.86%
Africa	***3.91%***	0.05%	0.09%	0.02%	3.00%	0.25%	0.10%	0.39%	2.68%
Low income	***2.64%***	0.04%	0.46%	0.09%	0.66%	0.20%	0.10%	1.09%	7.44%
Global [a]									
Output weighted	***1.50%***	***0.13%***	***0.05%***	***0.32%***	***0.10%***	***-0.29%***	***0.17%***	***1.02%***	***6.94%***
Population weighted	***1.88%***	***0.17%***	***0.23%***	***0.12%***	***0.56%***	***-0.03%***	***0.10%***	***1.05%***	***7.12%***

Note: Global total is regional impact weighted by shares of output in 2100 or population in 1995.

Source: Nordhaus [1998c]

Table 3-13

Non-CO2 Radiative Forcings According to IPCC-1990, IPCC-1995, and in RICE-98 Model

A. Estimated Forcings (watts per meter squared)

Year	[1] IPCC-1990	[2] IPCC-1995	[3] NewDICE
1960	0.39	-0.18	
1990	0.95	-0.15	-0.15
2000			-0.17
2010			-0.16
2020			-0.15
2030			-0.12
2040			-0.07
2050	1.85	-0.01	-0.01
2060			0.07
2070			0.16
2080			0.27
2090			0.39
2100	2.12	0.53	0.53
2200			0.53
2300			0.53

B. Components of forcings (watts per meter squared

	1990	***2050***	***2100***
CO2	1.57	3.77	5.85
N2O, CH4, and Halocarbons	0.85	1.41	1.87
CH4	0.46	0.84	1.07
N2O	0.15	0.37	0.52
Halocarbons	0.24	0.20	0.28
Stratospheric O3	-0.10	-0.02	0.00
Tropospheric O3	0.40	0.50	0.56
Tropospheric aerosols: direct	-0.50	-0.70	-0.70
Tropospheric aerosols: indirect	-0.80	-1.20	-1.20
Total	***1.42***	***3.76***	***6.38***
Total, non-CO2 forcings	***-0.15***	***-0.01***	***0.53***

Part A, column [1] is from Nordhaus [1994], p. 72-73.
Part A, column [2] is from IPCC [1996], Chapter 6.
Part A, column [3] estimates non-CO2 forcings as -.15 -.002285(t-1990)+.000077(t-1990)^2.
Part B from IPCC [1996], Chapter 6, especially pp. 117, 321. The emissions scenario is revised IP92a.

Source: forcings 121097.wb3

Table 4-1
Comparison of RICE-98 and DICE-98 Results

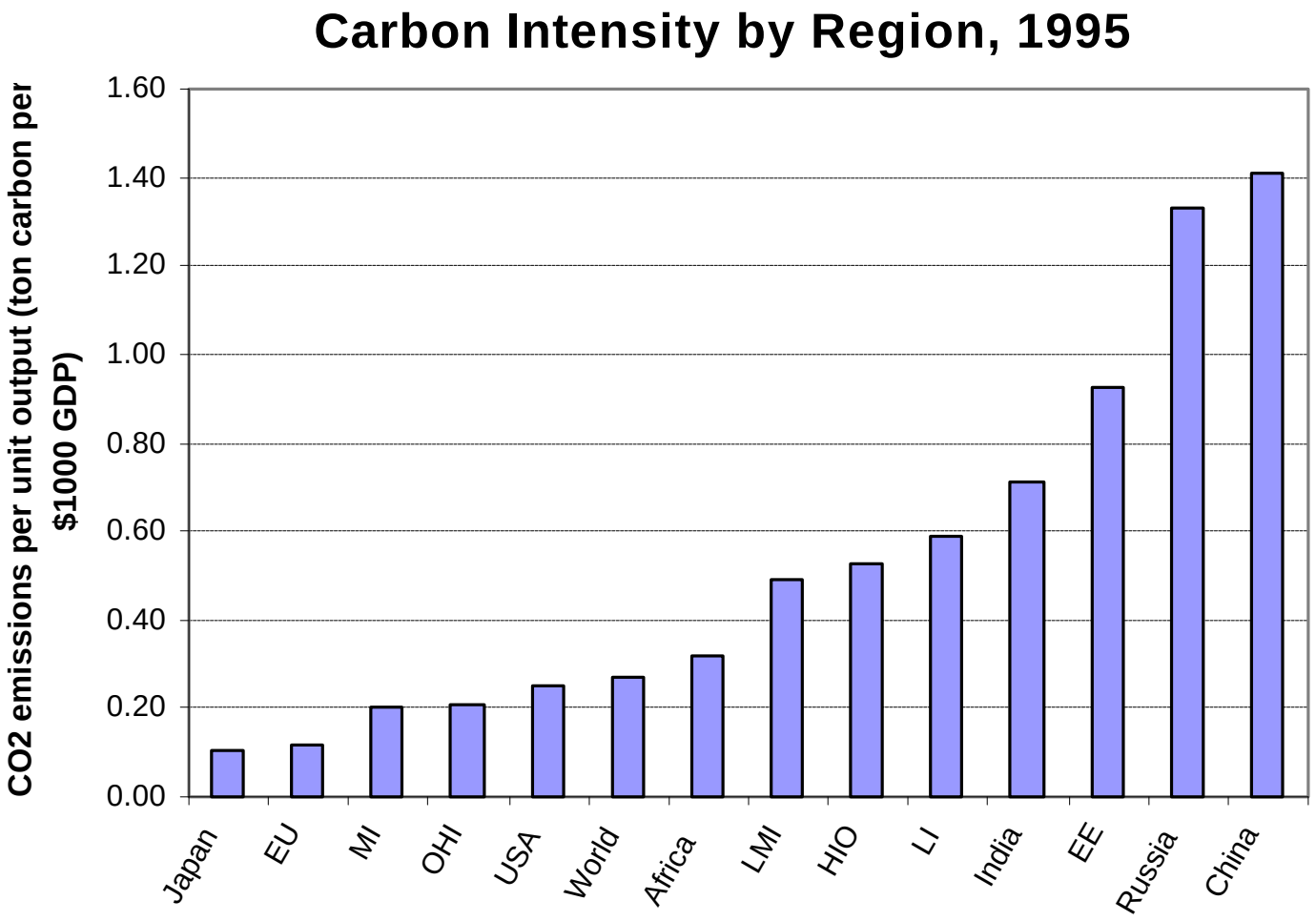
[Ratio of Calculation for DICE-98 to RICE-98]

	1995	2005	2015	2025	2035	2045	2055	2065	2075	2085	2095	2105
Output	0.998	1.032	1.061	1.082	1.104	1.104	1.094	1.078	1.059	1.039	1.019	0.999
Population	1.000	1.000	1.000	1.000	1.003	1.003	1.002	1.002	1.002	1.002	1.002	1.002
Carbon prices:												
World prices	1.662	1.618	1.608	1.611	1.626	1.647	1.675	1.703	1.735	1.768	1.805	1.840
Emissions control rate	1.684	1.452	1.284	1.144	1.033	0.944	0.877	0.826	0.785	0.753	0.728	0.695
Carbon intensity	1.004	0.985	0.969	0.957	0.943	0.939	0.941	0.945	0.951	0.958	0.966	0.976
Industrial emissions	1.002	1.017	1.028	1.035	1.041	1.037	1.029	1.019	1.007	0.996	0.985	0.975
Total CO2 emissions	1.002	1.015	1.025	1.032	1.038	1.035	1.028	1.018	1.007	0.996	0.985	0.976
Global temperature	1.000	1.001	1.001	1.003	1.007	1.011	1.014	1.016	1.017	1.016	1.014	1.012
CO2 concentrations	1.000	1.000	1.002	1.004	1.006	1.008	1.010	1.011	1.010	1.009	1.007	1.005

Note: The ratios for all variables other than the carbon prices and the emissions control rates are calculated in the base (no-controls) case. The carbon prices and the emissions control rates are calculated in the optimal control policy.

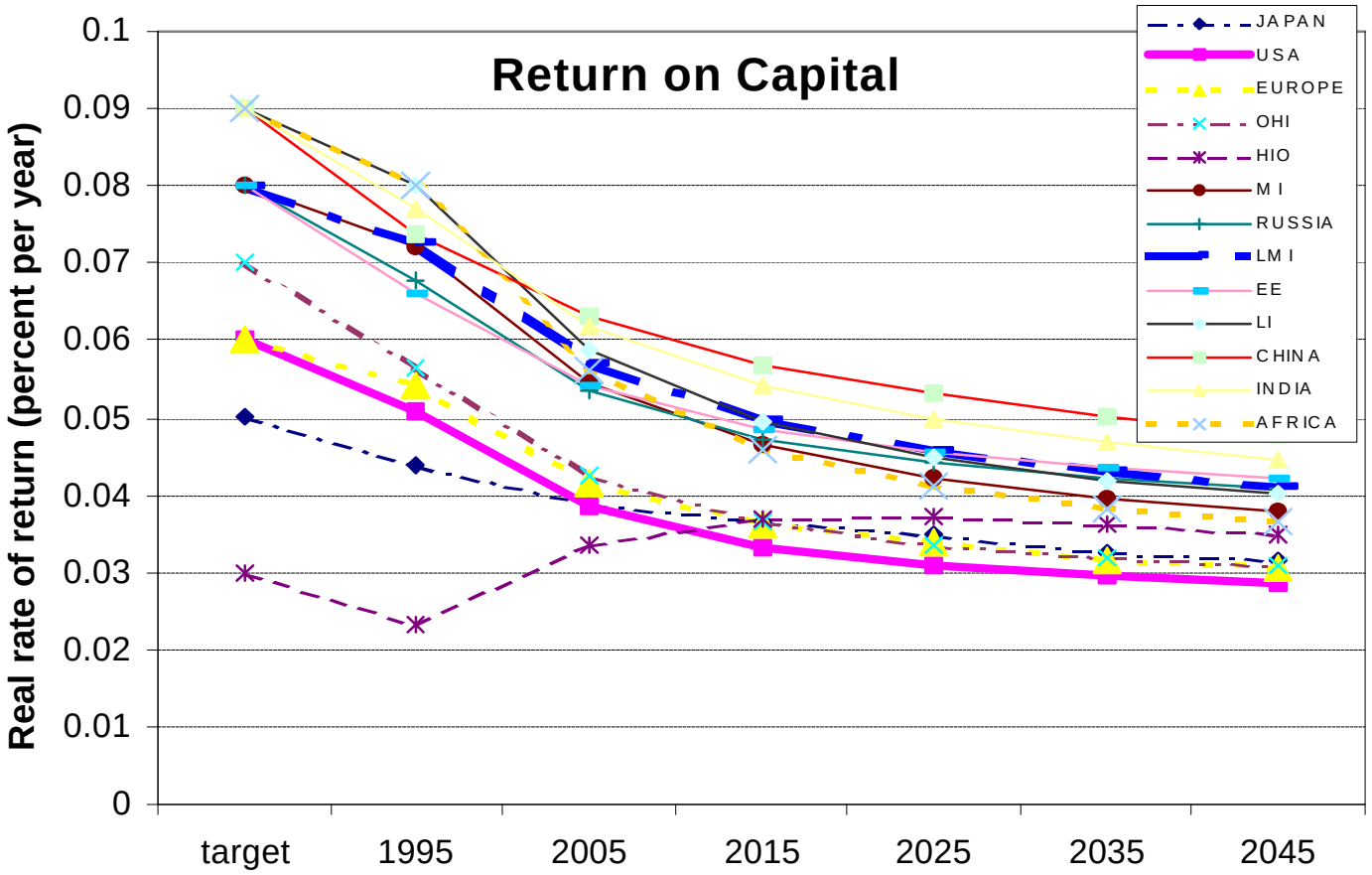
Source: compare dices 121898.xls

Figure 3-1. Industrial CO_2-Output Ratios for RICE Regions, 1995



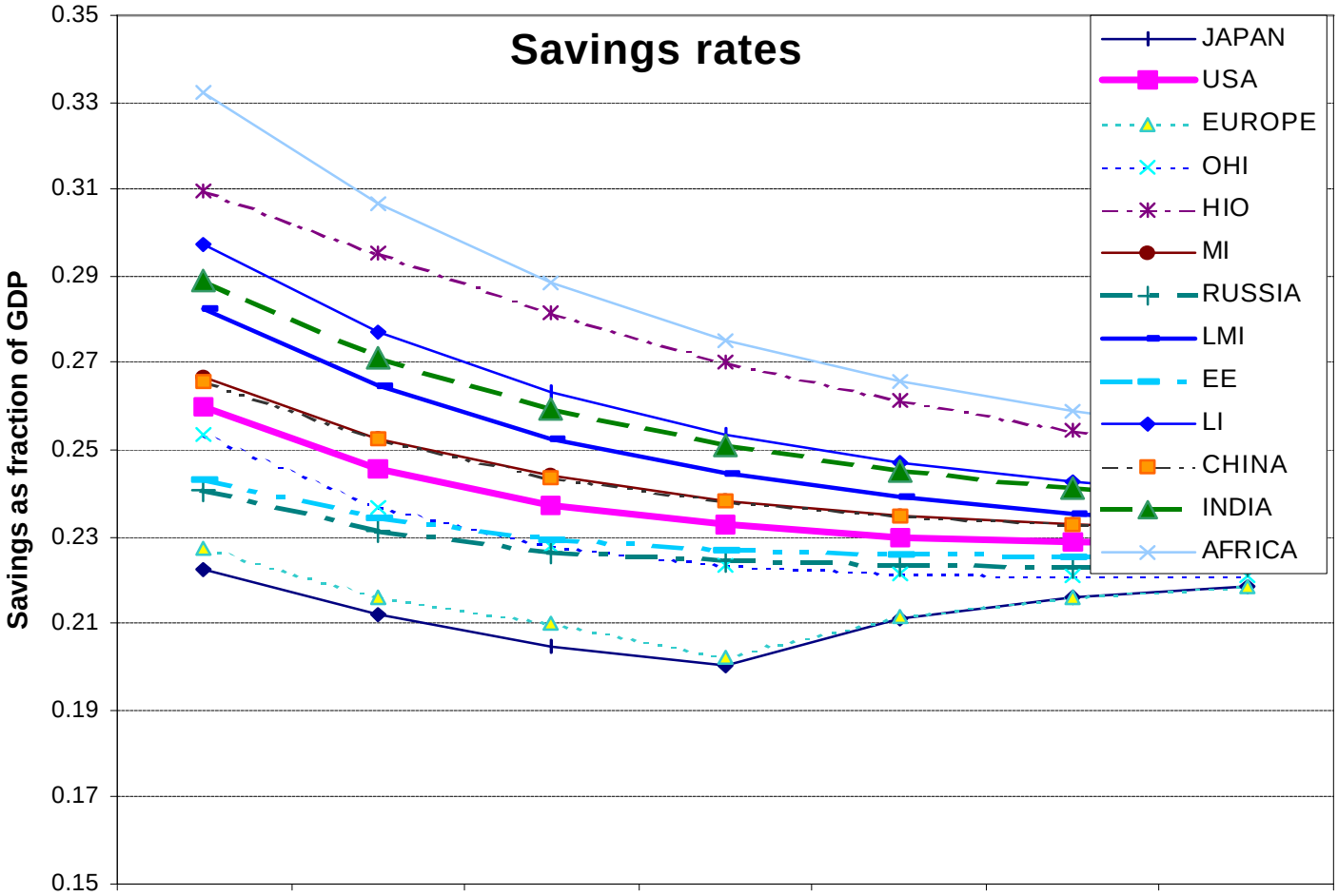
Source: growth sheet 121598.xls

Figure 3-2. Estimated Historical Returns on Capital and Solution for Initial Periods



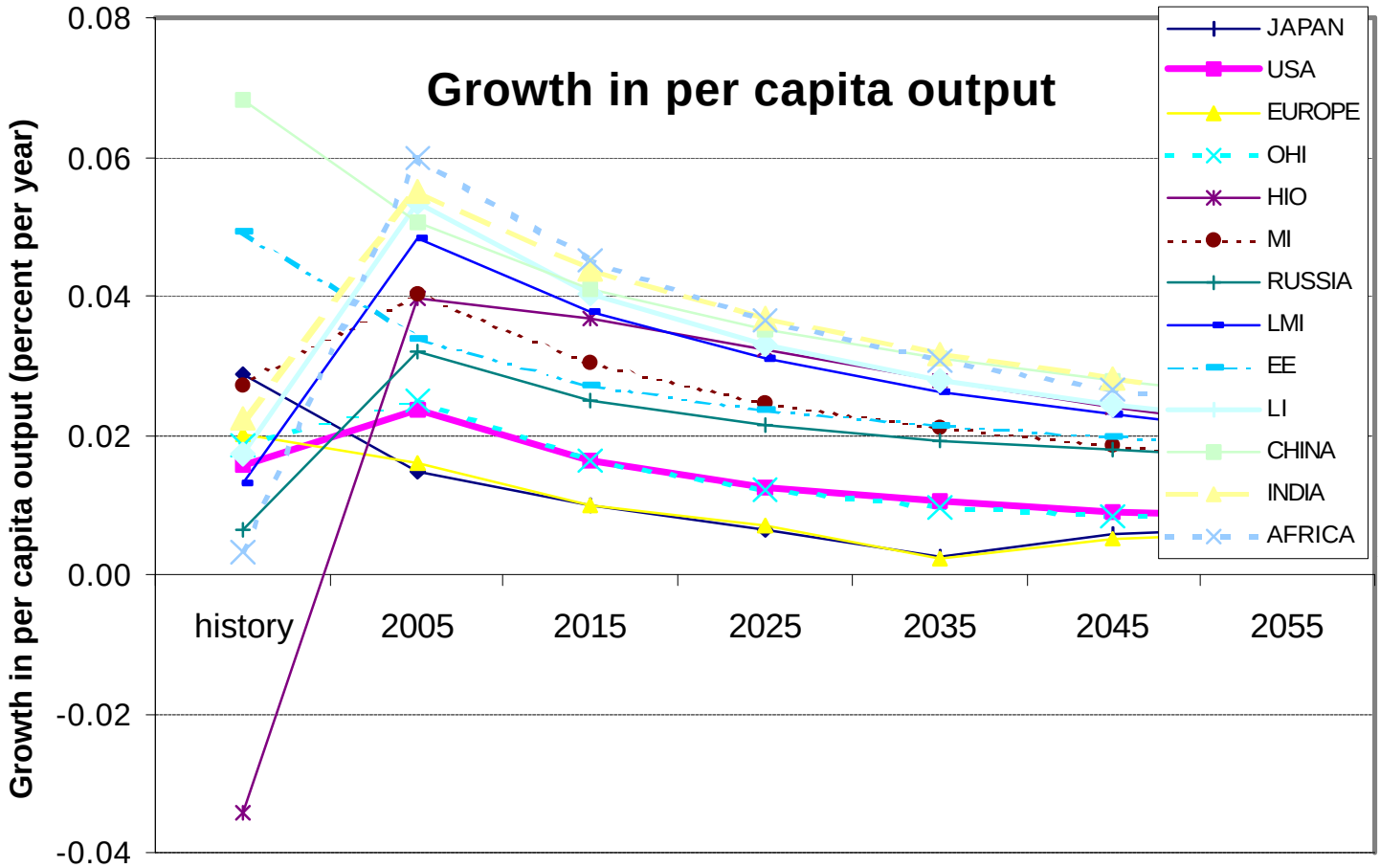
Source: growth sheet121598.xls

Figure 3-3. Projected Savings Rates in RICE-98 Model



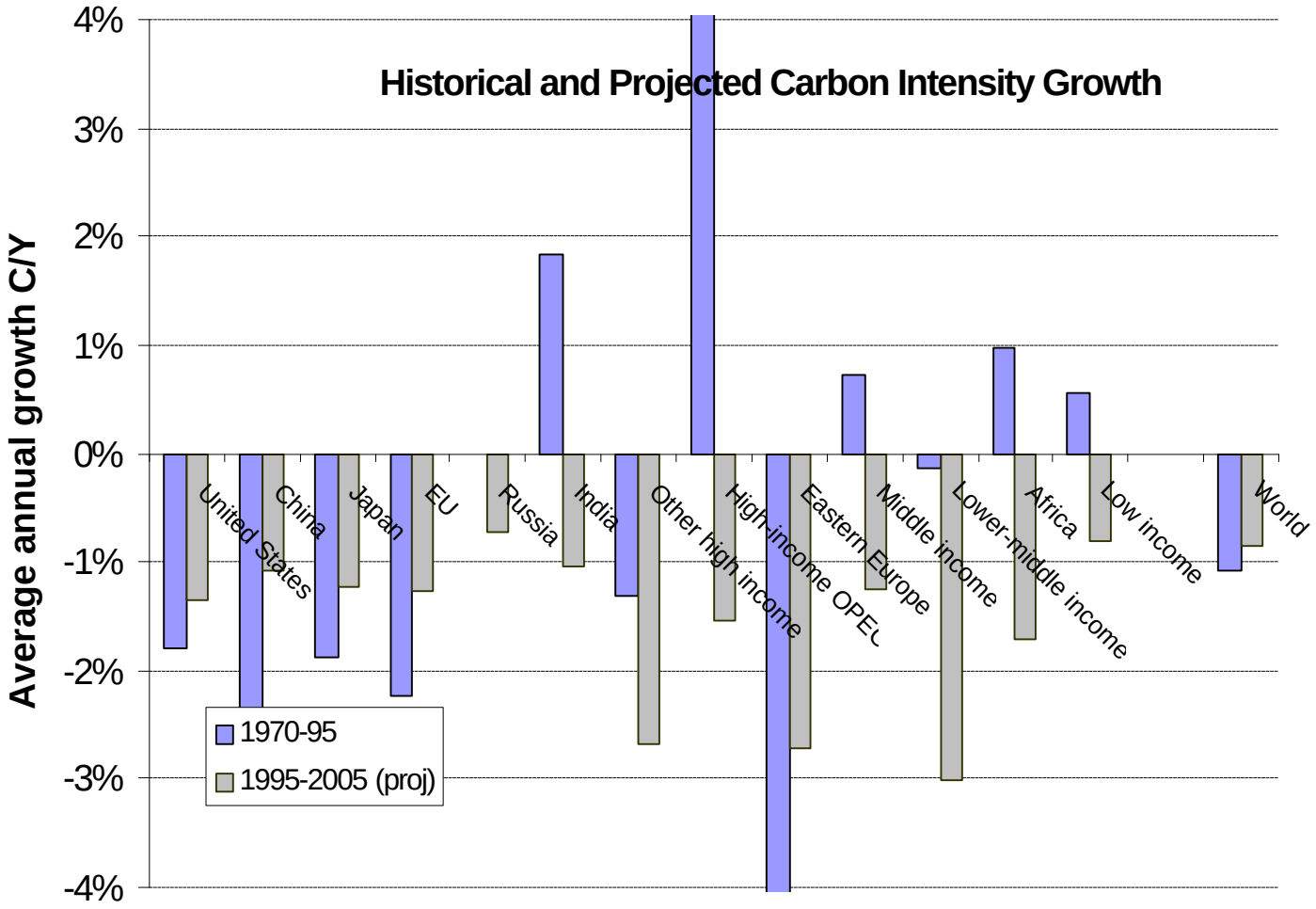
Source: growth sheet121598.xls

Figure 3-4. Growth in Per Capita Output for 1970-95 and Projections in RICE-98 Model



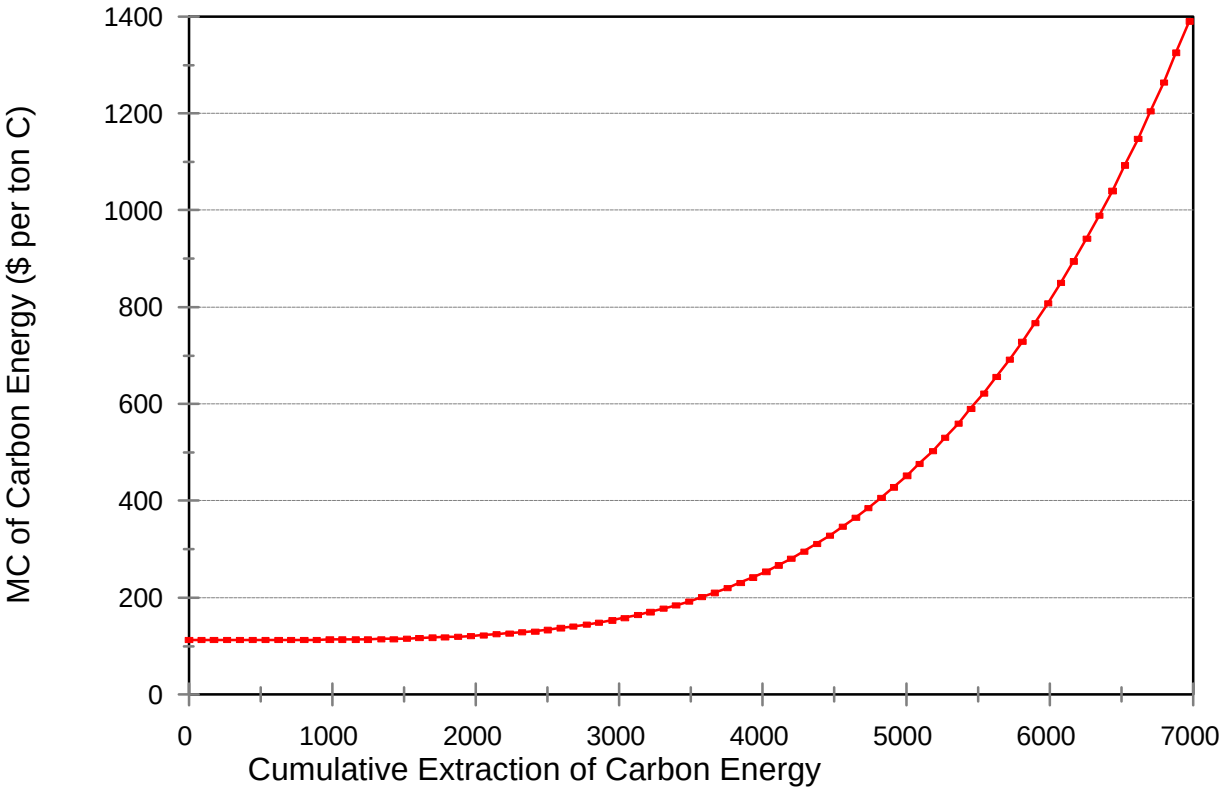
Source: growth sheet121598.xls

Figure 3-5



Source: growth sheet121598.xls

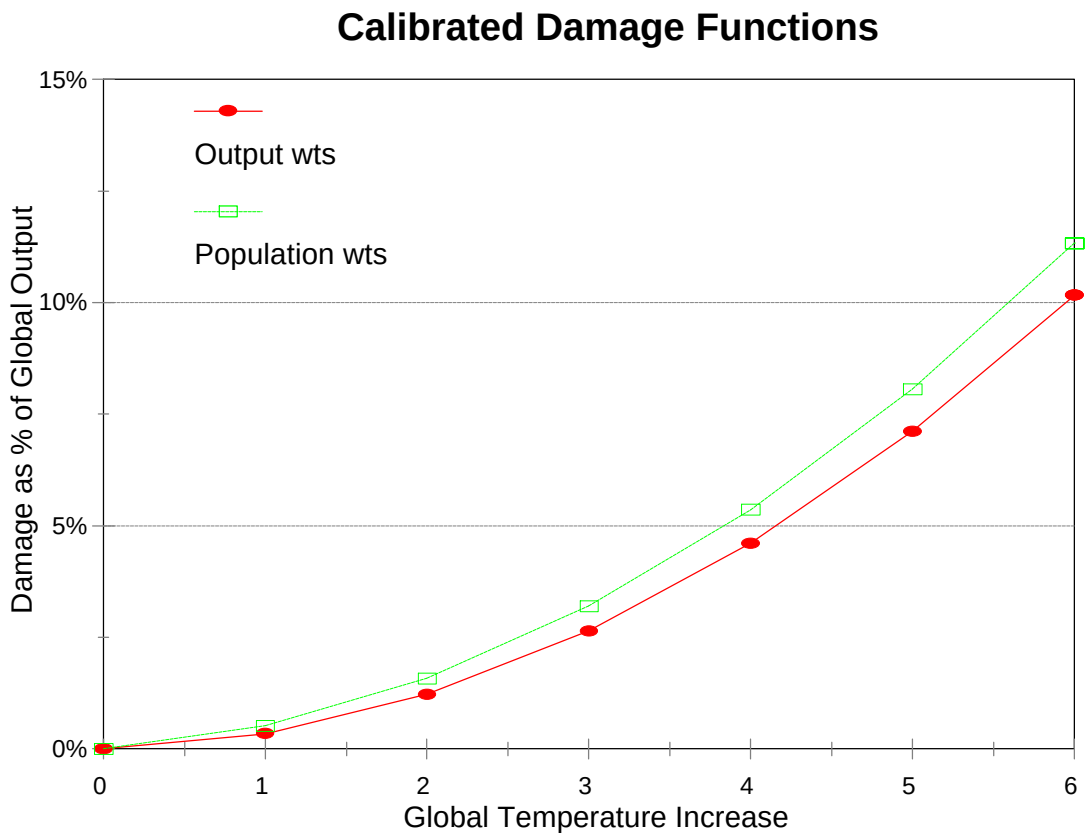
Figure 3-6. Carbon Supply Function in RICE-98 Model



Note: Cumulative extraction is measured as the carbon content of fossil fuels in billions of tons.

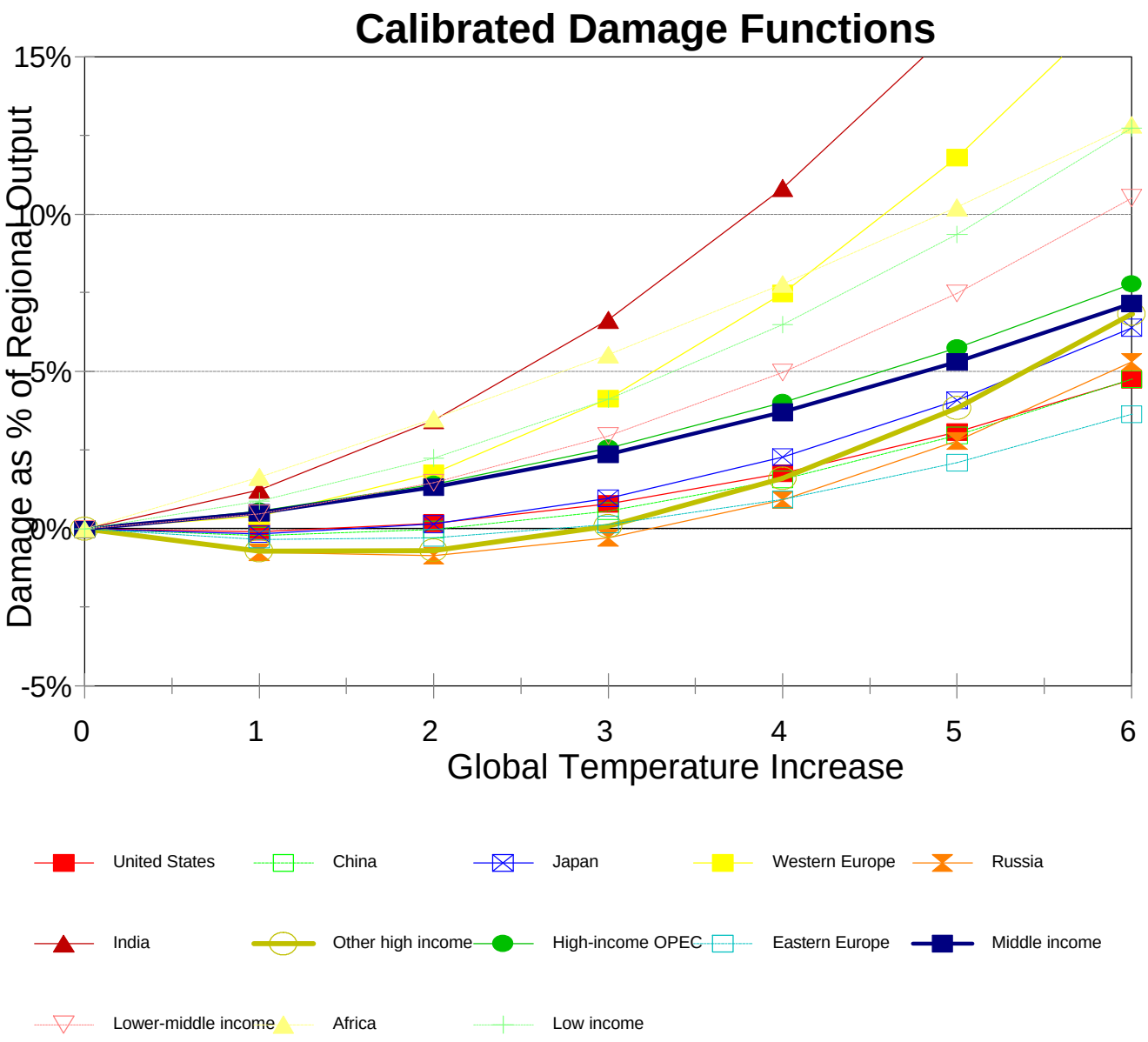
Source: carbon supply figure 102898.wb3

Figure 3-7



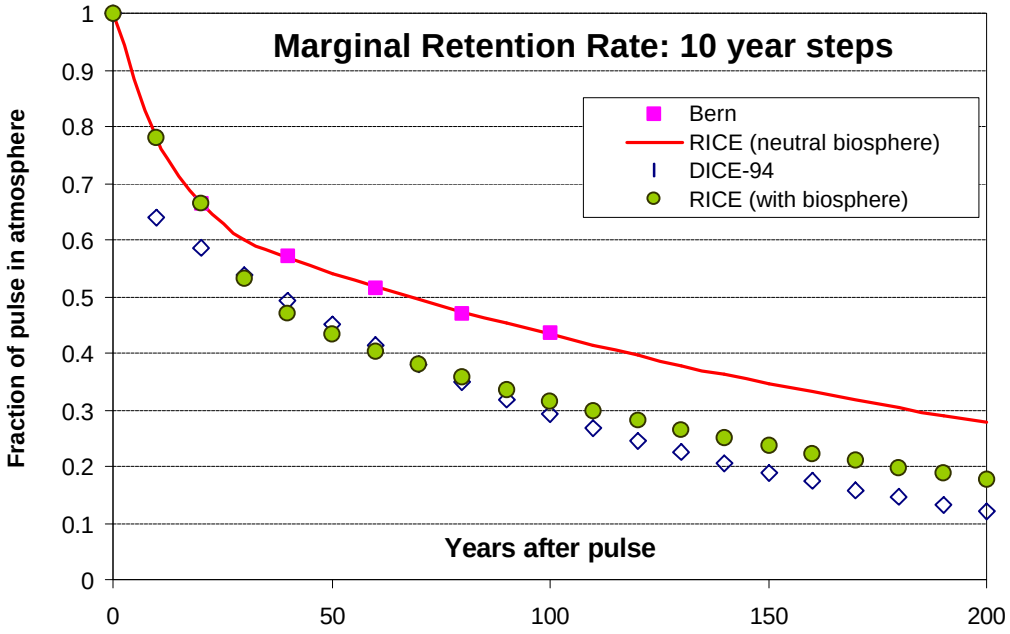
Source: *impact 101998a.wpd*

Figure 3-8



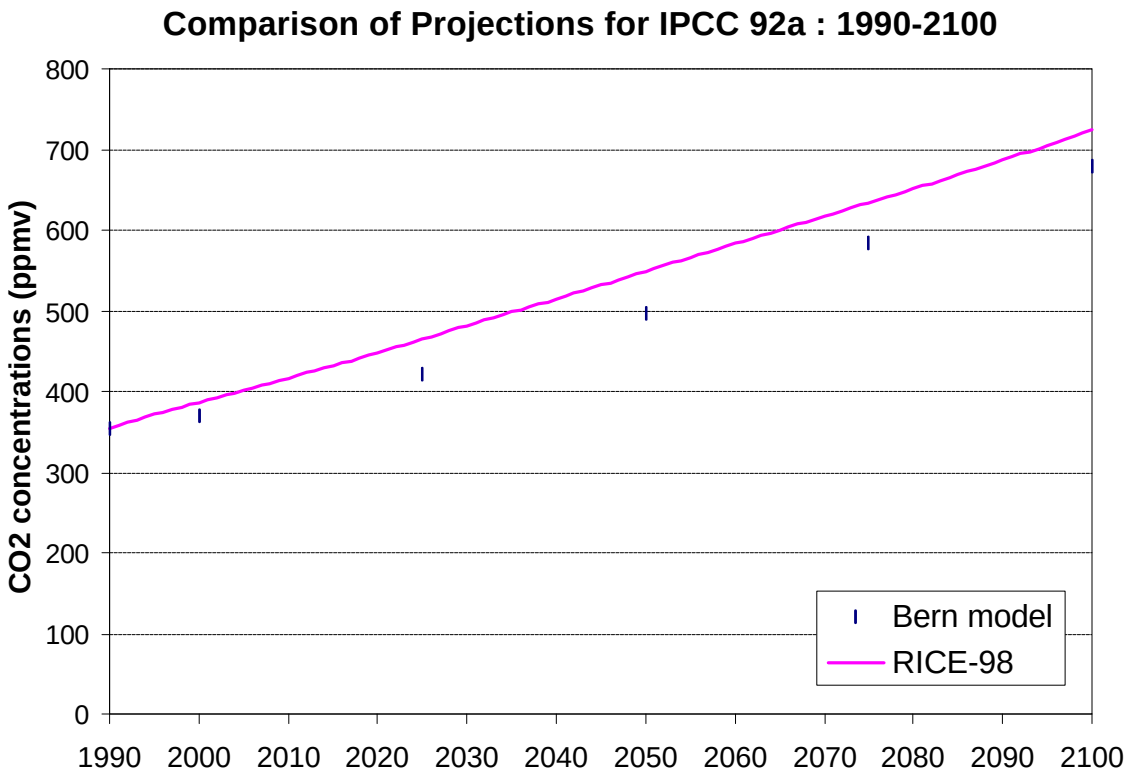
Source: *impact 101998a.wpd*

Figure 3-9
Impulse Response Functions for Different Models



Source: carbon calibrate 110398d.xls

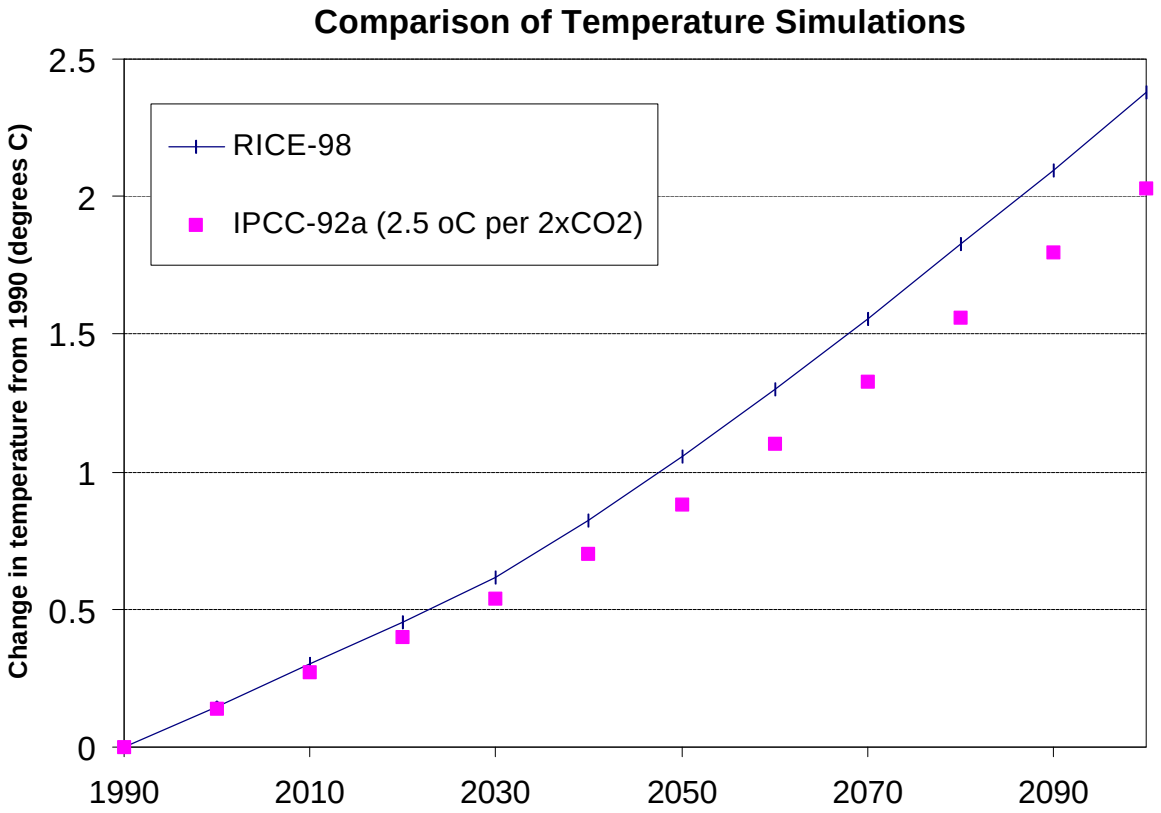
Figure 3-10



Note: Solid line is projection of CO2 concentrations using IPCC 92a emissions projection. Diamonds are projections using Bern model. Emissions and the Bern simulation are from IPCCI [1996c], p. 23.

Source: carbon calibrate ipcc a 111198.xls

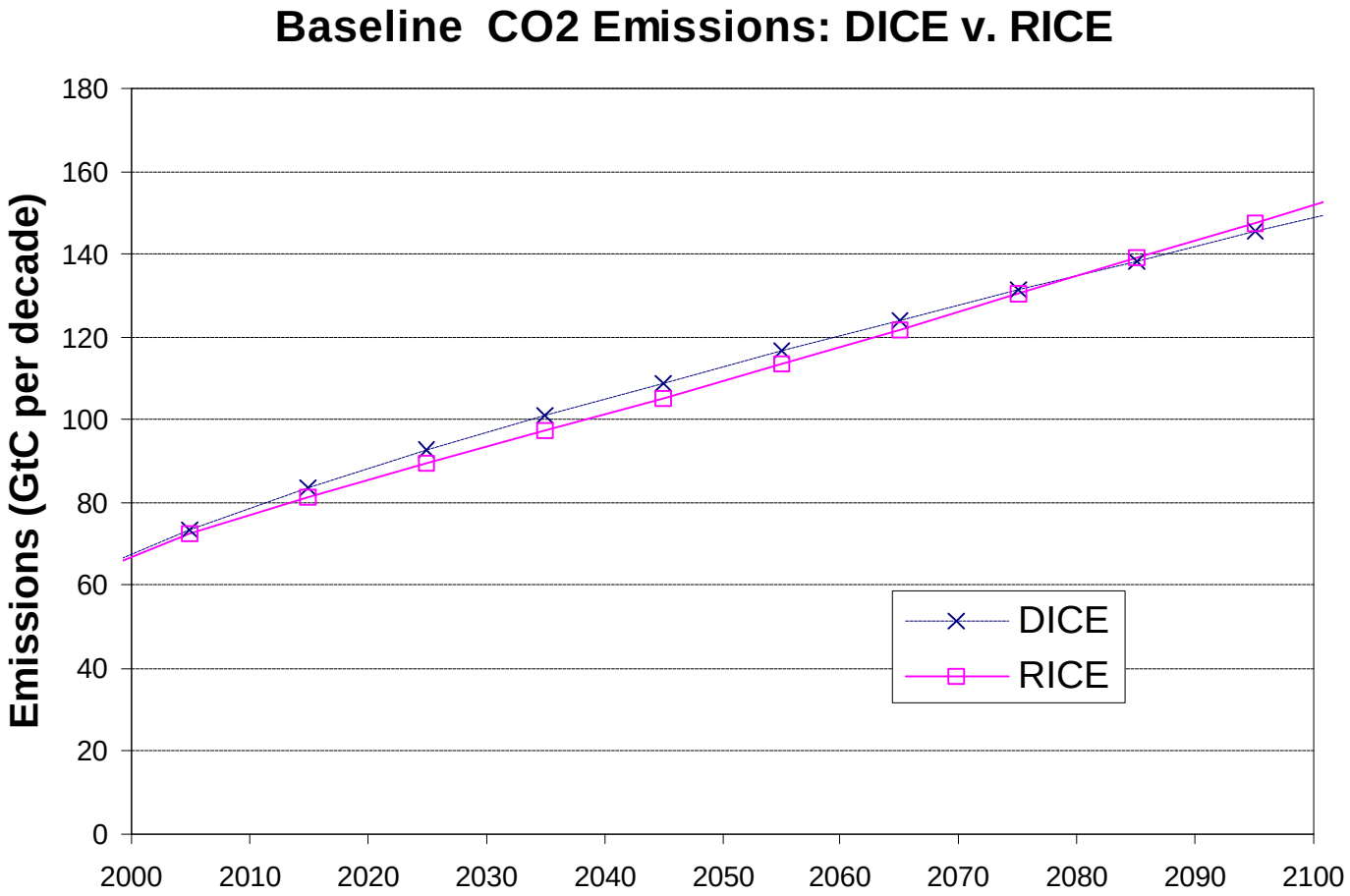
Figure 3-11



Note: Both calculations use the radiative forcings with aerosols and emissions according to IPCC 92a from IPCCI [1996c], pp. 321. The IPCC calculation has an equilibrium temperature increase of 2.5 ºC for an equilibrium CO2 doubling, whereas the RICE model has an equilibrium temperature increase of 2.9 ºC for an equilibrium CO2 doubling.

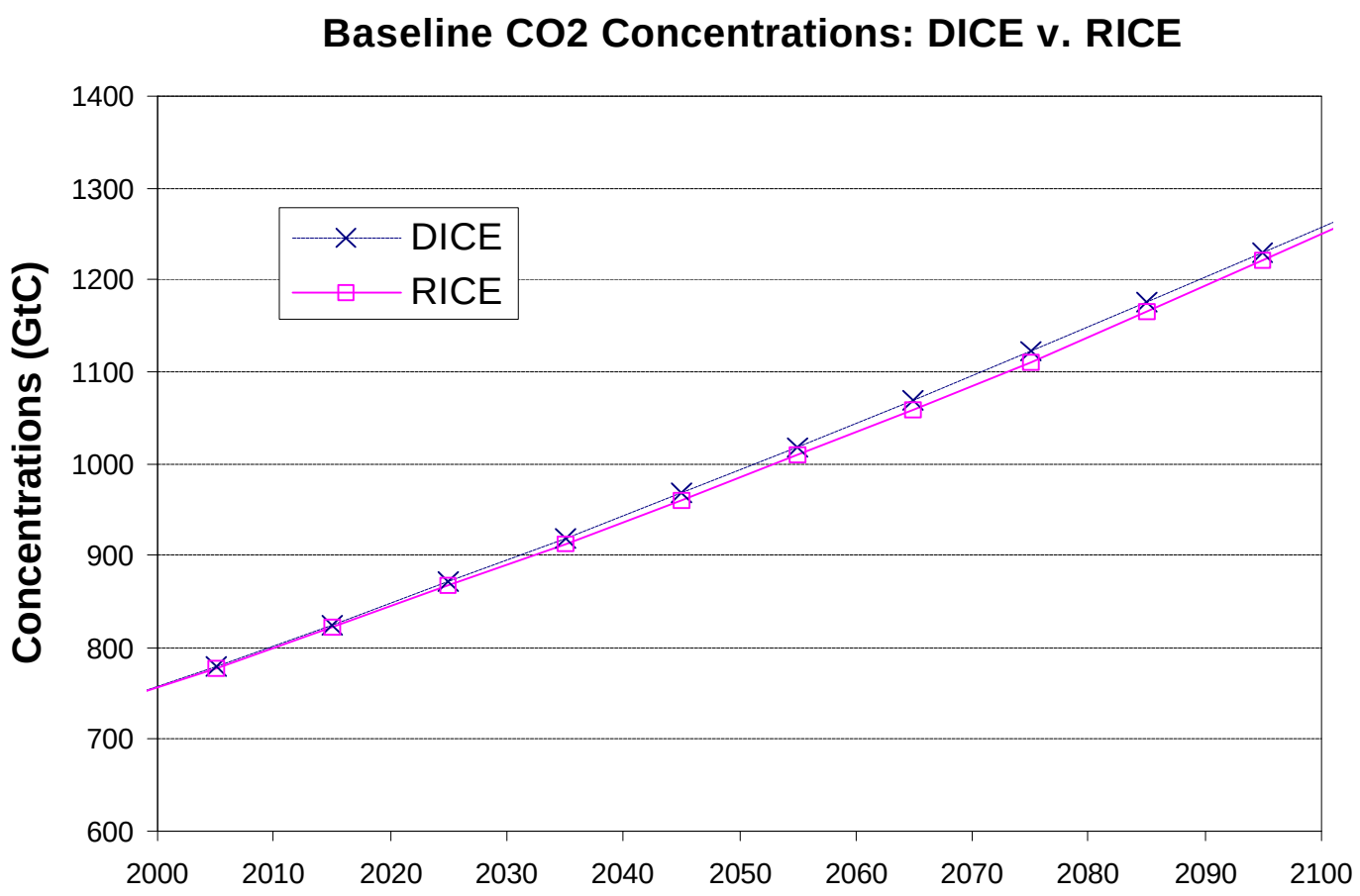
Source: bern-ipcc compare 111198.xls

Figure 4-1



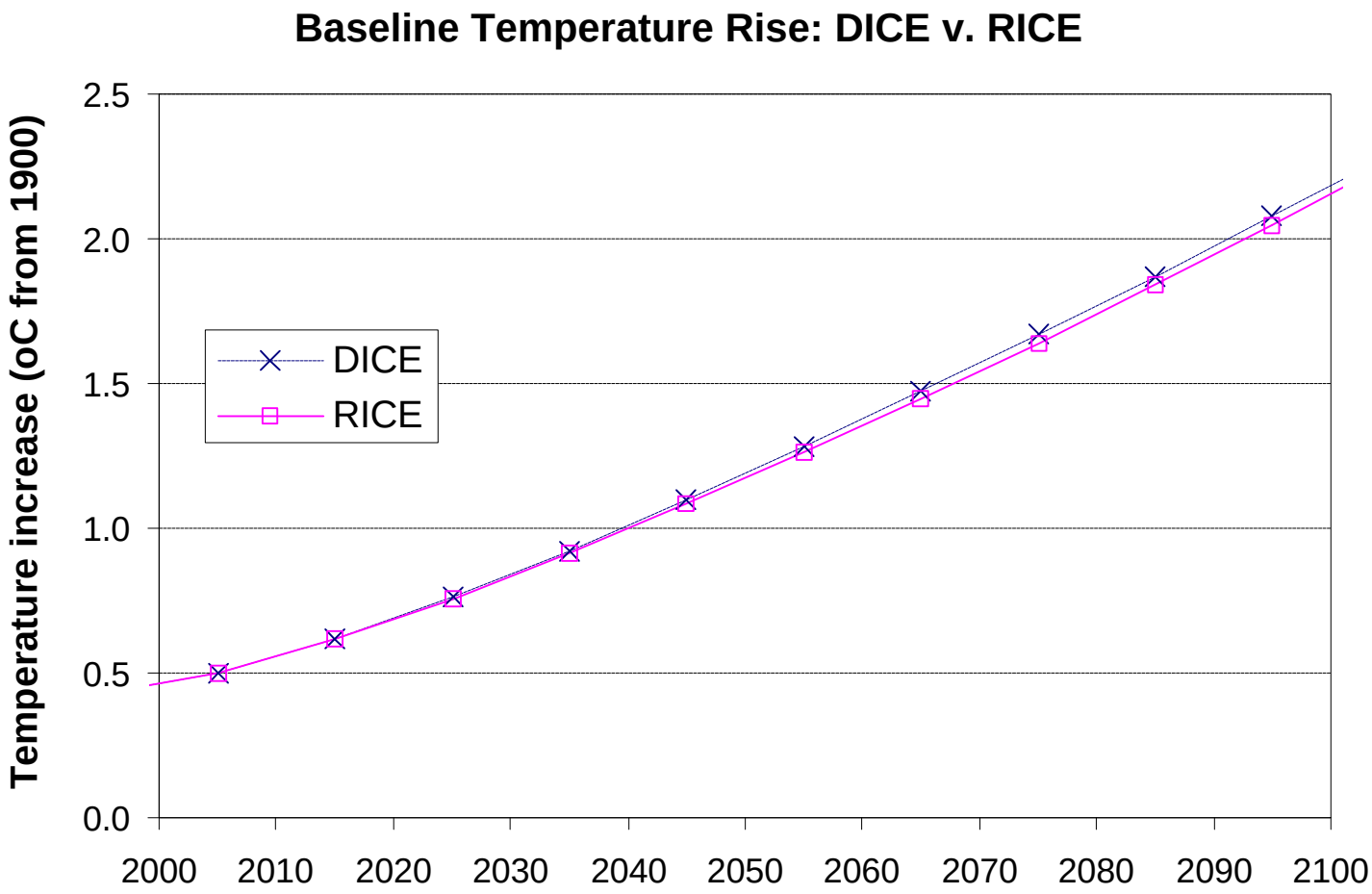
Source: compare dices 121898.xls

Figure 4-2



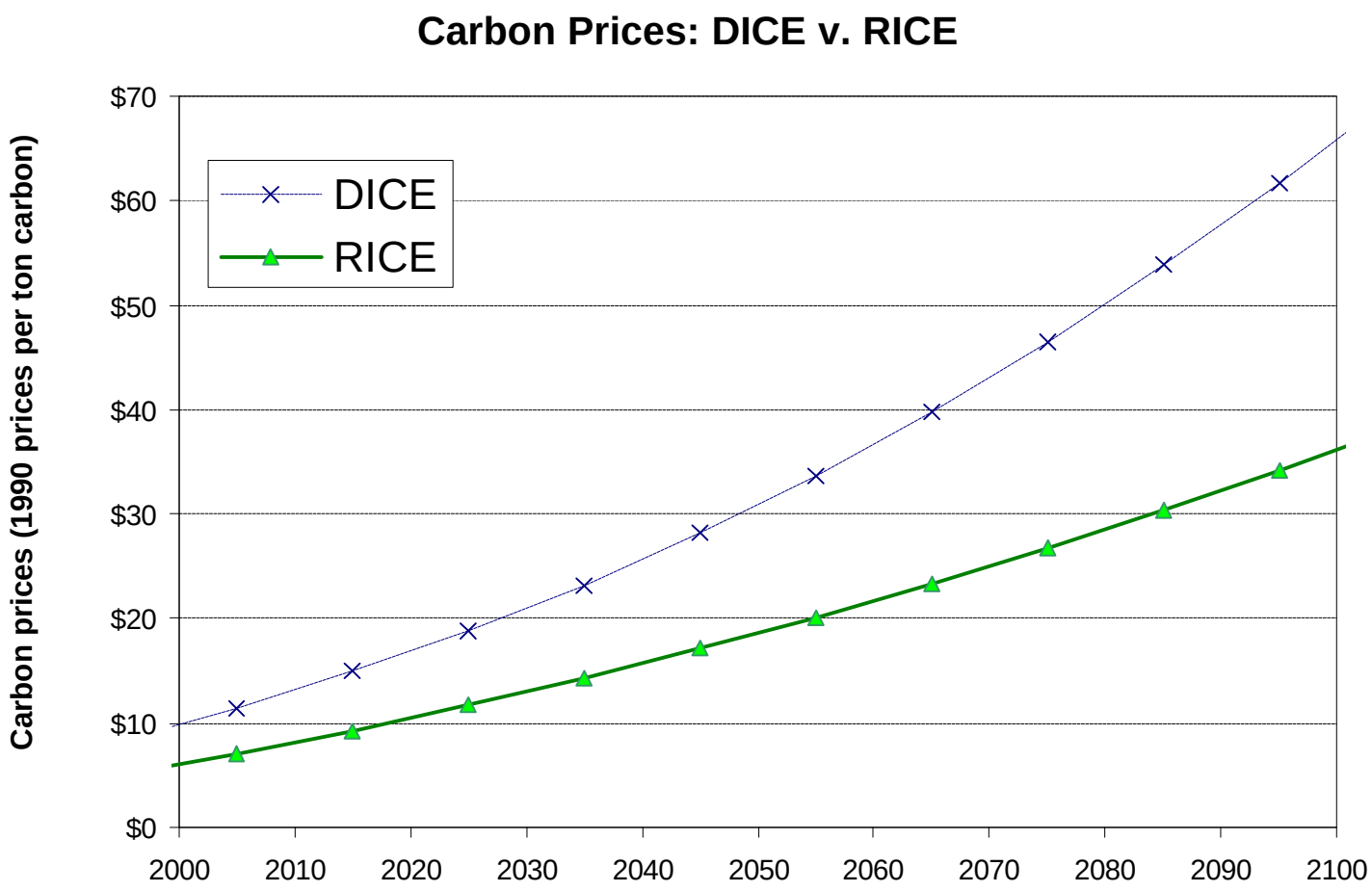
Source: compare dices 121898.xls

Figure 4-3



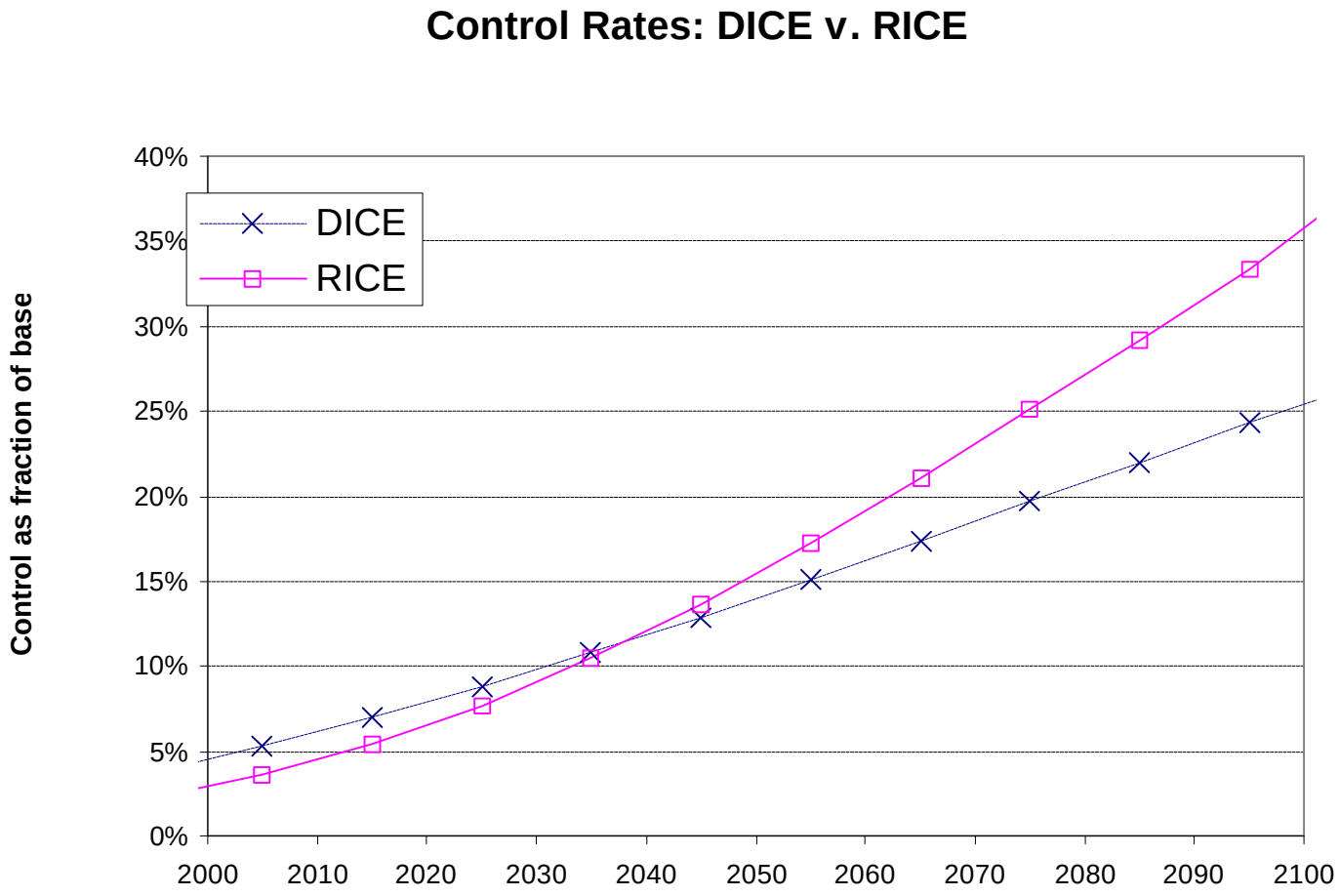
Source: compare dices 121898.xls

Figure 4-4



Source: compare dices 121898.xls

Figure 4-5



Source: compare dices 121898.xls

Appendix A

Table A-1. Equations of RICE-98

Market equilibrium

(1) $\max_{\{c_J(t)\}} \sum_J \phi^J W^J$

Utility function for region J

(2) $W^J = \sum_t U^J[c_J(t),L_J(t)]R(t) = \sum_t L_J(t)\{\log[c_J(t)]\}R(t)$

**Production function for region J*

(3) $Q_J(t) = \Omega_J(t)A_J(t)K_J(t)^{\gamma} L_J(t)^{1-\gamma-\beta_J(t)}EC_J(t)^{\beta_J(t)} - p^E_J(t)\, EC_J(t) - p^B(t)\, B_J(t)$

**Output plus income from permit sales equals investment and consumption plus energy costs:*

(4) $Q_J(t) + \tau(t)[EC_J(t) - \Pi_J(t)] = C_J(t) + I_J(t)$

Per capita consumption

(5) $c_J(t) = C_J(t)/L_J(t)$

Capital accumulation

(6) $K_J(t) = (1-\delta_K)K_J(t-1) + 10\, I_J(t-1)$

**Retail price of carbon-energy*

(7) $p^E_J(t) = q(t) + \text{markup}^E_J(t) + \tau(t)$

**Cumulative world extraction of carbon-energy*

(8) $CumC(t) = CumC(t-1) + 10EC(t)$

** Energy supply*

(9a) $q(t) = \xi_1 + \xi_2[CumC(t)/CumC^*]^{\xi_3}$

(9b) $E_J(t) = EC_J(t) + B_J(t)$

**Carbon cycle*

(10a) $M_{AT}(t) = 10 \times E^C(t) + \phi_{11} M_{AT}(t-1) - \phi_{12} M_{AT}(t-1) + \phi_{21} M_{UP}(t-1)$

(10b) $M_{UP}(t) = \phi_{22} M_{UP}(t-1) + \phi_{12} M_{AT}(t-1) - \phi_{21} M_{UP}(t-1) + \phi_{32} M_{LO}(t-1) - \phi_{23} M_{UP}(t-1)$

(10c) $M_{LO}(t) = \phi_{33} M_{LO}(t-1) - \phi_{32} M_{LO}(t-1) + \phi_{23} M_{UP}(t-1)$

Radiative forcings

(11) $F(t) = \eta\{\log[M_{AT}(t)/M_{AT}^*]/\log(2)\} + O(t)$

Climate equations

(12a) $T_{UP}(t) = T_{UP}(t-1) + \sigma_1\{F(t) - \lambda T_{UP}(t-1) - \sigma_2[T_{UP}(t-1) - T_{LO}(t-1)]\}$

(12b) $T_{LO}(t) = T_{LO}(t-1) + \sigma_3[T_{UP}(t-1) - T_{LO}(t-1)]$

**Damage equation*

(13) $D_J(t) = \theta_{1,J}\, T(t) + \theta_{2,J}\, T(t)^2$

Damage parameter

(14) $\Omega_J(t) = 1/[1+D_J(t)]$

(Note: Equations with asterisks (*) are for equations that are substantially revised since the original RICE model.

Table A-2. Equations of DICE-98

Objective function

(1) $\max_{\{c(t)\}} = \sum_t U[c(t),L(t)]\, R(t) = \sum_t L(t)\{\log[c(t)]\}R(t)$

Production function

(2) $Q(t) = \Omega(t)A(t)K(t)^{\gamma} L(t)^{1-\gamma}$

Output equals investment and consumption

(3) $Q(t) = C(t) + I(t)$

Per capita consumption

(4) $c(t) = C(t)/L(t)$

Capital accumulation

(5) $K(t) = (1-\delta_K)K(t-1) + 10\, I(t-1)$

Emissions

(6) $E^C(t) = [1-\mu(t)]\, \sigma(t)\, A(t)K(t)^{\gamma} L(t)^{1-\gamma}$

**Carbon cycle*

(7a) $M_{AT}(t) = 10 \times E^C(t) + \phi_{11} M_{AT}(t-1) - \phi_{12} M_{AT}(t-1) + \phi_{21} M_{UP}(t-1)$

(7b) $M_{UP}(t) = \phi_{22} M_{UP}(t-1) + \phi_{12} M_{AT}(t-1) - \phi_{21} M_{UP}(t-1) + \phi_{32} M_{LO}(t-1) - \phi_{23} M_{UP}(t-1)$

(7c) $M_{LO}(t) = \phi_{33} M_{LO}(t-1) - \phi_{32} M_{LO}(t-1) + \phi_{23} M_{UP}(t-1)$

Radiative forcings

(8) $F(t) = \eta\{\log[M_{AT}(t)/M_{AT}*]/\log(2)\} + O(t)$

Climate equations

(9a) $T_{UP}(t) = T_{UP}(t-1) + \sigma_1\{F(t) - \lambda T_{UP}(t-1) - \sigma_2[T_{UP}(t-1) - T_{LO}(t-1)]\}$

(9b) $T_{LO}(t) = T_{LO}(t-1) + \sigma_3[T_{UP}(t-1) - T_{LO}(t-1)]$

**Damage equation*

(10) $D(t) = \theta_1 T(t) + \theta_2 T(t)^2$

Damage parameter

(11) $\Omega(t) = [1- b_1 \mu(t)^2] / [1 + D(t)]$

Note: Equations with asterisks (*) are for equations that are substantially revised since the original DICE model.

Table A-3. Variable definitions in RICE-98 and DICE-98*

$A_J(t)$ = total factor productivity of region J
$B_J(t)$ = backstop energy supplied in region J
$C_J(t)$ = consumption of region J
$c_J(t)$ = per capita consumption of region J
CumC(t) = cumulative world extraction of carbon energy
CumC* = total recoverable world resources of carbon-energy
$D_J(t)$ = damage from climate change of region J as fraction of regional output
$E_J(t)$ = energy use in region J (equal to carbon energy plus backstop energy)
$E^C(t)$ = global carbon emissions = $EC_J(t)$ + land use emissions
$EC_J(t)$ = carbon-energy consumption = industrial CO_2 emissions of region J
$EC(t) = \Sigma\, EC_J(t)$ = total consumption of carbon-energy = CO_2 emissions
F(t) = total radiative forcings
$I_J(t)$ = gross investment of region J
$K_J(t)$ = capital stock of region J
$L_J(t)$ = population, proportional to employment of region J
$markup^E_J(t)$ = markup of carbon energy of region J (exclusive of carbon prices)
$M_{AT}(t)$ = mass of carbon in atmosphere
$M_{LO}(t)$ = mass of carbon in lower reservoir (lower ocean)
$M_{UP}(t)$ = mass of carbon in upper reservoir (atmosphere, biosphere, upper ocean)
$\mu(t)$ = emissions control rate
$\Omega_J(t)$ = damage factor of region J
O(t) = other radiative forcings
$p^B(t)$ = price of backstop substitute for carbon-energy
$p^E_J(t)$ = price of carbon-energy of region J
$\Pi_J(t)$ = allocation of carbon emissions permits of region J
ϕ^J = welfare weights of region J
q(t) = world wholesale price of carbon-energy (including Hotelling rent)
$Q_J(t)$ = gross output of region J
$\rho(t)$ = pure rate of social time preference for period t
R(t) = discount factor (derived from rate of time preference)
$\sigma(t)$ = carbon intensity (emissions per unit output)
t = periods (t=1 for 1990-99, t=2 for 2000-09, and so forth)
$\tau(t)$ = carbon tax
$T_{LO}(t)$ = global mean temperature of lower oceans
$T_{UP}(t)$ = global mean surface temperature
U^J = utility function per period of region J
W^J = social welfare function of region J

* Note that most variables are identical for the DICE model except that the regional identifiers are unnecessary.