Reduced deforestation and the carbon market: the role of market regulations and future commitments*

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APPENDIX

* **Acknowledgements:** The authors would like to thank Rachel Holden for scientific support. Funding by the New Zealand Ministry of Agriculture and Forestry is gratefully acknowledged.

Appendix A. Tables summarizing simulation results

Table A1. *Emission reductions by region and scenario (% of BaU emissions)*

Scenario / *Region*	IET	CDM	REDD	REDD_ SUP	REDD_ DEM	REDD_ MAC	REDD_ MAC+	REDD EXP	REDD_ SUP EXP	REDD_ DEM EXP	REDD_ MAC EXP	REDD_ MAC+ EXP
EU-27	15.2	7.2	4	5.8	5.8	3.2	4.9	5.2	6.3	7	4.2	6.1
Canada	20.4	10.6	6.3	8.8	8.7	5	7.5	7.9	9.4	10.3	6.4	9.1
Japan	8.8	4.5	2.7	3.8	3.7	2.2	3.2	3.4	4	4.4	2.8	3.9
Form. Sov. Un.	22.1	12.8	8.6	11	11	7.2	9.8	10.2	11.7	12.5	8.7	11.4
Pacific OECD	27.9	9.5	4.3	6.9	6.9	3.2	5.5	5.9	7.8	9	4.5	7.4
United States	23.9	11.9	6.6	9.6	9.5	5.1	8	8.5	10.4	11.4	6.8	10
Brazil	0	0.5	0.3	0.4	0.4	0.2	0.3	0.4	0.5	0.5	0.3	0.4
China	0	20.6	10.7	16.3	16.2	8	13.4	14.3	17.9	19.8	11.1	17.2
South Korea	0	5.7	3	4.5	4.5	2.3	3.7	4	5	5.5	3.1	4.8
Mexico	0	6.4	4.3	5.5	5.5	3.7	4.9	5.1	5.9	6.3	4.4	5.7
India	0	6.1	3	4.6	4.6	2.2	3.7	4	5.2	5.8	3.1	4.9
Africa	0	0	77.9	19.3	34.3	90.6	60.2	85.3	19.3	34.3	98.2	69.5
South-East Asia	0	0	10.7	15.8	4.9	17	6.4	13.9	17.3	4.9	22.6	8.1
Central America	0	0	22.5	19.3	10.3	35.9	13.5	29.4	19.3	10.3	47.6	17.1
South America	0	0	20.4	19.3	9.3	32.4	12.2	26.6	19.3	9.3	43.1	15.5

Table A2. *Total compliance costs by region and scenario (million €2005)*

Region \ *Scenario*	IET	CDM	REDD	REDD_ SUP	REDD_ DEM	REDD_ MAC	REDD_ MAC+	REDD EXP	REDD_ SUP EXP	REDD_ DEM EXP	REDD_ MAC EXP	REDD_ MAC+ EXP
EU-27	34708.6	17874.3	10415.2	14667.4	12380.5	8300.4	12476.4	16522.1	17183.1	17624.3	13371.9	19283.7
Canada	2630.4	1659.1	1027.2	1398.8	1157.7	831.8	1211	1627.1	1638.3	1648.6	1336.5	1874.1
Japan	624.6	724.9	495.6	640.6	512.2	410.7	570.3	784.5	750.1	730.3	658.4	885.5
Form. Sov. Un.	-14198	-3308.6	-1173.6	-2248.4	-2228.6	-768.3	-1650	-1829	-2613.7	-3097	-1235.6	-2442.9
Pacific OECD	2067.1	1499.6	898.1	1250.5	1052.5	717.9	1071.1	1419.1	1460.2	1484.7	1153.9	1646.4
United States	28428.5	19195.1	11977.6	16264	13479.4	9697.1	14108.4	18911.7	19010	19093.3	15551.6	21743.4
Annex I regions	**54261.2**	**37644.4**	**23640.1**	**31972.9**	**26353.7**	**19189.6**	**27787.2**	**37435.5**	**37428**	**37484.2**	**30836.7**	**42990.2**
Brazil	0	-40.1	-11.7	-25.3	-25.1	-7.1	-17.6	-19.8	-30.2	-37	-12.4	-27.9
China	0	-11353	-3231.1	-7116.9	-7040.3	-1939.4	-4885.4	-5537.4	-8542.8	-10485.1	-3439.1	-7871.2
South Korea	0	-412.4	-119.9	-259.8	-257	-72.8	-179.6	-203	-311	-381	-127.4	-286.9
Mexico	0	-495.2	-184.9	-342.3	-339.4	-124.1	-255.1	-281.3	-395.2	-464.7	-194.1	-370.5
India	0	-1496.8	-416	-921.4	-911.2	-250.5	-629.2	-713.9	-1111.7	-1376.4	-442.7	-1021.7
CDM regions	**0**	**-13797.5**	**-3963.6**	**-8665.7**	**-8573**	**-2393.9**	**-5966.9**	**-6755.4**	**-10390.9**	**-12744.2**	**-4215.7**	**-9578.2**
Africa	0	0	-5136.8	-2917	-718.7	-2505.2	-6124.7	-8118.1	-3233.1	-718.7	-4611	-9436.2
South-East Asia	0	0	-180.4	-389.8	-38.9	-13.8	-193.9	-304.7	-466.8	-38.9	-23.9	-309.1
Central America	0	0	-162.7	-276.9	-35.1	-24.9	-171.3	-274.8	-312.3	-35.1	-43.2	-273
South America	0	0	-1323.8	-2394.6	-285.5	-202.9	-1393.7	-2235.5	-2713.1	-285.5	-351.8	-2221
Rainforest regions	**0**	**0**	**-6803.7**	**-5978.3**	**-1078.2**	**-2746.8**	**-7883.6**	**-10933.1**	**-6725.3**	**-1078.2**	**-5029.9**	**-12239.3**

Table A3. *Carbon prices by credit type and scenario (€2005 per ton of CO_2)*

Scenario / *Type*	IET	CDM	REDD	REDD_ SUP	REDD_ DEM	REDD_ MAC	REDD_ MAC+	REDD EXP	REDD_ SUP EXP	REDD_ DEM EXP	REDD_ MAC EXP	REDD_ MAC+ EXP
International permit price	37.9	15.7	8.6	12.5	12.5	6.7	10.4	11.1	13.7	15.1	8.8	13.2
CDM price	0	15.7	8.6	12.5	12.5	6.7	10.4	11.1	13.7	15.1	8.8	13.2
REDD price	0	0	8.6	12.5	4	6.7	10.4	11.1	13.7	4	8.8	13.2

Table A4. *Market volumes of CDM and REDD credits (Mt CO_2)*

Scenario / *Market*	IET	CDM	REDD	REDD_ SUP	REDD_ DEM	REDD_ MAC	REDD_ MAC+	REDD EXP	REDD_ SUP EXP	REDD_ DEM EXP	REDD_ MAC EXP	REDD_ MAC+ EXP
CDM market volume	0	1618.3	839.8	1277.9	1271	635.1	1048.7	1121.1	1403.4	1555.6	868.8	1346.2
REDD market volume	0	0	1462.9	636.3	650.1	1857.4	1066.3	1678.7	642.4	650.1	2155.4	1257

Table A5. *Net CDM credit exports (exports less imports, Mt CO_2)*

Scenario / *Region*	IET	CDM	REDD	REDD_ SUP	REDD_ DEM	REDD_ MAC	REDD_ MAC+	REDD EXP	REDD_ SUP EXP	REDD_ DEM EXP	REDD_ MAC EXP	REDD_ MAC+ EXP
Brazil	0	4.5	2.3	3.6	3.6	1.8	2.9	3	3.9	4.3	2.4	3.7
China	0	1338.3	693	1059.3	1053.4	521.4	868.4	928.5	1163	1287.7	717.3	1115.6
South Korea	0	48.9	25.5	38.5	38.3	19.5	31.7	33.8	42.3	46.9	26.4	40.6
Mexico	0	47	31.8	40.7	40.5	26.9	36.2	37.7	43.1	45.9	32.3	42
India	0	179.1	87.2	136.1	135.2	65.8	109.8	117.9	151.2	170.8	90.3	144.2
Annex I regions	**0**	**-1618.3**	**-839.8**	**-1277.9**	**-1271**	**-635.1**	**-1048.7**	**-1121.1**	**-1403.4**	**-1555.6**	**-868.8**	**-1346.2**

Table A6. *Net REDD credit exports (exports less imports, Mt CO_2)*

Scenario / *Region*	IET	CDM	REDD	REDD_ SUP	REDD_ DEM	REDD_ MAC	REDD_ MAC+	REDD EXP	REDD_ SUP EXP	REDD_ DEM EXP	REDD_ MAC EXP	REDD_ MAC+ EXP
Africa	0	0	1097.5	271.9	482.6	1275.9	847	1201.5	271.9	482.6	1382.8	979.1
South-East Asia	0	0	40.7	60.3	18.6	64.8	24.4	53.2	66.1	18.6	86	30.9
Central America	0	0	35.5	30.4	16.3	56.6	21.3	46.4	30.4	16.3	75.1	27
South America	0	0	289	274	132.5	460.3	173.6	377.6	274	132.5	611.1	219.9
Annex I regions	**0**	**0**	**-1462.9**	**-636.3**	**-650.1**	**-1857.4**	**-1066.3**	**-1678.7**	**-642.4**	**-650.1**	**-2155.4**	**-1257**

Table A7. *Core and expanded Annex I emission reduction commitments at constant compliance costs by region and scenario (commitments in % vs. BAU emissions in 2020)*

Scenario / *Region*	CDM	REDD EXP	REDD_ SUP EXP	REDD_ DEM EXP	REDD_ MAC EXP	REDD_ MAC+ EXP
EU-27	27.2	33.5	29.2	31.7	36.4	31.4
Canada	23.2	28.5	24.9	27.0	31.0	26.7
Japan	6.4	7.9	6.9	7.5	8.6	7.4
Former Sov. Un.	0.0	0.0	0.0	0.0	0.0	0.0
Pacific OECD	25.5	31.4	27.4	29.7	34.2	29.5
United States	24.8	30.5	26.6	28.8	33.2	28.6
Annex I regions	**19.9**	**24.5**	**21.4**	**23.2**	**26.7**	**23.0**
Relative expansion of commitment	0%	23%	7%	16%	34%	15%

Appendix B: Figures

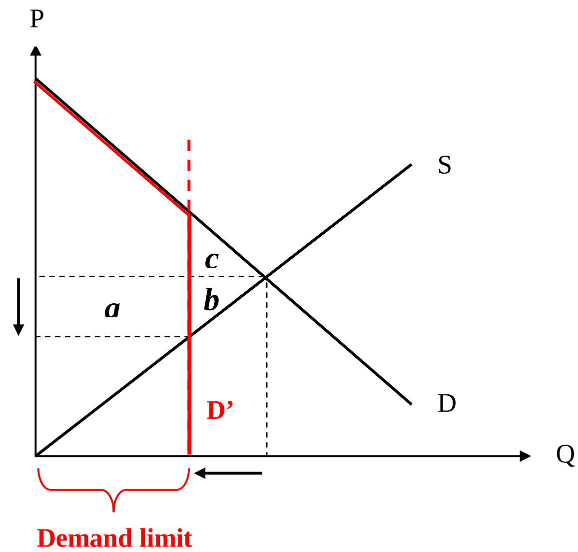

Figure A1. *Implications of restricting REDD credit demand (scenario REDD_DEM)*

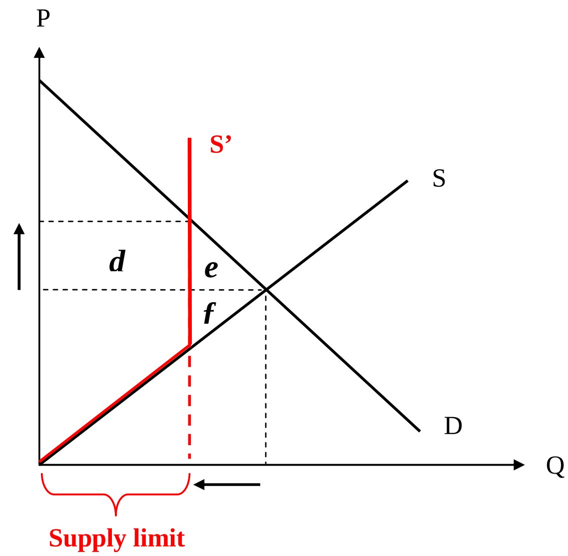

Figure A2. *Implications of restricting REDD credit supply (scenario REDD_SUP)*

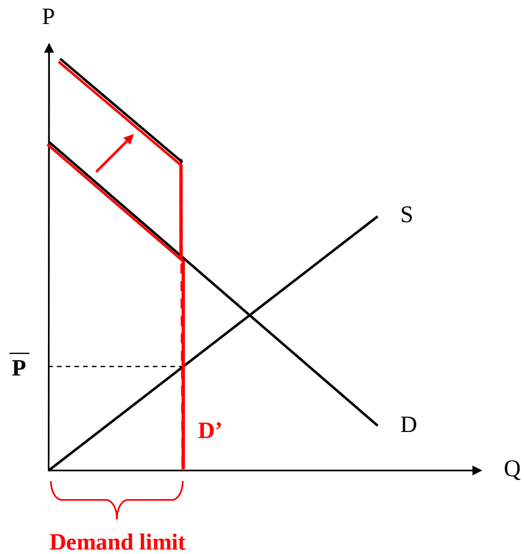

Figure A3. *Implications of expanding Annex I commitments in the context of restricted REDD credit demand (scenario REDD_DEM_EXP)*

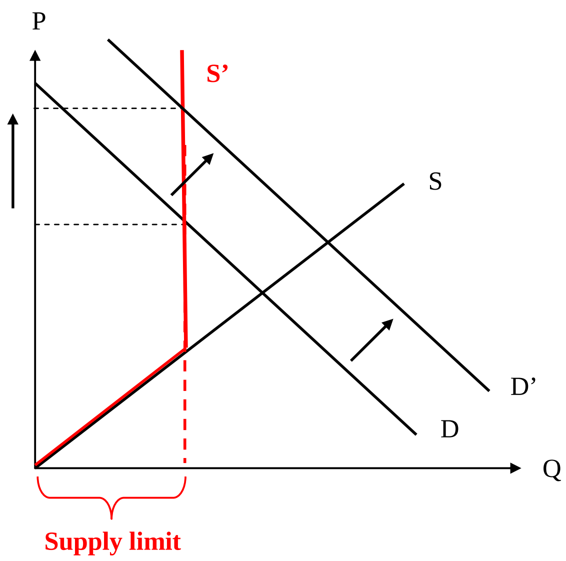

Figure A4. *Implications of expanding Annex I commitments in the context of restricted REDD credit supply (scenario REDD_SUP_EXP)*

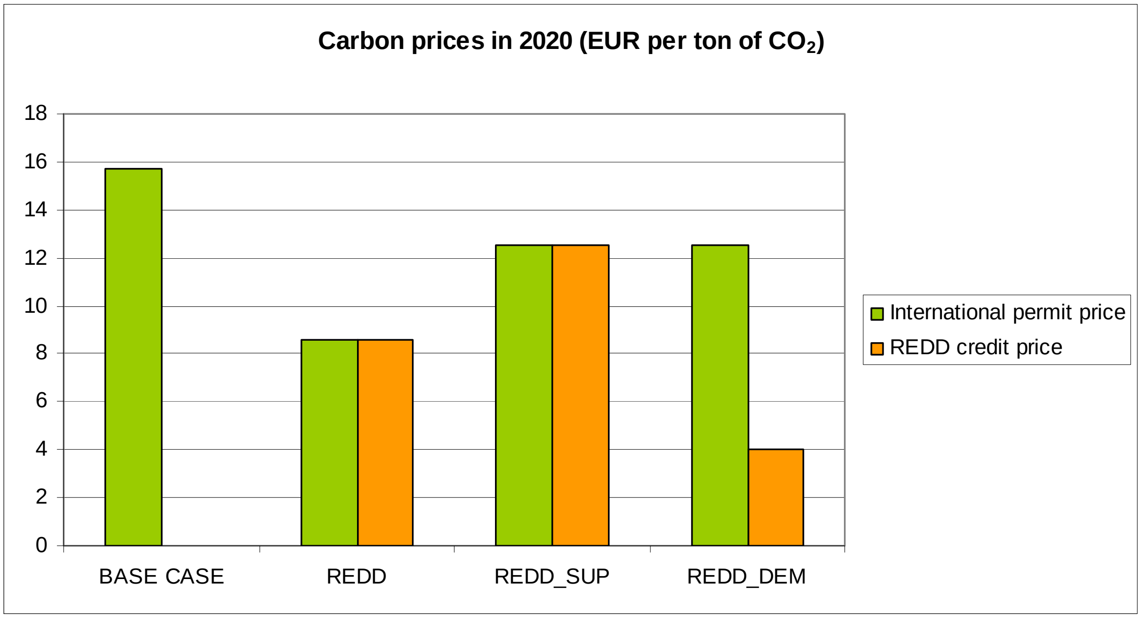

Figure A5. *Prices for international carbon permits and REDD credits by scenario*

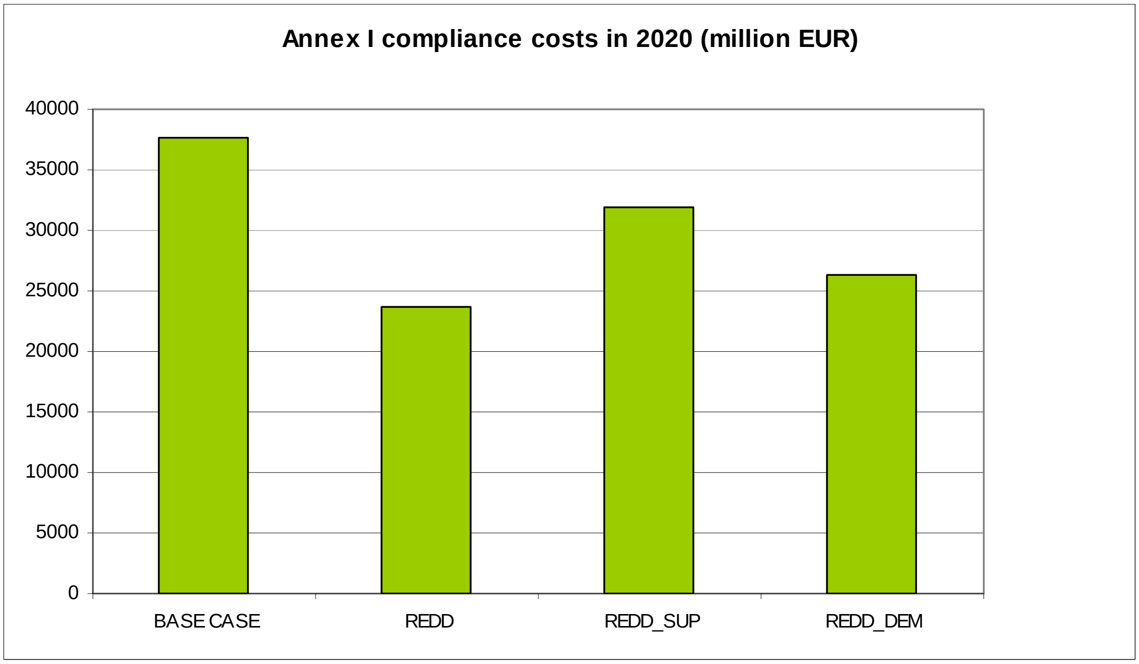

Figure A6. *Aggregate compliance costs for the Annex I region by scenario*

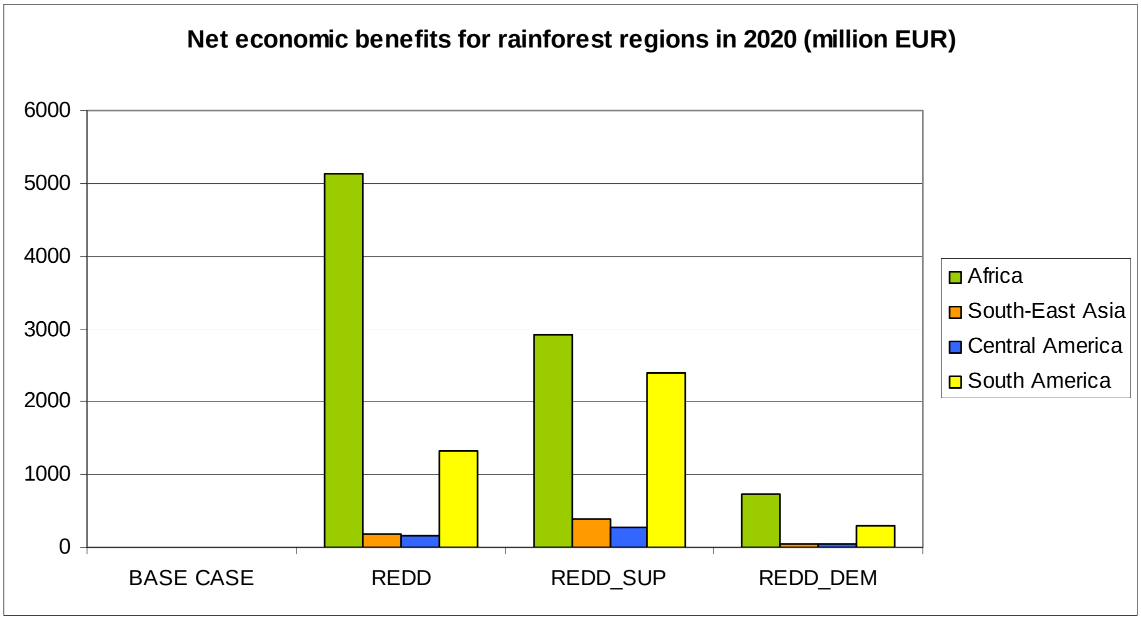

Figure A7. *Net economic benefits (revenues less costs) by rainforest region and scenario*

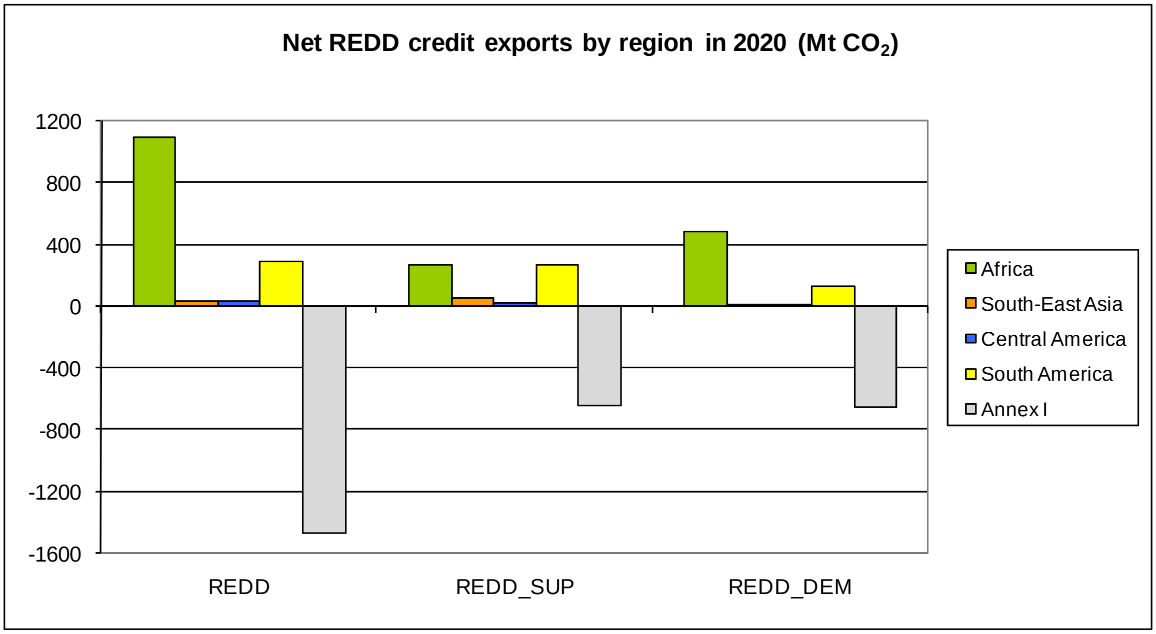

Figure A8. *Net exports (exports less imports) of REDD credits by region and scenario*

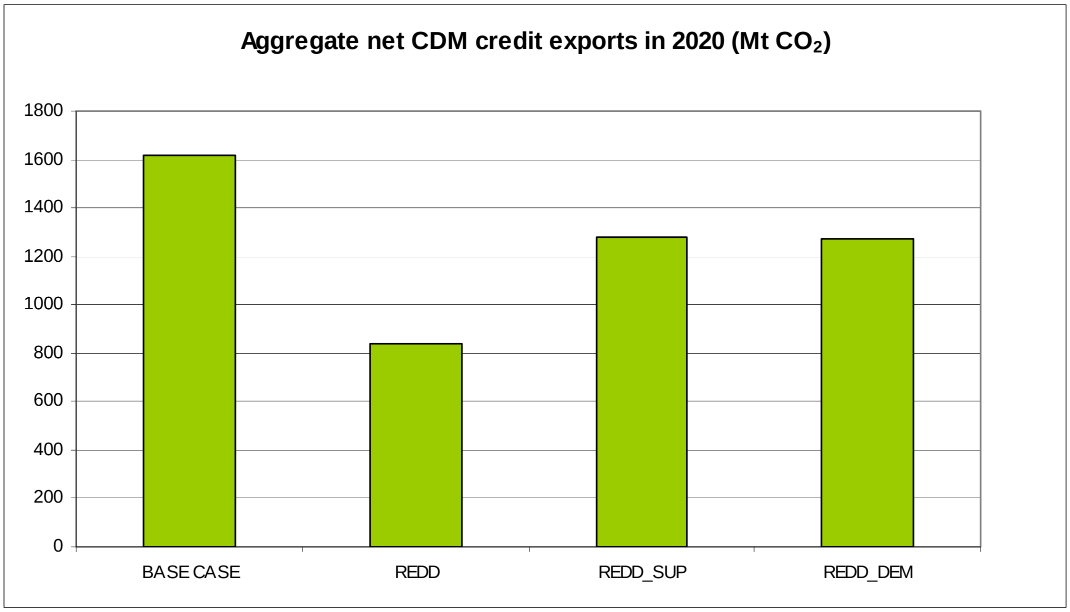

Figure A9. *Net credit exports (exports less imports) of CDM host regions by scenario*

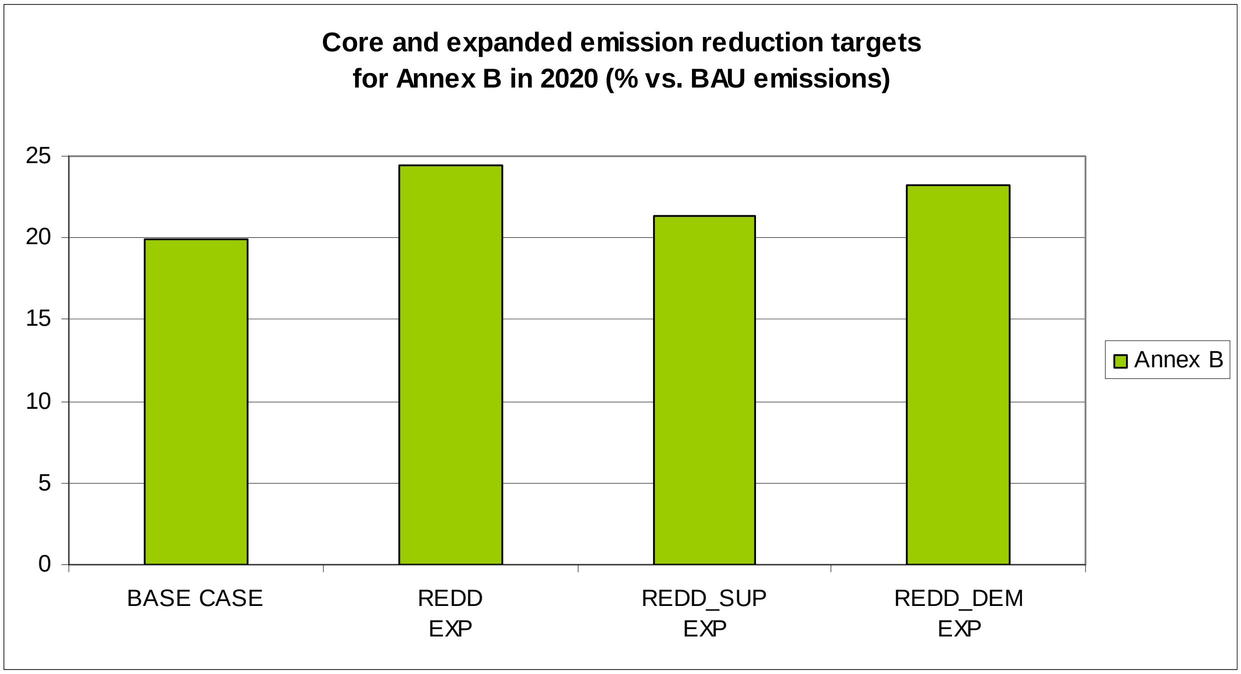

Figure A10. *Core and expanded commitment levels at constant compliance costs by scenario*

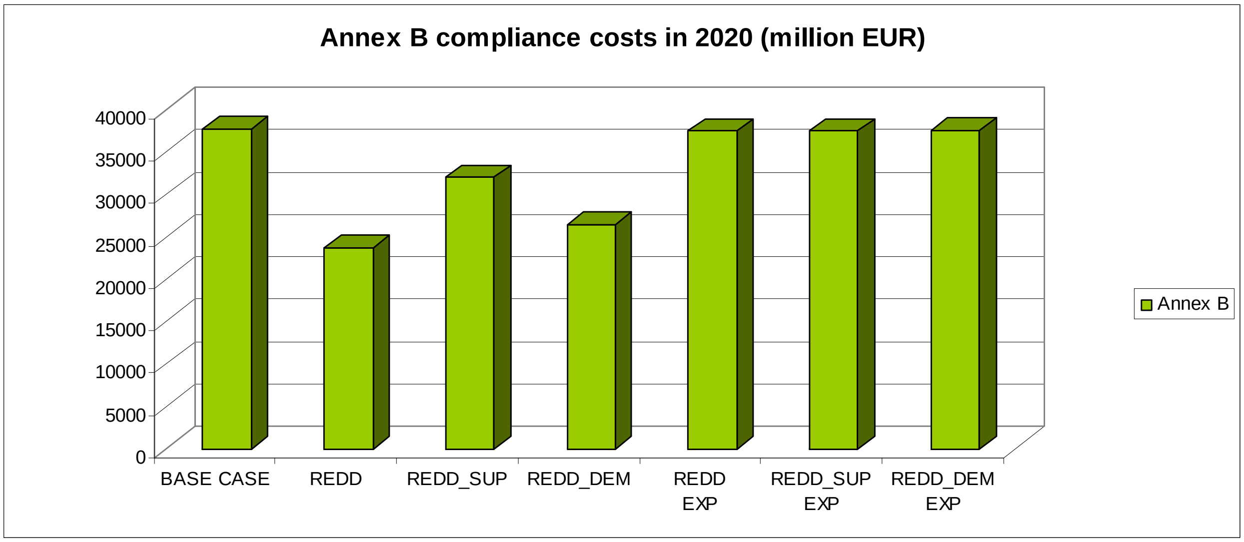

Figure A11. *Aggregate compliance costs for the Annex I region by scenario*

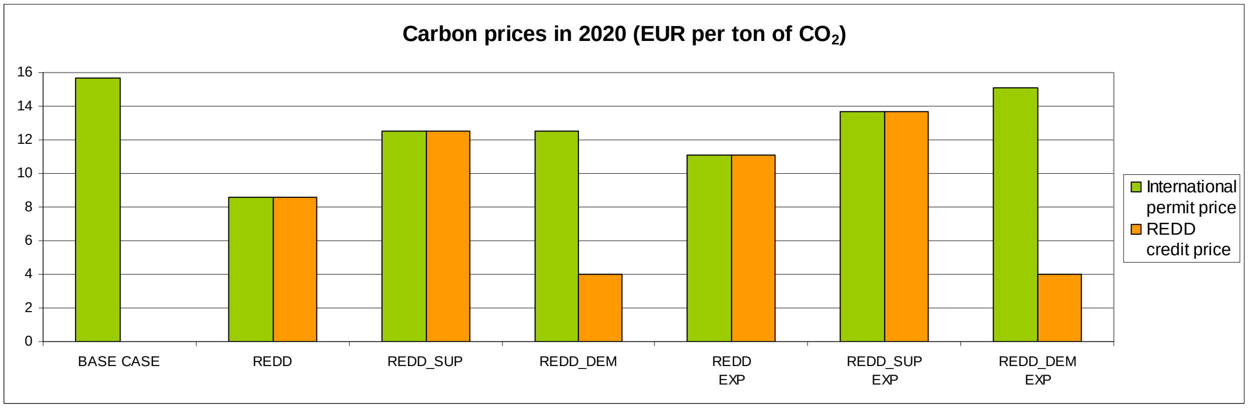

Figure A12. *Prices for international carbon permits and REDD credits by scenario*

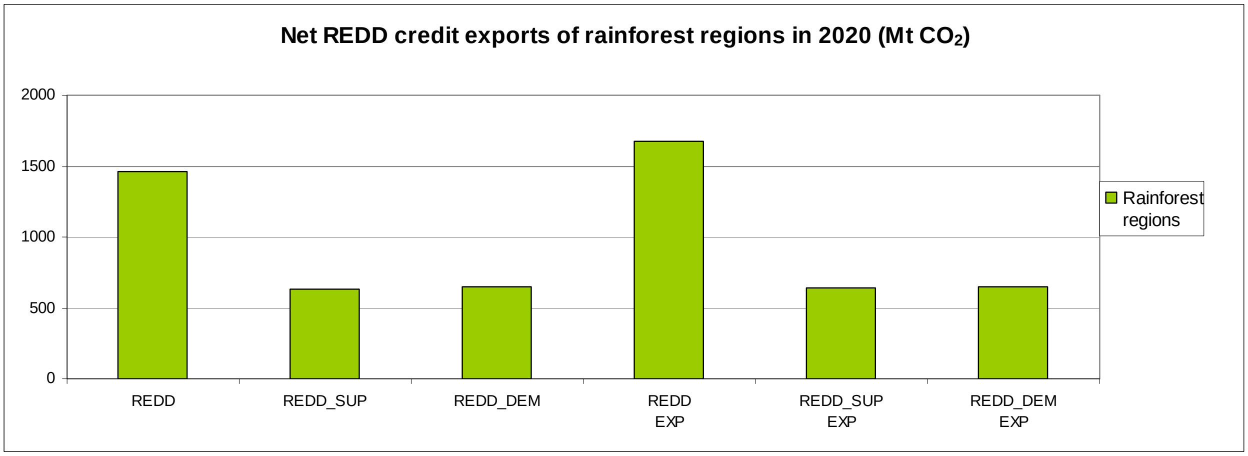

Figure A13. *Net exports (exports less imports) of REDD credits of rainforest regions by scenario*

Appendix C: Detailed model descriptions

Modeling the forestry sector

The Generalized Comprehensive Mitigation Assessment Process (GCOMAP) (Sathaye *et al*., 2005, 2006) is a dynamic partial equilibrium model that analyzes the carbon and social welfare benefits of forestation globally in 10 regions, and of reducing deforestation in four tropical rainforest regions, incorporating bottom-up forestry project data for the tropics. It establishes a reference case level of land use, absent carbon prices, for 2000 to 2100 before simulating the response of forest land users (i.e. farmers) to changes in prices in forest land and products, and prices emerging in carbon markets. The model's objective is to estimate the land area that land users would plant above the reference case level, or prevent from being deforested, in response to carbon prices. As a result, GCOMAP estimates the net changes in carbon stocks while meeting the annual demand for timber and non-timber products. It models the reduction of deforestation in four tropical rainforest regions: Africa, South-East Asia, Central America and South America. For the data on the key deforestation parameters noted in the introduction above, GCOMAP used the following sources of information.

- Carbon density was derived from the biomass and carbon density values published in the FAO 2005 Global Assessment of Forests.
- The baseline was estimated on the basis of FAO historical deforestation rates for each region. These baseline values are described in Sathaye *et al*. (2006).
- The opportunity cost of deforested land consists of two components, net present value (NPV) of timber harvested prior to deforestation, and net present value of the revenue stream from agricultural crops or cattle ranching over a period of 10 years.

As regards the implementation of carbon stock changes from forest degradation, in its reference case scenarios of land use change the GCOMAP model uses historical data on land use change patterns and the estimated availability of lands for tree planting by region. This data input includes both degraded and deforested lands from FAO sources (see Sathaye *et al.*, 2005). For alternative approaches to estimate carbon stock changes from forest degradation see Ebeling and Yasué (2008).

Modeling the carbon market

In order to assess the emissions market effects of alternative climate policy scenarios, we employ a numerical multi-country, two-sector partial equilibrium model of the global carbon market in 2020. For each region, this top-down model incorporates calibrated marginal abatement cost functions for energy-intensive and non-energy-intensive sectors. The objective of the model is to minimize compliance costs of achieving targeted carbon emissions reductions by means of international emissions trading. An algebraic model summary is given in Anger (2008).

The model corresponds to a nonlinear program that seeks cost-minimizing emissions abatement among sectors and regions subject to initial emissions allocation. The nonlinear optimization problem can be interpreted as a market equilibrium problem where prices and quantities are defined using duality theory. Two classes of conditions characterize the (competitive) equilibrium for the model: zero profit conditions and market clearance conditions. The former class determines activity levels (quantities) and the latter determines prices. The economic equilibrium features complementarity between equilibrium variables and equilibrium conditions: activities will be operated as long as they break even, positive market prices imply market clearance – otherwise commodities are in excess supply and the respective prices fall to zero.

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