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Massachusetts Institute of Technology
15.023-12.848-ESD.128 Climate Change: Economics, Science and Policy
Problem Set #4

GLOBAL POLICY ANALYSIS USING THE TOY IGSM

Due: Monday, 28 April 2008

BACKGROUND

This homework is divided into two sections: Problem 1 investigates the economic impacts of near term policies: Lieberman-Warner in the US, and the European Trading System (which encompasses the EU and EET in the EPPA definitions). Problem 2 is an uncertainty analysis of the climate impacts of the business-as-usual case.

PROBLEM 1 – THE ETS AND LIEBERMAN-WARNER

Part A: Independent EU and US Systems. Estimated targets for the Lieberman-Warner bill draw on “Assessment of US Cap and Trade Proposals” (Paltsev *et al.*, 2008, from the course reading, and Appendix D of Joint Program Report #146), and approximation of EU ETS uses information from “An Analysis of the European Trading Scheme” (Reilly and Paltsev, 2005, Joint Program Report #127). Use the following guidance in setting up the analysis.

Basic Model Procedures: Before implementing constraints in the model, use the **Clear Display** button on the **GHG_Constraints** sheet to ensure that all regions outside the US and the EU have no constraints. Also, for the purposes of this problem select the **2020** radio button on the EPPA 4.0 worksheet. This will make the model stop in 2020, keeping runtime to about 3 minutes for simulation runs. To save runs and compare data, you can manually cut and paste the **Ref_Results** and/or the **EPPA_Results** worksheets. Also, saving the entire workbook using “Save As...” (Excel’s File Menu) might be useful for you. If you want to save graphs, you can manually copy and paste the graphs into another worksheet before running the model again. If you do this, don’t forget to de-link the graphs (use “paste special”), or they will update when the Toy is run again.

Approximating the Lieberman-Warner Bill: Assume that emissions are to be held to 2005 levels in 2010, and returned to 1990 levels by 2020. (Note: the bill regulates emissions through 2050, but we only examine the bill through 2020 for this assignment.) These provisions can be approximated by returning to 2005 levels in 2010, 1997 levels in 2015, and 1990 levels in 2020. While the bill is designed to cover all gases, the first part of the exercise will only address CO₂. Therefore, we can set the constraints on CO₂ as follows:

Year	2010	2015	2020
US Target (MMT C eq)	1680	1480	1350

Fill these values in on the **GHG_Constraints** worksheet (after pressing the Clear button), and make sure that the CO₂ radio button is active in the upper left hand corner.

In addition to not addressing non-CO₂ GHGs, the approximation also ignores any restriction on covered versus non-covered sources. Nor does it allow for banking between time periods.

Approximating the ETS: The initial ETS target is about 1104 MMT carbon-equivalent. This policy covers both the EU and EET. In this first period (2010), the allocation to EU nations is about 896 MMT and the allocation to EET nations is 208 MMT. The EU has adopted a 2020 target that is 20% below 1990 levels, which can be approximated by the following constraints:

Year	EU Target (MMT Ceq)	EET Target (MMT Ceq)
2010	896	208
2015	836	208
2020	776	208

Fill these values in on the **GHG_Constraints** worksheet. The EU and the EET form one trading system, therefore activate trading in both regions for all time periods (2010, 2015, 2020).

(Note on policy reality: The ETS covers only CO₂ in 2010, but will be extended to other GHGs in later time periods. It actually covers a rather limited number of sectors – about 54% of the total CO₂ emissions. The Toy Model does not allow partial sectoral coverage.)

Running the Model: With EU and the EET trading enabled (but not the US!), you can run the model. Click the “**Run EPPA Policy Scenario**” button. A command window (black with white text) will pop up. The model will take about 3-5 minutes to run, during which time Excel will be inoperable and unresponsive to mouse clicks.

Part A: Independent Systems, CO₂ Only Policy

- A1:** Report the carbon prices in the US, EU, and EET (listed in the **EPPA_Results** worksheet). Comment briefly on these prices.
- A2:** Now consider the GDP impacts (the GDP/reference graph in **EPPA_Graphs**). Which nations (considering both Annex B¹ and Non-Annex B) have the largest losses measured by percent GDP, and which nations gain? Briefly explain these results, including why there are differences.
- A3:** If the US decided not to implement a climate policy, how would the results in Part A2 change? Why would these results occur?

Part B: Full Annex B Trading, CO₂ Only Policy

Now examine what happens if the US decides to allow trade between Lieberman-Warner and the ETS system. Activate trading in the US and run the model again.

¹ Note that Mexico is not in Annex B despite its listing in the Toy.

- B1:** What are the new carbon prices in the three regions? How did they change from Part A1 and why? Explain the benefits of “where” flexibility.
- B2:** In the EPPA_Analysis Worksheet, the Toy reports how many carbon permits are bought and sold. How much does the EU buy (or sell) in 2010? How does this number compare to the original (pre-trade) reduction of carbon emissions required?
- B3:** The EPPA_Analysis Worksheet also lists GDP/capita (in tens of thousands of US\$). What is the cost per person in the US of the policy compared to BAU GDP/capita in 2010, 2015, and 2020? If you take the 2010 cost and assume a 5% increase per year, what would the cost be in 2020? How does this compare to the actual cost? What does this imply in terms of banking?

Part C: All-Gas Policy.

The US policies include all gases. The EU ETS may include all gases in later periods. Therefore it is instructive to examine a case in which all greenhouse gases are constrained. Use the same total carbon-equivalent reductions, but now impose the constraint on all gases. Keep trading enabled for all three regions. Make sure the GHG radio button is active in the upper left hand corner of the **GHG_Constraints** worksheet. Click the “**Reset Display to Reference Values**” button. In the appropriate cells, overwrite the current numbers with the numbers in the following table for the constraints:

Year	US Target (MMT Ceq)	EU Target (MMT Ceq)	EET Target (MMT Ceq)
2010	2080	1350	300
2015	1895	1200	305
2020	1801	1086	310

- C1:** What is the new carbon price under the all gas policy? Explain the benefits of “what” flexibility.
- C2:** What is the GDP/capita in the US in 2010 compared to the old policy with trading?

PROBLEM 2 – ECONOMIC AND CLIMATIC UNCERTAINTY

Prepare estimates of the uncertain temperature change faced over the 21st Century under no-policy reference conditions. Uncertainty in emissions can be represented by three combinations of the underlying determinants:

- RR** Reference economic growth and energy efficiency in all regions
HL High economic growth and Low energy efficiency in all regions
LH Low economic growth and High energy efficiency in all regions

This analysis will require three emissions projections and analysis of their impacts on temperature, with each run based on different values of the uncertain economic parameters.

A range of values for the three key uncertain climate parameters in analysis of the climate response—ocean diffusivity (K_v), climate sensitivity (S) and aerosol forcing (F_{aer})—are shown in the following table.

K_v	S	F_{aer}
1	2	0.5
4	4	1
7		

These parameter combinations are not thought to occur with equal probability. Using data and expert judgment, the following prior probability distribution over the three parameters has been developed. They may be treated as statistically independent.

K_v	Prob.	S	Prob.	F_{aer}	Prob.
1	0.04	2	0.29	0.5	0.31
4	0.70	4	0.71	1	0.69
7	0.26				

Part 2A: Temperature Change under Reference Emissions. For the **RR** emissions projection, construct a probability density function (PDF) of global mean temperature change in the year 2100.

Part 2B: Full Uncertainty of Temperature Change. Prepare a PDF of uncertain temperature change to 2100 on the assumption that the probabilities of the emissions projections are $RR=.5$, $HL=.25$ and $LH=.25$. Show your analysis and explain briefly.

For both 2A and 2B please submit copies of any worksheets (yours, not those in the Toy solution) used to perform these calculations and include a brief description of how you put the analysis together. Also turn in the PDF graph.

Hints:

- (1) With advance planning, this problem requires only three runs of the model, one for each emissions projection. (Running time to 2100 under business as usual is about 15 minutes) The attached event tree can be used as a guide when systematically varying the climate parameter. (Check that all of the probabilities sum to one!)
- (2) For the PDF use a temperature range of 0°C to 7°C with 0.5°C increments. (For example, the 2°C bin will contain values from 1.75°C to 2.25°C .) The probabilities on the y-axis will be the aggregated probability that the occurrence of warming falls into each 0.5°C bin.
- (3) There should be no constraints on any of the regions. Be sure to clear the reference values (quota constraints) from the spreadsheet. (Note the handy button to do this.)

