UNIVERSITY OF OSLO
DEPARTMENT OF ECONOMICS

Exam: **ECON4910 – Environmental economics**

Date of exam: Thursday, May 31, 2007 **Grades are given: Friday, June 15**

Time for exam: 09:00 a.m. – 12:00 noon

The problem set covers 2 pages

Resources allowed:
- No resources allowed

The grades given: A-F, with A as the best and E as the weakest passing grade. F is fail.

1. Consider R environmental receptors from which people derive utility. Define environmental services as M_j and assume that the amount of services is influence by emissions of a common pollutant from N sources
   $M_j = m_j(e_1, e_2, ..., e_N),\ m_j' < 0,\ j = 1, ..., R$,
   where e_i is the emission from source i (i = 1,…,N).

   a) Define non-uniform and uniform dispersion of the pollutant based on the general relation above.

   Consider the end-of-pipe purification cost functions
   $c_i(r_i),\ c_i', c_i'' > 0\ (i = 1, ..., N)$.
   Here purification is given by $r_i = e_i^o - e_i\ (i = 1, ..., N)$, where e_i^o is the emission without purification and e_i is the actual emission from source i (i = 1,…,N). Assume that the pollutant is uniformly dispersed. The environmental regulator does not have information about environmental damage functions. The regulator pursues an environmental policy of minimizing purification costs given a constraint on the total emission allowed from all sources: $\sum_{i=1}^{N} e_i \le d^*$.

   b) Explain why it is not relevant to impose a specific standard on each of the R environmental receptors.
   c) Formulate the regulator's social planning problem when the purification cost functions are known and the purification possibilities of each source are subject to the following limits:
      $0 < e_i^{\min} \le e_i \le e_i^o,\ i = 1, .., N$
      Discuss the relevance of these limits.

Overleaf.

d) Discuss the properties of interior solutions, that is, solutions where $e_i^{\min} < e_i < e_i^o \ (i = 1,..,N)$.

e) Give economic interpretations of the corner solutions $e_i = e_i^{\min}$ and $e_i = e_i^o$.

2. The regulator introduces emission permit quotas totalling d^* units, requiring one permit per unit emission. The regulator gives quotas free to the sources based on the grandfathering principle, that is, the number of quotas is proportional to the initial emissions e_i^o for all *N* sources: $d_i^* = ae_i^o$, $a = \dfrac{d^*}{\sum_{i=1}^{N} e_i^o}$.

a) Discuss the cost-effectiveness of the grandfathering principle.

b) Assume that the emission permits are tradable after they are given out free. Derive the sources' actual use of quotas, assuming that there is a market-clearing quota price (that is, demand for quotas equals supply). Discuss the cost-effectiveness of tradable emission permits.

c) Does the initial distribution of quotas influence the distribution of emission on sources?

3. We are considering the Kyoto protocol for restricting emissions of greenhouse gases by 2012. For simplicity we assume that there is only one greenhouse gas, namely carbon dioxide, CO_2. A number of industrialized countries are signatories to the protocol. There is an emission standard for each signatory country based on a percentage reduction (or increase) compared to the countries' emissions in 1990. Assume that the purification cost functions of the sources within a signatory country can be described by the cost functions given in question 1 above, and that capital investments are included in the cost functions. The purification functions for *K* sources in developing countries have the same properties as those for the industrialized countries and are given by
$c_{Dj}(e_{Dj}^o - e_{Dj}), 0 < e_{Dj}^{\min} \le e_{Dj} \le e_{Dj}^o, (j = 1,...,K)$.

It is assumed that the investment costs are included in the cost functions and that $e_{Dj}^{\min}$ is not a choice variable, but a technical constraint. The amounts emitted before interventions of signatory countries are $e_{Dj}^o \ (j = 1,...,K)$.

Now assume that the signatory countries can meet their obligations of restricting their emissions in 2012, in whole or in part, by using the Clean Development Mechanism. That is, they can be credited reductions of CO_2 by financing purification in developing countries.

a) Assume that the *N* cost functions in question 1 are cost functions for sources in a signatory country. Analyze the choice of a signatory country of meeting its obligations by restricting sources at home and financing purification in developing countries. Discuss both interior solutions and corner solutions.

b) What is the condition for the signatory country choosing to finance purification in developing countries?

c) What is the condition for the signatory country choosing to cover its total emission reduction obligations by paying for purification in developing countries?