ECON4910 - Spring 2023

Each subpoint can give you 5 points. Thus, the max total is 80.

If you do not understand a question, or the text, please make and state the assumptions that you think are correct, and proceed from there.

Question I

Suppose there are n = 10 firms indexed by *i* and m = 6 firms indexed by *j*. All firms emit the same type of pollution *E* and the aggregate harm for the consumers in the society is δE^2, where $E = \sum_i e_i + \sum_j e_j$.

It is costly to reduce emissions, and each firm of type i has the following abatement cost function:

$$c_i(e_i) = (\theta_i - e_i)^2$$

While firms of type j have the following abatement cost function:

$$c_j(e_j) = (\theta_j - e_j)^2$$

with $\theta_j < \theta_i$.

a) Give an intuition for the signs of the derivatives of the abatement cost functions, e.g., why do we have $\partial c_i/\partial e_i \leq 0$ and $\partial^2 c_i/\partial e_i^2 > 0$? What is the interpretation of $\theta_{i/j}$?

b) What is the optimal level of emissions for each firm and in total? Set up the problem of the social planner and derive the optimality conditions. What do they tell you?

c) Derive the aggregate marginal abatement cost curve and illustrate the social optimum in a figure with emission on the x-axis and a monetary value measure on the Y-axis. Derive the optimal level of aggregate emissions.

d) Set $\theta_j = 8$, $\theta_i = 16$ and $\delta = 1/16$. The regulator wants to introduce a tradeable permit market. How many emissions permits should she issue? Assume permits are tradeable, what will be the resulting permit price σ? How much will firms of type *i* and type *j* emit in equilibrium?

e) The industry argues that permits should be allocated free of charge based on historical emissions, while the regulator would like to auction out the permits. Discuss shortly the pros and cons of the two alternatives for allocating permits.

An innovator has come up with an idea making it possible for the *i*-firms to become *j*-firms, e.g., get abatement costs equal to $(\theta_j - e_i)^2$ instead of $(\theta_i - e_i)^2$. The innovator charges a price ϑ for using the idea even though providing the idea to the firms implies no cost for the innovator. Furthermore, *i*-firms differ with respect to how costly it is for the firms to adopt the new technology. We rank the firms according to their adoption cost denoted by *F(X)* where $X \in \{1, \ldots, 10\}$.

f) Why is it reasonable that the innovator charges a price ϑ for using the idea even though providing the idea to the firms implies no cost for her?
g) Set up the condition for the marginal firm (of type *i*), that is, the firm being indifferent between adopting the new idea or not. Assume that the regulator won the argument, and that *L* permits are allocated by auctioning. Derive the effect of reducing the number of permits on the rate of adoption, e.g., find an expression for $\partial X/\partial L$.
h) Discuss to what extent the rate of adoption is socially optimal and also whether the incentives for innovation are sufficient from a social point of view.

Question II

a) Just verbally: Based on the lectures, what is the main motivation for free riding, and what is the main motivation for participation in a climate agreement in a static game?
b) Again, verbally: How and why can these motivations pin down the number of countries when the coalition size is endogenous?

Suppose now that each country has the utility function

$$b(Y-(g_i+r_i))^2-cG$$

where b is a parameter, g_i is country i's emission, r_i is the country's windmill stock, while G is the sum of all the emission levels.

c) Can you try to explain an intuition for why g_i and r_i enter the utility function the way they do?

From now on, consider every r_i to be exogenous (for instance, it is determined before our game starts).

d) Consider a world with n countries. There is a coalition with m<n countries. The coalition maximizes the sum of payoffs for the coalition members, while individual free-riding countries simply maximize their own utility. Can you show the inequality for when a nonparticipating country benefits from free riding, rather than to participate?
e) Based on this inequality, derive the largest m that can motivate all the m members to continue to participate. Discuss the comparative static results of this largest possible coalition size.
f) Consider two countries with different stocks of windmills. Country 1 has a larger stock than country 2. Show which one that has a highest benefit from entering the coalition, instead of free riding. Please explain the result.

From now on, we will relax the assumption that the coalition maximizes the sum of payoffs. Instead, each coalition member is assumed to maximize a weighted sum of payoffs, where the weigh on one's own payoff is 1, but the weight on every other coalition member's payoff is w. The weight on every non-participating country is 0. Before, w=1, but here, we permit w<1.

In fact, it might be argued that the Paris agreement was so weak that $w<1$ was smaller than under the Kyoto Protocol.

g) Analogously to question e, please derive the largest possible coalition size, as a function of w. Please discuss the intuition for your results.

h) Based on this result, what is the optimal type of agreement, if different types of agreements vary in the weight, w? Discuss the intuition and relevance of this result.