In total, questions 1 and 2 count for 70% of the exam, and each subquestion in question 1 and 2 count equally to your final grade (so, ca 6% each).

1. Two pollutants.

Suppose that there is a permit market where a certain number of permits is given to the firms and they can trade them. Equilibrium price for right to pollute C (CO_2), is q_C, and for the right to pollute N (SO_2) or NO_x, is q_N. Each firm takes prices as given.

The aggregate harm for the consumers in the society is $k_C g_C + k_N g_N$, where $k_C = 10$, $k_N = 5$ and $g_C = \sum_i g_C^i$ and $g_N = \sum_i g_N^i$. But it is costly to reduce emission, so each firm benefits from emitting and has the profit function:

$$\pi_i (g_i) = g_C^i \left(60 - 2g_C^i\right) + g_N^i \left(60 - 2g_N^i\right).$$

(a) Can you illustrate the socially optimal solution graphically and discuss it?

(b) What is the socially optimal level of CO_2 (g_C^i) ?

(c) Suppose now that each firm takes as given the prices for buying the right to pollute C, q_C, and N, q_N, and that there is a permit market where a certain number of permits is given to the firms and they can trade them. Which quantity of g_N^i would firm i like to emit, as a function of the two prices?

(d) How many total (aggregate for all firms) permits for emitting CO_2 (C) should the industry receive as a whole to maximize welfare?

(e) Suppose thatthe planner also distribute the optimal number of permits for SO_2 (N). What is then the equilibrium market price, q_N?

(f) Which allocation(s) of the permits among the firms would you suggest, if you were advising the government? Explain in words and justify your answer.

2. Deforestation

This is a new problem (unrelated to the one above). Suppose that there are two districts or countries, S (Sudan) and N (Namibia), and each $i \in \{S, N\}$ has a stock X_i of forest. If an amount $x_i \in [0, X_i]$ is illegally extracted, it is supplied to the market and each unit is sold at price q:

$$q = P - ax$$

where $x = x_S + x_N$. To discourage illegal logging on one unit of the forest, the expected penalty when illegally logging at that unit must be at least as large as the price q. The cost of raising the expected penalty at a unit of forest is c. The marginal value of conserving the forest $(X_i - x_i)$ is measured by the constant v_i for country i.

(a) How will the deforestation leve in a country, say, Sudan, depend on enforcement cost, c, you think? Please only use words and intuition here.

(b) Assume now that country S takes x_N as given when deciding on x_S. Derive an equation showing how x_S depends on S's expectation of x_N. Explain the intuition for your formula.

(c) Derive a formula showing how the total amount of logging, x, depends on c. Can you explain the similarity / difference to your answer in the first subquestion, above?

(d) Suppose that N is going to decide on x_N at some specific time, t, while S decide on x_S at a different time, t'. How is x_S, x_N and x depending on whether $t > t'$, $t < t'$, or $t = t'$?

(e) Which of these sequences is preferred by district N?

(f) Suppose the World Bank attempts to lower deforestation. How do you suggest that it goes ahead, based on the model?

Problem 3 (30%)

i) (10%) Write a brief essay explaining the basics of an integrated assessment model of climate change (no equations needed).

ii) (10%) Nordhaus' calibration of the DICE model aims to be descriptive. His base calibration results in a lower social cost of carbon than that of the Stern review. Briefly discuss possible short-comings of the descriptive account.

iii) (10%) Assume future consumption growth is uncertain but the payoffs of climate change mitigation are deterministic. What would you expect to happen to optimal abatement as compared to the deterministic case? Would the reasoning be the same if the abatement project's outcome was uncertain as well?