University of Toronto
Faculty of Arts and Science
December Examinations 2011
ECO313H — Matthew A. Turner
Duration - 2 hours

Examination Aids: No notes or books are allowed, but you may use a calculator.

When you write up your answers, your goal should be to (1) be correct, and (2) convince your reader that your answer is correct. Answers which do not achieve these goals will not be awarded full credit. To accomplish the second objective, it is helpful if your work is legible and if all steps are presented, possibly with a line of explanation. Point counts of individual problems are indicated in parentheses. Total points =100.

1. Let Y_0 and E_0 denote world income and emissions of CO_2. Suppose that $Y_0 = 1$ and that the world consists of two sets of countries, A and B. Under the Kyoto Protocol, Countries in A are Annex I countries and reduce their emissions by 10%. Countries in B are the non-Annex I countries and do not reduce their emissions. Annex I countries are responsible for about 40% of world emissions and (to make things easy) the same share of income.

   Suppose that the relationship between income and mitigation is given by

   $$\Lambda_i = \frac{2}{3}\mu_i^3$$

   where $\mu_i E_i$ is the reduction in emissions in country i and $\Lambda_i Y_i$ is the cost of this reduction.

   (a) (10) Calculate the cost of the proposed Kyoto reduction.

   (b) (10) Calculate the cost of this reduction if the proposed reduction is distributed across the two sets of countries in the cost minimizing way.

   (c) (10) Suppose that a CDM (Clean Development Mechanism) program exists which allows annex I countries to undertake mitigation in non-Annex-I countries, but that the cost of certification and paperwork increases the cost of such mitigation efforts by 10%. Given the availability of the CDM, find the first order condition that describes the cost minimizing amount of mitigation undertaken by each set of countries to comply with the Kyoto emissions reduction.

2. Suppose two firms produce steel and have cost functions $c_1(y_1) = 3y_1^2$, and $c_2(y_2) = y_2^2$. The market price of steel is $p = 5$. Steel is jointly produced with smoke, and a planner has determined that social welfare is maximized when only one unit of steel is produced.

   (a) (10) Suppose that the planner regulates steel production with a tax on steel of $\tau = 1/3$. Determine the amount of steel produced by each firm and the total costs to produce steel.

   (b) (10) Suppose that the planner regulates production by issuing each firm tradable quota to produce one unit of steel and offers to sell any amount of additional quota at price $\widehat{p_Q} = 1/3$. How much steel is produced under this regulation? What are the total costs to produce the one unit of steel?

   (c) (10) Do the firms prefer the tax or the tradable permit with pressure valve? Explain.

   (d) (10) Suppose that there is also a tax on labor in this economy. Which of the two types of regulation should the planner prefer?

3. In 2008, Annex I countries were responsible for about 40% of world emissions. The Kyoto protocol calls on these countries to make a 10% reduction in their emissions for a four year commitment period. World carbon emissions in this period were about 10Gt/year.

   (a) (10) Using Nordhaus' rule of thumb for the relationship between atmospheric Carbon concentration and climate 100 years from now, calculate the impact of mitigation during the first Kyoto commitment period on climate in 50 and 100 years from now. (Hint: (1)This question partly tests whether you remember the relevant constants to go from emissions to climate. If you don't remember them, fill them in with a variable and go ahead as best you can. (2) Nordhaus's rule of thumb tells us what happens in 100 years, suppose that half the change occurs in 50 years)

   (b) (10) Mendelsohn et al (1995) presents the following regression results

   $$\text{Farm value/acre} = 1500 - 32 \times \text{January Temperature} \times -93 \times \text{July Temperature}$$

   (this is a partial report of their results in table 3, and I've adjusted the coefficients so you can work in Celsius rather than Fahrenheit). Suppose that the cooling you calculated in the first part of this problem is the same for both January and July. Find the increase in value per acre of farmland in 50 and 100 years associated with the Kyoto reductions.

   (c) (10) The regression results reported above explain the way land values vary with climate. In the first part of this exercise you found the effect of a change in emissions on climate in 50 and 100 years. Using these two results, write down the expression for the discounted present value of the increase in farm values that results from Kyoto mitigation. (Hint: If you couldn't do an earlier part of the problem, fill in the relevant quantity with a variable and go ahead with the problem.)

(a) ANNEX I COUNTRIES REDUCE EMISSIONS BY .1

$E_A = .4 \times E_0$, $Y_A = 0.4 \times Y_0$

$\mu_A = .1$

SO KYOTO REDUCTION IS $\mu_A E_A = \frac{4}{100} E_0$

THUS THE COST OF KYOTO REDUCTION IS

$$\Lambda_A Y_A \quad \text{FOR} \quad \Lambda_A = \frac{2}{3} \mu_A^{3}.$$

$$\Rightarrow \text{COST IS} \quad \frac{2}{3} \mu_A^3 \left(\frac{4}{10} Y_0 \right)$$

$$= \frac{2}{3000} \cdot \frac{4}{10} Y_0$$

$$= \frac{4}{15000} Y_0 = \frac{1}{3750} Y_0 \cong 0{,}00027\, Y_0$$

(b) IF AN EMMISSION REDUCTION OF $.1 \times (\underbrace{.4 \times E_0}_{(E_A)}) = \frac{4E_0}{100}$ IS DISTRIBUTED ACCROSS ALL COUNTRIES, THEN WE NEED... A WORLD REDUCTION RATE OF $\mu_0 = 4/100$.

THE COST OF THIS REDUCTION IS

$$Y_0 \Lambda_0 = Y_0 \left(\frac{2}{3} \left(\frac{4}{100} \right)^3 \right)$$

$$= Y_0 \left(\frac{2}{3} \; \frac{64}{10^6} \right)$$

$$= Y_0 \times \frac{128}{3} \times 10^{-6} \cong 0.00004\, Y_0$$

(c) NEED TO FIND Λ_A, Λ_B SUCH THAT

$$\mu_A E_A + \mu_B E_B = \frac{1}{10} E_A$$

THE COST OF THIS PROGRAM IS $\Lambda_A Y_A + 1.1 \Lambda_B Y_B$

SO WE WANT TO SOLVE

$$\text{MIN } \Lambda_A Y_A + \Lambda_B Y_B \cdot \tfrac{11}{10}$$
$$\text{S.T. } \mu_A E_A + \mu_B E_B = \frac{1}{10} E_A$$

$$\Rightarrow \text{MIN } \Lambda_A \frac{4}{10} Y_0 + \Lambda_B \frac{66}{100} Y_0$$
$$\text{S.T. } \mu_A \frac{4}{10} E_0 + \mu_B \frac{6}{10} E_0 = \frac{1}{10} \cdot \frac{4}{10} E_0$$

$$\Rightarrow \text{MIN } \frac{2}{3} \mu_A^3 \frac{4}{10} Y_0 + \frac{2}{3} \mu_B^3 \frac{66}{100} Y_0$$
$$\text{S.T. } 4\mu_A + 6\mu_B = \frac{4}{10}$$

$$\Rightarrow \text{MIN } \frac{2}{30} Y_0 \left[4\mu_A^3 + \frac{66}{10} \mu_B^3 \right]$$
$$\text{S.T. } \mu_A = \frac{1}{10} - \frac{6}{4} \mu_B$$

$$\Rightarrow \text{MIN } \frac{2}{30} Y_0 \left[4\left[\frac{1}{10} - \frac{6}{4}\mu_B \right]^3 + \frac{66}{10} \mu_B^3 \right]$$

$$\text{F.O.C. } \frac{2}{30} Y_0 \left[4\left(3\left(\frac{1}{10} - \frac{6}{4}\mu_B\right)^2\left(-\frac{6}{4}\right) + 3 \cdot \frac{66}{10} \mu_B^2 \right] = 0$$

(a) WITH $\tau = 1/3$ FIRM 1 SOLVES

$$\text{MAX } (5-\tfrac{1}{3})y_1 - 3y_1^2$$

$$\Rightarrow \frac{14}{3} = 6y_1 \Rightarrow y_1^* = \frac{7}{9}$$

FIRM 2 SOLVES

$$\text{MAX } \frac{14}{3}y_2 - y_2^2$$

$$\Rightarrow \frac{14}{3} = 2y_2 \Rightarrow y_2^* = \frac{14}{6} = \frac{7}{3}$$

TOTAL COSTS ARE $c_1(y_1^*) + c_2(y_2^*) = 3\left(\frac{7}{9}\right)^2 + \left(\frac{7}{3}\right)^2$

$$= \frac{49}{27} + \frac{49}{9}$$

$$= \frac{49}{27} + \frac{147}{27}$$

$$= \frac{196}{27} = 7\tfrac{7}{27} \approx 7.26$$

(b) WITH THE PRESSURE VALVE, THE PRICE OF QUOTA IS CAPPED AT 1/3. THE TRICK IS TO FIGURE OUT IF, WITH 2 UNITS OF QUOTA, THE QUOTA MARKET CLEARS BELOW THIS PRICE

FIRM 1 SUPPLY FUNCTION:

$$\text{MAX } (5-P_Q)y_1 - 3y_1^2 + P_Q$$

$$\Rightarrow 5 - P_Q = 6y_1$$

$$\Rightarrow y_1^* = \frac{5-P_Q}{6}$$

FIRM 2 $\text{MAX } (5-P_Q)y_1 - y_1^2 + P_Q$

$$\Rightarrow 5 - P_Q = 2y_2$$

$$\Rightarrow y_2^* = \frac{5-P_Q}{2}$$

→

FOR 2 UNIT SUPPLY OF QUOTA, MARKET CLEARING GIVES

$$y_1^* + y_2^* = 2$$

$$\Rightarrow \quad \frac{5-P_Q}{6} + \frac{5-P_Q}{2} = 2$$

$$\Rightarrow \quad 5-P_Q + 15-3P_Q = 12$$

$$\Rightarrow \quad 20-4P_Q = 12$$

$$\Rightarrow \quad 4P_Q = 8 \quad \Rightarrow \quad P_Q^* = 2$$

$\Rightarrow$ TO CLEAR QUOTA MARKET WITH TWO UNITS OF QUOTA WE NEED QUOTA PRICE OF 2!
THIS IS MUCH HIGHER THAN PLANNER'S RESERVE PRICE.

$$\Rightarrow \quad P_Q = \tfrac{1}{3}$$

THIS MEANS FIRMS SOLVE

VALUE OF ONE UNIT OF QUOTA.

(#1) $\quad \text{MAX} \ (5-\tfrac{1}{3})y_1 - 3y_1^2 + \tfrac{1}{3}$

(#2) $\quad \text{MAX} \ (5-\tfrac{1}{3})y_2 - y_2^2 + \tfrac{1}{3}$

THESE GIVE THE SAME F.O.C.'S AS WE HAD WITH A TAX OF $\tau = \tfrac{1}{3}$.

THUS, WE GET EXACTLY THE SAME PRODUCTION AND COSTS AS IN (a)

$$y_1^* = \tfrac{7}{9} \quad , y_2^* = \tfrac{7}{3} \quad , \quad \text{COSTS} = 7\tfrac{7}{27} \approx 7.26$$

WITH TRADABLE QUOTA, HOWEVER, EACH FIRM HAS $\tfrac{1}{3}$ DOLLAR MORE PROFIT – THEY GET TO SELL THEIR UNIT OF QUOTA FOR $\hat{P}_Q = \tfrac{1}{3}$

(d) THE FIRMS PREFER PRESSURE VALVE QUOTA. THEIR PROFITS ARE HIGHER BY THE VALUE OF THE QUOTA.

(e) IF THERE IS A LABOR TAX, THE PLANNER PREFERS THE <u>TAX</u>. THE TAX GENERATES MORE REVENUE THAT CAN BE USED TO REDUCE THE LABOR TAX.

(a) • KYOTO REQUIRES $\frac{1}{10} \times \frac{4}{10} \times 10$ GT MITIGATION FOR 4 YEARS

THIS IS 1.6 GT, CARBON.

• ABOUT $\frac{1}{2}$ OF EMISSIONS ARE ABSORBED BY THE EARTH AND OCEAN, SO .8 GT CARBON STAYS IN THE ATMOSPHERE

• 1 PPM OF CARBON IN THE ATMOSPHERE IS $2\frac{1}{8}$ GT.

$\Rightarrow$ KYOTO CAUSES AN $\dfrac{4/5}{17/8}$ PPM REDUCTION IN CONCENTRATION OR $\dfrac{32}{86} \approx 0.4$ PPM REDUCTION IN CO_2 CONCENTRATION.

NORDHAUS RULE TELLS US THAT AN INCREASE OF 280 PPM CAUSES $3^\circ C$ OF WARMING OVER 100 YEARS (OR $\frac{1}{2}$ OF THIS OVER 50 YEARS).

THUS, KYOTO'S FIRST COMMITMENT PERIOD CAUSES

$\frac{.4}{280} \times 3^\circ$ OF COOLING IN 100 YEARS $\cong 0.004^\circ C$

AND $\frac{1}{2} \times \frac{.4}{280} \times 3^\circ$ IN 50 YEARS $\cong 0.002^\circ C$

$\rightarrow$

(b) USING THE RESULTS FROM (a), THE FIRST KYOTO COMMITMENT PERIOD CAUSES A CHANGE FARM LAND VALUE OF

$$\Delta V = (-32 - 93) \times \frac{-4}{1000} = \frac{500}{1000} \text{ or } 0.5 \, \$ / \text{ACRE}$$

IN 100 YEARS.

THE EFFECT IS HALF AS LARGE, 0.25 \$/ACRE IN 50 YEARS.

(c) LAND VALUE IS DISCOUNT PRESENT VALUE OF RENT

$$V = \sum_{t=0}^{\infty} \delta R$$

$$= \frac{1}{1-\delta} R$$

THUS, $R = (1-\delta) V$.

THIS MEANS THAT $\Delta R = (1-\delta) \Delta V$.

THUS, THE FIRST KYOTO COMMITMENT PERIOD CAUSES LAND RENTS TO INCREASE BY $(1-\delta)\,0.25$ IN 50 YEARS, AND AGAIN, BY THE SAME AMOUNT IN 100 YEARS.

THUS, THE DISCOUNT PRESENT VALUE OF THIS INCREASE IS

$$W = \delta^{50} \sum_{t=0}^{\infty} \left[(1-\delta) 0.25\right] \delta^t + \delta^{100} \sum_{t=0}^{\infty} \left[(1-\delta) 0.25\right] \delta^t$$

OR, MORE SIMPLY

$$= \delta^{50} (0.25) + \delta^{100} (0.25)$$