ECN 275/375 – Natural resource and environmental economics
12:15-15:15 March 5, 2024

All help aids allowed except assistance from others.
This test consists of 3 questions, for a total score of 100 points.
All questions are to be answered. You may answer in English or Norwegian.

In the case that you find a question unclear, or you are uncertain about what is meant, state the extra assumptions you need to be able to answer the question.

This test has been designed to limit the benefits of using Chat GPT and similar artificial intelligence tools. If AI use is detected beyond reasonable doubt, unreported use leads to a score of zero. Students can use AI tools if they self-report such use at a cost: A question with self-reported AI use reduces the score by 40%.

When I submit my answers on this test, I confirm that I have worked alone on my answers and not cooperated with others. I am aware that cooperation with others is considered an attempt or a contribution to cheating.
I am aware of the consequences of cheating (Ch. 39, Academic regulations for NMBU).

Your name: NN (+ ECN 275 or ECN 375)

Question 1 (30 points – 10 points for each part a-c)

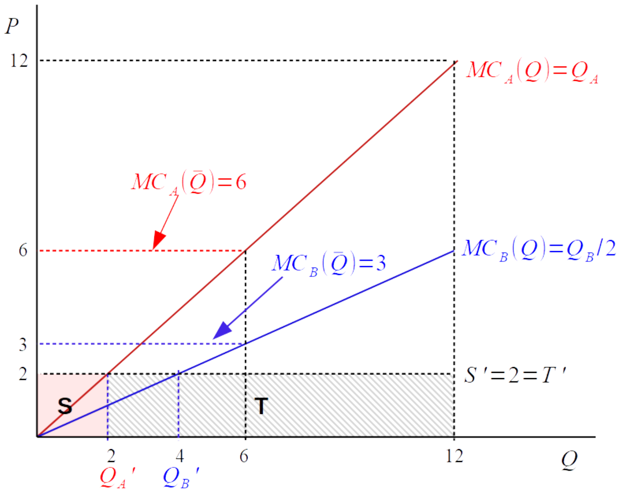
There are 2 firms, A and B, each with a maximum production capacity of 12 units of the same type public (non-market) good with the following **total cost functions of producing the public good**, Q:

The A-firm: $TC_A(Q_A)=Q_A^2/2$, and the B-firm: $TC_B(Q_B)=Q_B^2/4$.

(a) (i) Currently neither of the firms produce any of the public good. Draw the marginal cost functions for the two firms in the same graph. Mark the axes and the two firms' respective marginal cost functions. Explain how each of the two firms responds to a subsidy rate $S'=2$ for producing the public good. In the graph, mark the two firms' responses to the subsidy with Q_A' and Q_B'. **For firm A** mark the total amount of subsidies received in your graph.

(ii) Replace the subsidy by the tax rate, $T'=S'=2$, and mark the area of taxes paid **by firm A** in your graph. Explain the difference in the impact on firm A from the subsidy and the tax. What kind of effect does the subsidy-tax example illustrate?

Answer: (i) Differentiating the firms' total cost function gives $MC_A(Q_A)=Q_A$ and $MC_B(Q_B)=Q_B/2$. The two firms choose to adapt such that their respective marginal costs equal the subsidy rate, which gives $Q_A'=2$ and $Q_B'=4$. The graph to the right illustrates this with the subsidy rate $S'=2$ inserted and the total subsidy incomes S for firm A:



(ii) The tax $T'=2$ gives the total taxes paid **T** (gray shaded area) and in theory the same quantities as the subsidy, i.e.,

$Q_A'=2$ and $Q_B'=4$. Adding "in theory" as firm A does not make any profits from producing with the tax, which means firm A will not produce the public good. This illustrates the entry-exit conditions using subsidies or taxes. Note that the same actually holds for firm B.

For parts (b) and (c) you do not need to present your solutions graphically.

(b) (i) Each firm is required to produce at least half of their maximum production capacity, i.e., $\bar{Q}_A=\bar{Q}_B=6$. Show that this is not a cost-effective policy.

(ii) Find the cost-effective distribution of producing a total of 12 units of the public good, i.e., $Q_A'+Q_B'=12$.

Answer: (i) Valuing marginal cost functions at $\bar{Q}_A=\bar{Q}_B=6$ gives $MC_A(\bar{Q}_A)=2\bar{Q}_A=12$ and $MC_B(\bar{Q}_B)=\bar{Q}_B=6$, which violates the cost-effectiveness condition of equal marginal costs evaluated at the chosen production levels, i.e., $MC_A(Q_A')=MC_B(Q_B')$.

(ii) Total required emissions reductions are $Q_A'+Q_B'=12\Rightarrow Q_A'=12-Q_B'$. Inserting $Q_A'=12-Q_B'$ into the cost-effectiveness condition gives $MC_A(12-Q_B')=Q_B'/2$ = $MC_B(Q_{\prime})$. Hence, $12=(3/2)Q_B'$, which gives $Q_B'=8$. From $Q_A'=12-Q_B'$ we get $Q_A'=4$.

Remark: Can also be solved using Lagrange: $\mathcal{L}=Q_A^2/2+Q_B^2/4+\lambda(12-Q_A-Q_B)$, which basically is another way of carrying out the above substitution.

(c) Change total required emissions reductions to 9, i.e., $Q_A''+Q_B''=9$.

(i) Write down the condition for a per-unit production of emissions subsidy S'' giving a total number of emissions reduction of 9, calculate S'' and the two firm's respective produced emissions reductions, Q_A'' and Q_B''.

(ii) Assume that even with only two firms, the conditions for a well working market are met. Find the resulting market price P''.

Answer: (i) An elegant solution is to use the information in a-ii ($12=(3/2)Q_B'$) as we a subsidy (like a tax) would give a cost-effective solution. Replace 12 to by 9 to get $9=(3/2)Q_B''\Rightarrow Q_B''=6$. As $MC_B(Q_B)=Q_B$ we get $S''=MC_B(Q_B'')=Q_B''=6$, and consequently from $Q_A''+Q_B''=9$ that $Q_A''=3$.

Remark: A more cumbersome approach is horizontally summing the two marginal cost functions to get an aggregate marginal cost function. For A set $S''=MC_A(Q_A'')=Q_A''$ and for B set $S''=MC(Q_B'')=Q_B''/2\Rightarrow Q_B''=2S''$. Summing the two expressions gives $Q_{TOT}''=Q_A''+Q_B''=S''/2+S''=(3/2)S''\Rightarrow S''=2/3Q_{TOT}''=(2/3)9=6$. Set $S''=MC_A(Q_A'')=MC_B(Q_B'')\Rightarrow Q_A''=3$ and $Q_B''=6$. This approach also gives full score.

(ii) As a subsidy is just another word for a price, the same solutions as above emerge, i.e., the price $P''=S''$ and the solutions for the quantities of produced emissions reductions are the same, i.e., $Q_A''=3$ and $Q_B''=6$ in this case.

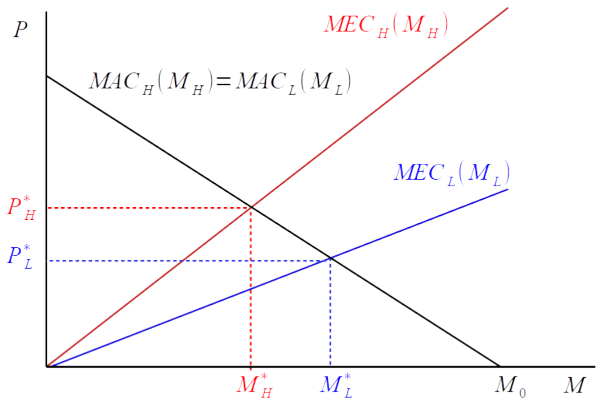
Question 2 (30 points – 10 points for each part a-c)

Characteristic features of nonpoint source pollution are that it is technically difficult or costly to measure the amount of pollution. The term nonpoint source pollution originates from agriculture where measuring phosphorus and nitrate runoffs from farm fields is difficult as it requires collecting drainage water to measure the concentration of nutrients, and hence enable assessing the soil nutrient runoffs. Phosphorus is a main driver for eutrophication in freshwater recipients, causing algae growth which reduces water clarity and leaves less oxygen available for other species. The latter could alter the species composition as stocks (amounts) of salmon and other species requiring high oxygen concentrations are reduced. In extreme cases the affected species may die. The environmental damages from phosphorus runoffs generally occur close to or downstream from the source of the emissions.

(a) (i) Using salmon as an example, show why the optimal amount of phosphorus emissions are likely to differ between high and low valued salmon rivers. Illustrate your reasoning and findings using a graph.

(ii) In Norway farmers frequently also owns the (salmon) fishing rights in rivers and lakes on or bordering to their properties. How could that influence farming practices?

Answer: (i) For simplicity, there are two types of salmon rivers, high and low value of the salmon fishing with $MEC_H(M_H)$ > $MEC_L(M_L)$. For added simplicity, also assume that the marginal abatement cost functions are the same for the high and low value salmon fishing rivers, i.e., $MAC_H(M_H)=MAC_L(M_L)\forall M_H=M_L$. From the figure we see that the optimal emission level in the high value salmon fishery river is lower than in the low value river, i.e., $M_H^*<M_L^*$.



(ii) For farmers who own (salmon) fishing rights or derive income from fishing, emissions are partly not an externality as the quality of the fishing influence their income, reflected by the MEC-curves. Consequently, farmers with high costs of emissions will seek to reduce their emissions until their marginal benefits in fish related incomes equal their marginal costs of reducing emissions.

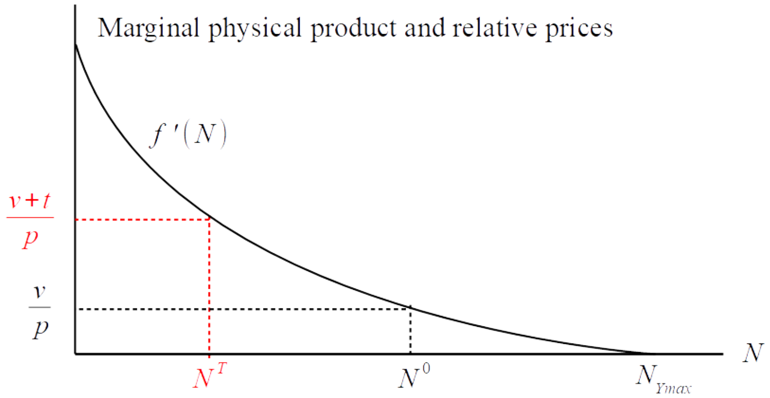
Remark: In the case that neighboring farmers without fishing rights create an externality that affects fishing income for farmers who own fishing rights, farmers with fishing rights may offer some side-payment for their neighbors to reduce their emissions.

The damages of nitrate runoffs are small in freshwater recipients. However, their negative impacts are strong in coastal waters, particularly where water from rivers enters the sea.

(b) For nitrogen the tax rate, *t*, on industrially produced nitrogen fertilizers, *N*, lowers emissions. Use a simplified production function where per hectare yields, *Y*, is a function of nitrogen use, *N*, per hectare, i.e., $Y=f(N)$. Define the additional terms needed to write an appropriate profit function with and without an input nitrogen tax. Show mathematically why the tax *t* reduces the use of nitrogen when the production function $f(N)$ has the standard properties in stage II of the production function, i.e. where $f'(N)>0$ and $f''(N)<0$. Draw a graph to illustrate your reasoning.

Answer: Denoting p the product price, v the nitrogen input price without the nitrogen tax, (v+t) the input price with the nitrogen tax t, and fixed costs FC give the profit function: $\pi(N)=p\,f(N)-(v+t)N+FC$.

Differentiating with N gives the FOC $\pi'(N)=p\,f'(N)-(v+t)=0 \Rightarrow f'(N)=(v+t)/p$ for $p > 0$. Remark: $p \leq 0$ implies that production does not take place as revenues then are non-prositve. Using the stage II conditions, i.e., $f'(N)>0$ and $f''(N)<0$, gives an everywhere decreasing marginal physical product curve $f'(N)$.

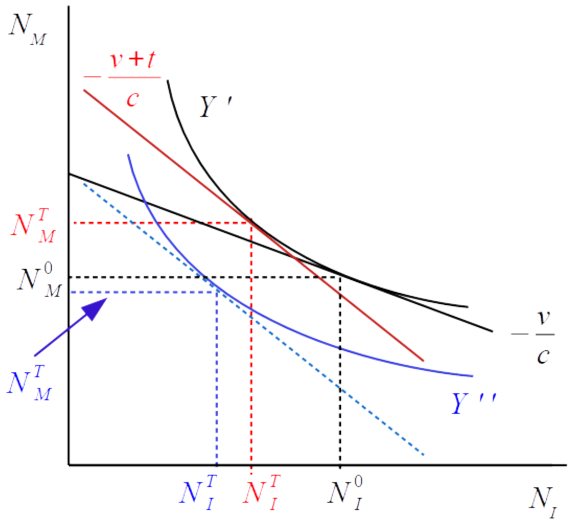


(c) (i) Show how the tax rate, t, on industrially produced nitrogen increases the use of manure ("shit" from on farm animals) when the farmers seeks to produce the same amount of products as the did before the tax on industrially produced nitrogen was introduced.

(ii) Explain why this effect could be uncertain under profit maximization.

Answer: (i) The condition that farmers seek to produce the same quantity defines the isoquant (here Y'). The optimal input mix is then where the relative input price line tangents the isoquant. In the graph the industrial nitrogen input prices are v and (v + t) without and with the tax on industrially produced nitrogen, and c is the input price (marginal costs) for manure nitrogen. For simplicity assume that c is constant. This gives the relative input price lines –v /c and –(v+t) /c.

Remark: There could be increasing marginal cost of manure use, i.e., $c'(N_M)>0$. as it is costs to make more N_M available for plants.



The figure shows the change in input use $\{N_I^0, N_M^0\}$ without and with the industrial nitrogen tax $\{N_I^T, N_M^T\}$. Blue items relate to the answer on (ii) below.

(ii) The economic reasoning behind a possible but unlikely decline in manure nitrogen under profit maximizing changes in yields is as follows: The tminimum costs of reaching a production target (isoquant Y' in the above graph. As the tax t on industrial nitrogen increases total marginal costs, the profit maximizing yields decline consistent with the analysis in (2b). A sufficiently large inward shift from isoquant Y' to isoquant Y'' (the blue items in the above figure) yields $N_M^T < N_M^0$. As the tax on industrial nitrogen makes its use more expensive relative to manure nitrogen, the use of industrial nitrogen declines even more than for manure nitrogen.

Question 3 (40 points – 10 points for each part a-d)

In a country about 40% of the gross domestic product comes from one sector in the economy. Nearly all of the goods produced in this sector are exported. The government is considering one of two economy wide policies to reduce emissions of this nontoxic pollutant. Its negative environmental impacts are mainly domestic.

i. Non-transferable grandfathered emission permits to be implemented *two years into the future*, where existing firms both within and outside the export sector are given an emission quota based on their emission level next year.
ii. A uniform emission tax for all sectors, where the tax rate is to be reduced for the export industry sector to avoid negative impacts on export revenues.

There is close to full employment and little slack in the economy.

(a) Suppose you are an advisor in environmental economics to the government. What changes would you recommend to the emission permit system? Briefly justify your changes.

Answer main points:

- Scrap the proposal of grandfathering permits as:
  - It constitutes a wealth transfer from households to industry owners. Remark: In theory such transfers are unproblematic as households own firms and thereby receive capital returns.
  - Such permits could actually pose an entry-barrier to new firms.
- Setting the base year for initial permit allocations to a future time period provides incentives for firms to pollute more. This effect is particularly strong for grandfathered permits.
- Make permits tradable to achieve cost-effectiveness. Remark: Cost-effectiveness is also a condition for welfare maximizing policies as cost savings of reaching a policy target entail potential welfare gains that can be redistributed to make one person better off without making anyone else worse off.

Representatives for the polluting export industry argue against both proposals, claiming that either policy will be very harmful to the industry because it sells its products in a highly competitive international market, which in turn could reduce national welfare. They therefore suggest voluntary regulations, where the exporting industry agrees to cut its emissions by half within ten years if the government promises not to introduce other regulations negatively affecting the competitiveness of the industry in the same time period.

(b) Briefly discuss the export industry arguments related to export revenues and welfare losses, their opposition towards any environmental regulations except their own proposal on voluntary environmental agreements.

Answer main points:

- Firms' export market shares could decline, particularly for the tax proposal, leading to reduced export revenues and employment. **Correct.**
- Exports are more important than production for the domestic markets. **Debatable** as domestic welfare would only decline if the sum of welfare impacts from reduced export revenues and employment exceed the welfare losses from the export related domestic environmental damages. Remark: The export industry receives a hidden subsidy "paid for" by inhabitants who bear the main costs from export related environmental damages. If production was geared towards domestic consumption, citizens could actually benefit from lower prices due to lax regulations.

- A 10 year exemption to environmental regulations without conditions. **Flawed** because:
  - It could prevent stricter regulations if environmental damages are more serious than initially believed.
  - It leaves out that technological progress could reduce emissions by half without the voluntary agreement, implying that industry would escape environmental regulations without offering anything in return. This risk is real as industry representatives are better informed than regulators on industry specfic technological change.

Representatives for businesses outside the export sector argue against the tax proposal as it increases the challenges for the domestically oriented firms to attract scarce labor with the same skills demanded by the tax-exempt export sector. Firms focusing on the domestic markets therefore favor a system with grandfathered emission permits, i.e., proposal (i) by the government.

(c) Discuss the validity of the arguments made by the domestically oriented firms regarding labor market impacts and the desirability of grandfathered tradable pollution permits.

Answer main points:

- Opposed to proposed tax regime favoring export firms. **Correct**: With nearly full employment and advantages to the export firms that are exempt from environmental regulations, domestically oriented firms may face difficulties attracting skilled labor wanted by export firms.
- Favoring grandfathered permits. **Incorrect:** Such permits constitute wealth transfers from households without industry ownership to industry owners. Assuming households without such ownership are less wealthy than those with industry ownership, distribution becomes more skewed and total welfare may hence decline.

The tax-payer association favors the emission tax proposal, arguing that the introduction of the emission tax will allow for lowering other distorting taxes, in particular on labor income. They claim the emission tax will produce massive welfare gains as lower tax rates on labor will induce people to work more, thereby compensate for the losses incurred by export firms.

(d) Discuss the validity of the claim made by the tax-payer association regarding the labor market and welfare effects of the proposed emission tax as it allows for lowering labor taxes.

Answer main points:

- Labor market effects. **Incorrect** as there is nearly full employment ==> small if any increases in employment possible ==> small welfare effects from employment.
- Welfare impacts. **Debatable** as some taxes (but maybe not labor taxes) could lead to welfare enhancing redistribution + the optimal trade-off between private and public spending is where the marginal utility of private income equals the marginal utility of tax financed governmental consumption.