ECN 275/375 – Natural resource and environmental economics
12:15-15:15 March 2, 2021

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 your extra assumptions needed to be able to answer the question.

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

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

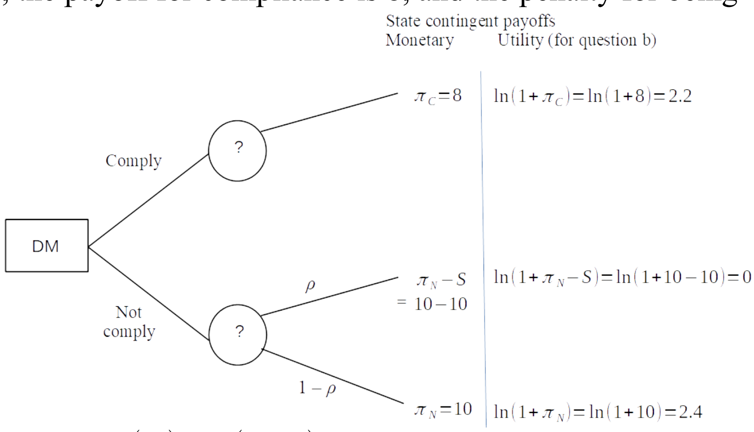
Question 1 (30 points)

The basic equation of monitoring and enforcement can be written as $\rho \geq \frac{\pi_N - \pi_C}{S}$, where π_N and π_C are the respective monetary payments for noncompliance and compliance, and S is the monetary fine if caught in noncompliance.

(a) (i) Draw a decision tree for this equation. (ii) Calculate the necessary monitoring probability for compliance to be more profitable than noncompliance when the state contingent payoff for noncompliance is 10, the payoff for compliance is 8, and the penalty for being caught in noncompliance is 10, all numbers in million NOK. **(10 points)**

Answer: (i) See figure to the right. The upper branch "comply" fully written out equals $\rho \pi_C + (1-\rho)\pi_C$ which simplifies to π_C.

(ii) $\rho \geq \frac{\pi_N - \pi_C}{S} = \frac{10-8}{10} = .2$



(b) Suppose an agent has a utility function $U(Y) = \ln(1+Y)$, where Y is the state contingent payoff and "1" are expressed in million NOK. (i) Show that the monitoring probability to ensure compliance for this agent is approximately 0.084. (ii) Explain why this monitoring probability is lower than the monitoring probability in (a). **(10 points)**

Answer: State contingent payoffs in utility terms $U(Y) = \ln(1+Y) = \ln(1+\pi_N - S)$ with the ln function does not allow to factor out the terms within the parantheses → need to solve from beginning:

$$\rho \ln(1+\pi_C)+(1-\rho)\ln(1+\pi_C)\geq \rho \ln(1+\pi_N - S)+(1-\rho)\ln(\pi_N)$$

$$\ln(1+\pi_C)\geq \rho \ln(1+\pi_N - S)+\ln(1+\pi_N)-\rho \ln(1+\pi_N)$$

$$\rho \geq \frac{\ln(1+\pi_N)-\ln(1+\pi_C)}{\ln(1+\pi_N)-\ln(1+\pi_N-S)}=\frac{\ln(1+10)-\ln(1+8)}{\ln(1+10)-\ln(1+10-10)}=0.084$$

(c) Explain why maintaining the monitoring probability from (a) is necessary to reach universal compliance as long as decision makers do not have risk loving (risk seeking) preferences. **(10 points)**

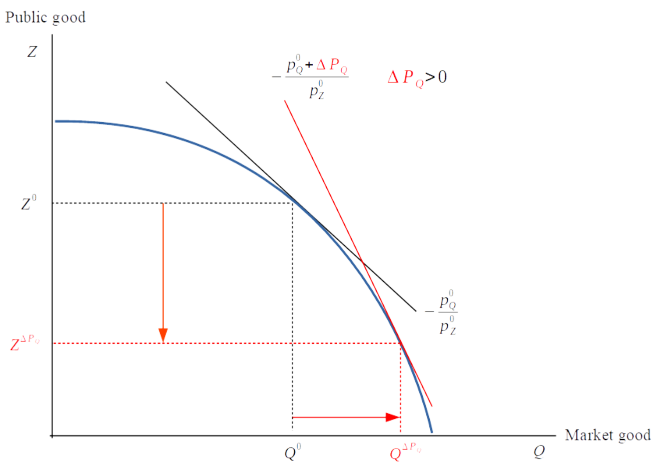
Answer: *Risk loving* preferences are excluded, but *risk neutral* preferences are not. *Risk neutrality* implies a linear utility function in wealth or income. The solution in (a) is therefore the necessary monitoring probability to secure universal compliance (this is the short and sufficient answer for full score).

Question 2 (30 points)

Suppose that a market good (*Q*) and a public good (*Z*) are produced together, which for instance is the case for acreage based productions like agriculture and forestry. Assume that the technically efficient relationship between *Q* and *Z* per hectare is captured sufficiently well by a standard shape production possibility frontier.

(a) (i) Show graphically why increasing the price of the market good, P_Q, with the standard shaped production possibility frontier most likely will lead to a decline in the production of the public good, *Z*. (ii) Explain why this likely result requires that the substitution effect is larger than the income effect that results from the price increase for the private good *Q*. **(10 points)**

Answer: (i) A standard shape production possibility frontier is convex to the origin. The initial relative price line $-P_Q^0/P_Z^0$ tangents the production possibility frontier at $\{Q^0, Z^0\}$. A price increase on *Q*, $\Delta P_Q > 0$, implies that the relative price line becomes steeper (the red line) giving the solution $\{Q^{\Delta P_Q}, Z^{\Delta P_Q}\}$.



(ii) The income effect implies that the production possibility frontier moves outwards to the northeast. This move is due to increased income from the price increase on *Q*, and is an indirect effect. In most cases the direct effect (here, the substitution effect) is larger than the indirect effect (here the income effect), which in this case must be large and be stronger in the expansion in the *Z*-direction that the *Q*-direction to offset the strong decline in *Z*: $Z^0 \rightarrow Z^{\Delta P_Q}$. The latter is highly unlikely given the increase in P_Q which generally would induce producers to look at ways to move the frontier in the *Q*-direction.

(b) Suppose that the government wants to increase the production of the public good, *Z*, by increasing the price of the market good, *Q*. Barring income effects, what appears to be the most direct economic policy response to approximately restore the production level of Z prior to the price increase on Q. Explain your reasoning. **(10 points)**

Answer: The economically most direct economic policy response would be to restore the initial slope by increasing the payment for the public good by $\Delta P_Z > 0$, such that

$$\frac{P_Q^{\Delta P_Q}}{P_Z^0 + \Delta P_Z} = -\frac{P_Q^0}{P_Z^0}.$$

This would move the optimal allocation back along the production possibility curve. The term "approximately" in the way the question is formulated, relates to the income effects of first increasing P_Q and then to increase P_Z as shown in the fraction above.

(c) Now, suppose we look at public good production in agriculture, and that it suffices for the government that large increases in the production of a public good, Z, takes place on a low number of farms compared to the total number of farms. Moreover, assume that the government does not know farmers' costs of increasing the production of Z. (i) Explain why procurement auctions for management contracts are likely to bring cost savings compared to a per hectare fixed payment for increasing the production of Z under the above conditions. (ii) Which factors would influence your choice of auction format? Briefly justify the factors you list. **(10 points)**

Answer: (i) There are two key factors for the potential cost savings of procurement auctions over fixed payments: First, as the government does not know farmers' costs of meeting contract terms, there is a risk that the government would set payment too high, attracting high cost providers to accept the contract. Second, with contracts only awarded to a small share of farms, there would be competition for getting contracts. The competition for contracts would make farmers consider their opportunity costs (= the possible decline the income from producing Y) more carefully when bidding, resulting in increased likelihood of awarding contracts to farmers with low cost of increasing their production of Z.

(ii) As multiple contracts are to be awarded, only multi unit auctions will work. Multi unit auctions come in two forms: *discriminatory* and *uniform price* auctions.

Past experiences suggests that *discriminatory price auctions* often lead to lower expenditures on behalf of the regulator than *uniform price auctions*, but that the cost advantage of discriminatory price auctions declines as agents gain more experience with such auctions. Hence, if bidder experiences with auctions are limited, the extent of strategic bid adjustment is likely to be small, rendering cost savings compared to uniform price auctions.

Of the two auction forms, only *uniform price auctions* provide incentives for truthful bidding, i.e., that bidders bid their opportunity cost of getting the contract. This could be important for the government if knowledge about the true costs of the auction scheme is needed, for example for later fixed per hectare payments, or under strong demands for accountability for the use of government funds.

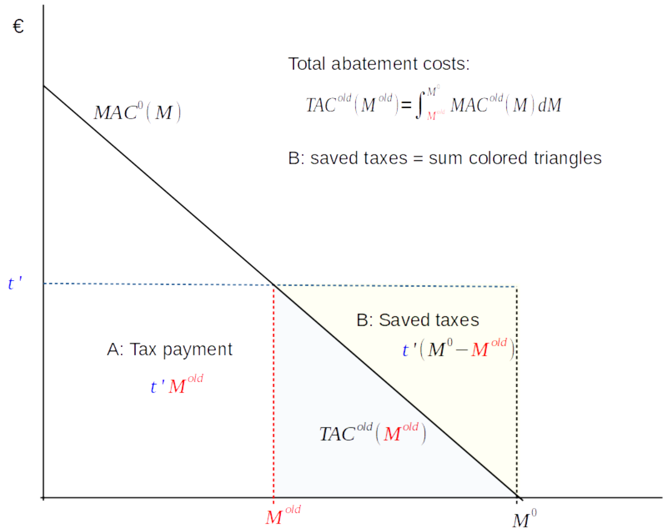
Question 3 (40 points)

The Norwegian government has just launched its climate plan 2021-2030. It is an ambitious plan that aims for reductions of climate gas emissions measured in CO_2-equivalents of about 50% from today's emissions. A central element in the plan is strong increases in the price of carbon emissions measured in CO_2-equivalents from aprx. NOK 800 per ton to NOK 2000 per ton.

In the following questions, we simplify matters somewhat and discuss the expected impacts of substantial increases in climate gas emission taxes.

(a) (i) Draw a graph clearly illustrating the *short term impacts* of an increase in CO_2-emission taxes on emissions, increases in abatement costs, and tax payments for an aggregate economy. (ii) Write down the relevant general formulas for increases in total abatement costs and tax payments. **(10 points)**

Answer: (i) Short term impacts mean that new technology is not available → movement along the initial MAC-curve. To simplify the graph I choose to set existing taxes as the reference level (t = 0) and M^0 as the existing emission level before the emission tax is increased. The emission tax rate is set at t'.



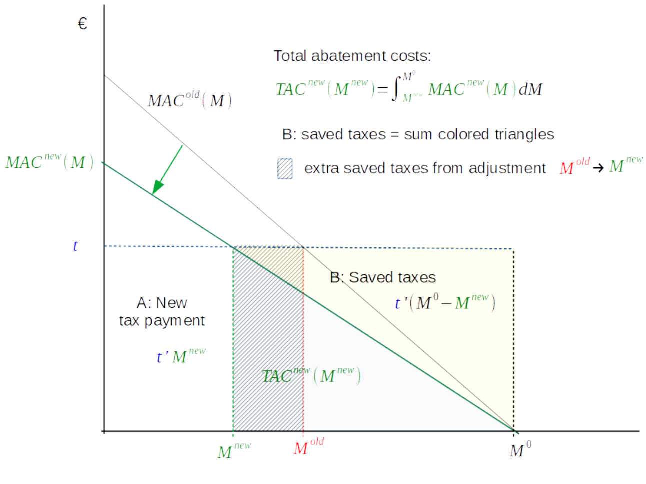
(ii) Tax payment: $t'M^{old}$

Total abatement costs:

$$TAC^{old}(M^{old})=\int_{M^{old}}^{M^0} MAC^{old}(M)\,dM$$

(b) What will be the longer term impacts of emission taxes? (i) Illustrate these impacts graphically, preferably by adding the changes to a copy of your graph form sub-question (a) and add the new information. (ii) Write down the adjusted formulas for the aggregate total abatement costs and tax payments. **(10 points)**

Answer: (i) Due to the existence of the tax for some time, agents have more chances of adopting new technologies and improved management practices. That rotates the MAC-curve counter clockwise as shown. The emission tax rate remains at t'. This yields a lower optimal emission level at M^{new}.



(ii) The new tax payment: $t'M^{new}$.

The new total abatement costs are:

$$TAC^{new}(M^{new})=\int_{M^{new}}^{M^0} MAC^{new}(M)\,dM$$

In a comment to the government's proposal, Statistics Norway (SSB) remarked that the large tax increases could reduce consumer purchasing power significantly, and that the government therefore should consider redistributing (some of) the climate emission tax revenues to consumers.

(c) (i) Explain why economists would point to reimbursing consumers, not businesses, for the tax increases. (ii) Write down a formula that captures the concerns raised by SSB on the overall welfare impacts of high emission taxes in the economy for a representative consumer. Comment verbally on your formula. **(10 points)**

Answer: (i) Because welfare is derived from consumption (does not need to be material consumption). Note that firms eventually are owned by consumers, and changes in firms' profits are therefore captured by the money income in consumers' indirect utility functions (or the tightness in consumers' budget constraints).

(ii) The most direct way to capture this is through the indirect utility function which expresses utility through money income, Y_i, and a vector of prices, **p**. Making taxes taxes paid in the indirect utility function is easily done by subtracting the sum of extra taxes paid, T_i from money income. This yields: $V_i(Y_i, \boldsymbol{p}) = V_i(Y_i - T_i, \boldsymbol{p})$.

Remark: this can also be done through ordinary utility maximization with a budget constraint: Max $U_i(\boldsymbol{q}_i)\, st.\, Y_i - T_i = \boldsymbol{p}\boldsymbol{q}_i$ (or its Lagrangian equivalent) which also gives full score.

(d) (i) What are the policy implications from polluter responses to emission taxes on the *design of tax refund schemes*? Explain briefly. (ii) Point to at least one possible way to deal with the implications in (i). Briefly justify your suggestion. **(10 points)**

Answer: (i) Emission taxes strengthen incentives for adopting new technologies or seeking better management practices. This rotation is captured in a counter clockwise rotation in the MAC-curve as in (b). This leads to shrinking emission tax revenues. Initial reductions in other taxes followed by increases of the same taxes as emission tax revenues decrease, create uncertainty regarding tax policies, in particular if firms and consumers reduce their emissions faster than expected.

(ii) Alternative approaches include:

- Partial reimbursements, where the amount not spent on reimbursements is saved to allow for more gradual adjustments of other taxes or reduce the financial burden of future societal obligations (like pensions). A disadvantage with such a strategy is that it does not solve the concerns of the SSB on reduced consumer purchasing power, in particular in the short run.
- Minor or no tax reimbursement and increased use of governmental funds (subsidies) for behavioral change (increased supports for adopting more climate friendly technologies). Once economic agents have adopted these technologies, the need declines for such technology adoption supports. Such a strategy is even less suited to meet SSB concerns as technology adoption also involves extra costs for agents as long as the supports do not cover the full costs of investing in new technologies.
- A combined use of technology investment supports could lower the need for high taxes to reach the desired climate gas emission targets implicit in the government's proposal. While such a proposal addresses the SSB concerns on not lowering consumer spending, supports to certain technologies could reduce innovation for other and even more cost saving solutions.

Other well argued ways of dealing with the issue of declining emission tax revenues as emissions are reduced may also give full score.

A final response option: Is it possible that the overall tax level in Norway is too low? Consider the following – the value of the current public services that Norwegian citizens receive currently exceed tax payments by almost NOK 50 000 on average per inhabitant (NOK 250 billion divided by 5.2 million inhabitants). This strategy does not meet SSB concerns on declining purchasing power at all, but takes a longer term perspective on sustainability and how we may choose to organize our society.