ECN 275/375 – Natural resource and environmental economics
12:15-15:15 March 7, 2025

All help aids allowed except assistance from others.
This test consists of three 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.

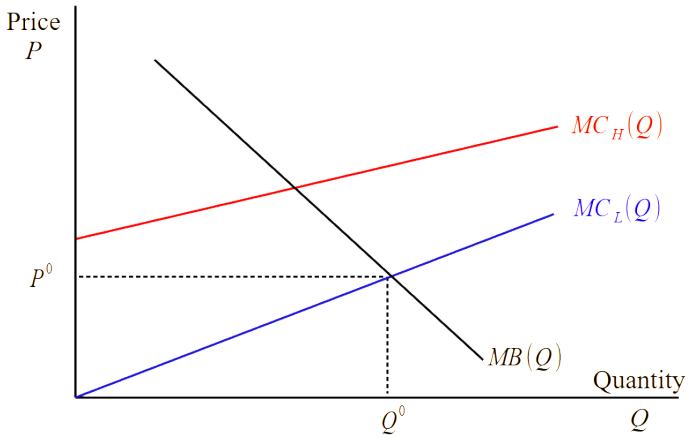
This test has been designed to limit the benefits of using artificial intelligence (AI) . If AI use is detected beyond reasonable doubt, unreported use leads to a score of zero. Students can use AI if they self-report such use on specific questions at a cost: A question with self-reported AI use reduces 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 (cfr. 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 two firms, L and H, each with marginal costs of producing a public good Q equal to $MC_L(Q)$ and $MC_H(Q)$. $MB(Q)$ represents the marginal benefits of the public good. Its optimal quantity is Q^0 with the existing production costs. It is paid for by a government subsidy to producers equal to P^0 such that total tax outlays are $T^0 = P^0 Q^0$. The figure to the right illustrates the situation:



(a) (i) Explain why the cost effective distribution of the optimal production quantity Q^0 is that the H firm produces $Q_H = 0$, and the L firm produces $Q_L = Q^0$.

(ii) Explain why this does not conflict with the standard definition of cost effectiveness that marginal costs should be equal at their chosen production levels. What is the situation in the figure called?

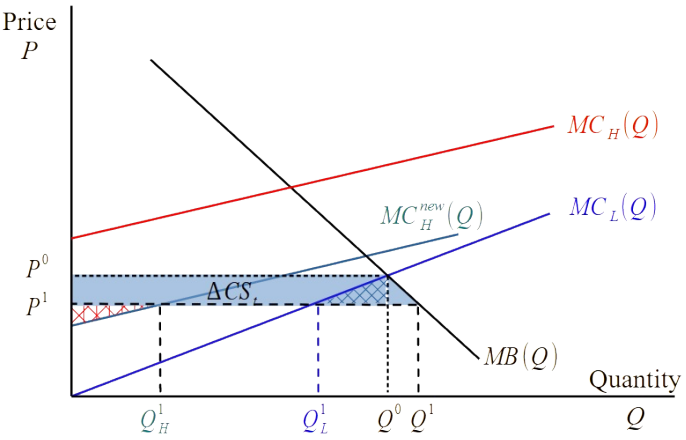
Answer: (i) In this particular case $MC_H(Q) > P^0 \forall Q > 0$, which means that the H firm chooses not to produce. Hence, only the L firm produces at the price P^0 . This distribution of the production between the two firms corresponds to the rationale for the cost effectiveness condition.

(ii) The standard definition of cost effectiveness is $MC_H(Q_H') = MC_L(Q_L')$ for the two agents H and L evaluated at their respective chosen production quantities Q_H' and Q_L' . That condition does not apply here because it is not profitable for H to produce. This situation is called a *corner solution*.

(b) Suppose the government wonders if consumer welfare would increase if it pays the investment costs of firm H so it can lower its marginal costs to become recipients of the production subsidy. Draw a situation with lower marginal costs of firm H in the figure below – a copy from part (a), and explain what happens.

Answer: The investment support lowers the marginal costs of the H firm so that it can produce with a profit.

The new production levels: H firm = Q_H^1 , L-firm = $Q_L^1 < Q_0$, and total production increases to $Q^1 = Q_H^1 + Q_L^1 > Q_0$. Hence, the price falls from P^0 to P^1 . This gives an increase in consumer surplus, ΔCS_t , per year.



(c) What is the condition for such investments in year zero to be welfare enhancing for the households in a country?

Answer: The condition for this investment to be welfare enhancing is that the investment is less than the discounted value of the change in yearly consumer surplus, ΔCS_t for the lifetime, *T*, of the policy. *r* is the discount rate. The conditions for varying time formats:

Discounted, continuous time:	Discounted, discrete time:	Without time/discounting
$I \le \int_{t=0}^{T} \Delta CS_t e^{-rt} dt$	$I \le \sum_{t=0}^{T} \Delta CS_t (1+r)^{-t}$	$I \le \Delta CS$

Remark 1: Full score is given without getting any of the net present value expressions. The main point is to get that the lower price increases the consumer surplus.

Remark 2: The net producer surplus falls as a result of the lower price as follows: For the H firm the producer surplus (rents) increases by the red crosshatched area, but the L firm looses producer surplus by the blue crosshatched area (not needed for full score).

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

The basic equation for monitoring and enforcement (ME) can be written as $\rho \ge \frac{\pi_N - \pi_C}{S}$,

where ρ is the minimum monitoring probability to secure compliance,
π_N is the agent's payoff under non-compliance,
π_C is the agent's payoff under compliance, and
S is the penalty when monitored and caught in violation (non-compliance).

(a) The above expression implies that the necessary monitoring probability, ρ , needs to increase when the agent gains more from non-compliance (cheating) compared to compliance, i.e. $\pi_N - \pi_C$ grows with the size of the violation, *v*.
(i) To monitor agents, the regulator needs to be able to observe the size of the violation, *v*. What property must the penalty function $S(v)$ have to addresses this concern?
(ii) Other concerns include that the regulator spends too much time pursuing minor violations, and that losses to society grow proportionally more than the size of the violation. Give an example of a penalty function that addresses these concerns? Briefly explain your reasoning behind this penalty function.

Answer: (i) Replace S in the basic ME equation with a penalty function that is increasing in the size of the violation, i.e. $\partial S(v)/\partial v>0$.

(ii) Penalties are only levied when $v>k$. Under this condition two penalty functions that address these concerns for $v>k$ are: $S(v)=S_0+\alpha(v-k)^2$ and $S(v)=S_0 e^{\alpha(v-k)}$ where $S_0>0$ is a fixed part of the penalty, and $\alpha>0$ is the variable component of the penalty, and k is a forgiveness parameter, i.e. small violations, $v<k$, are not penalized.

Concerns that losses grow proportionally more than the size of the violation can be countered by a convex penalty function in violation. This implies that the second order partial derivative is positive, i.e. $\partial^2 S(v)/\partial v^2>0$. This holds for $\alpha>0$. Other example specifications may meet the convexity condition for increasing violations..

Remark: The sizes of S_0 and α may differ depending upon the functional form chosen.

(b) In the reputation based model habitual non-compliers must pay a monitoring fee, M, whenever monitored, while habitual compliers do not because they are under a different set of rules. This changes the equation for compliance to:

$$\rho \geq \frac{\pi_N - \pi_C}{S+M}$$

(i) Using the above expression, explain why this reduces the necessary monitoring probability, ρ , in the reputation based model compared to the basic model. What is this effect called? (ii) Set up the expression for arriving at the above condition, and explain your reasoning behind this expression.

Answer: (i) As M is a positive number, the value of the denominator increases while the numerator is unchanged compared to the basic equation. Hence, the monitoring probability for compliance decreases compared to the basic model. This effect is called the *compliance rent*.

(ii) The intuition behind is the same as for the basic model, i.e. the expected payoffs from compliance must be greater than or equal to the expected payoffs non-compliance. Adding monitoring costs for habitual non-compliers, M when monitored with probability ρ gives the additional term ρM , that is subtracted from the state contingentpayoff for habitual non-compliers. This gives:

Expected payoff habitual compliance ≥ Expected payoff habitual non-compliance

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

(c) From your starting expression in (b-ii) show how you arrive at the stated modification of the necessary monitoring probability to provide incentives for compliance.

Answer: Repeating the condition from (b-ii) but dropping the color on ρM yields:

Expected payoff habitual compliance ≥ Expected payoff habitual non-compliance

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

$$\rho\pi_C+\pi_c-\rho\pi_C \geq \rho\pi_N-\rho S-\rho M+\pi_N-\rho\pi_N \quad \text{(same color cancel)}$$

$$\pi_c \geq -\rho M-\rho S+\pi_N=-\rho(S+M)+\pi_N$$

$$\rho(S+M) \geq \pi_N-\pi_C$$

$$\rho \geq \frac{\pi_N-\pi_C}{S+M} \quad \text{(condition: } S+M>0\text{)}$$

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

Three of the most notable negative externalities from using cars as a means of transportation are:

i. Greenhouse gas (GHG) emissions, though only from fossil fuel powered vehicles, hereafter FV.
ii. Particulate matter due to wear from roads and tires.
iii. Congestion which increases the risk of accidents and makes travel more time consuming during peak traffic hours.

The setting is like Norway, i.e. the electric vehicle (EV) share of new private cars sold is about 90%. You, an expert in environmental economics, are asked to comment on the government plans to develop a more coherent environmental policy for private cars aiming to reduce the above three externalities from private (household) transport.

(a) One of the proposals is to increase the fossil fuel taxes to reduce the kilometers driven by private cars to lower all of the three mentioned externalities. Comment on the **weak sides** of this proposal.

Answer main points:

- Limited impact on all three externalities as the share of FVs is low.
- Particulate matter (PM) emissions may even increase as higher fossil fuel taxes may further increase the share of EVs as EVs are generally heavier and accelerate faster, thereby increasing PM emissions.

(b) The Ministry of finance supports the introduction of higher fuel taxes as it makes it easier to lower or abolish the current subsidies for buying EVs. (i) Explain the conditions that need to be in place for upholding or increasing the share of new EVs sold. (ii) Which are the other major expected benefits of replacing subsidies for buying EVs with fossil fuel taxes? For each major benefit you list, explain why this is a benefit to society.

Answer: (i) The main issue here is the relative lifetime costs of FVs versus EVs. Specifically, if net present value for the expected lifetime cost of buying and using FVs and EVs remain fairly unchanged, the share of EVs sold would remain or even increase over time.

(ii) The main benefits with brief explanations are:

- Current expenses on the state budget are replaced with income: Reducing other distortionary taxes or frees up government funds for other good purposes like better education or health care.
- It lowers the rebound effect: It increases the costs of buying a new car. This provides incentives for extending the lifetime of new cars, i.e. driving less. That makes substitution to public transport more profitable. Suppose this benefit fails to materialize. To correct for this, the government may increase congestion fees or reduce ticket prices for using public transportation.
- Reduced congestion and fewer traffic accidents for the same reasons as in the previous bullet.

(c) The government also considers implementing road pricing. Road pricing means that each vehicle is tracked in terms of where and when. Based upon distance driven, the weight of the vehicle, and the time of driving when congestion is an issue, drivers are charged accordingly. (i) Explain how road pricing will impact the three externalities mentioned.

(ii) What are the main obstacles against introducing road pricing. Briefly comment on those objections, and how concerns about these objections can be met.

Answer: (i) Road pricing enables issuing targeted taxes (separate taxes for each emission) based upon time and location of a vehicle: a kilometer fee for direct use of the car, a wear and tear factor based upon the type of road (PM emissions are higher for roads with high speeds), and the damages of PM emissions (perceived higher in urban areas due to higher population densities with more people per square km), than rural areas. This would entail three emission taxes which all rests on the same mechanism for gathering the information needed for collecting these emission taxes.

(ii) The main obstacles are:

- Privacy rights. This kind of surveillance of private persons opens for concerns that the collected data will be used for other purposes. Ways to reduce these concerns are strict regulations on who should have access to these data and how the data can be used (specifically, uses that are illegal).

  Remark: Maybe privacy concerns are not that massive given most people's behavior where we voluntarily let our mobile phones tell mobile phone operators and service providers about our location.
- The costs of installing sensors and collecting the data. This concern could be reduced by allowing people to pay a fixed fee per year or month not to be tracked. Those who drive older cars soon to be scrapped (or who have privacy concerns) would then opt out. Such a fee needs to be sufficiently high that most people do not opt-out.

(d) *Tinbergen's rule* implies that **to achieve multiple policy targets, one needs one policy instrument per target to reach the target**. The rule originates from macroeconomics, but has been useful for all types of regulation.

Explain how the *Tinbergen rule* aligns (is consistent) with your answer on (c). If you think your answer in (c) is inconsistent with the Tinbergen rule, explain how you would modify your answer in (c).

Answer: As long as your answer in (c) has three separate instruments for the three stated policy objectives, you are fine provided you see this, and make a comment consistent with one instrument for each objective.

If you think your answer is inconsistent, your score depends on how well you spot the inconsistencies and what modification you suggest.

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