NTNU
Det skapende universitet

Institutt for samfunnsøkonomi

Eksamensoppgave i SØK1101 – Miljø- og ressursøkonomi /

Environmental and Resource Economics

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Eksamensdato: 5. juni 2014

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Sensurdato: 27. juni 2014

Hjelpemiddelkode/Tillatte hjelpemidler: C /Flg formelsamling: Knut Sydsæter, Arne Strøm og Peter Berck (2006): Matematisk formelsamling for økonomer, 4utg. Gyldendal akademiske.
Knut Sydsæter, Arne Strøm, og Peter Berck (2005): Economists' mathematical manual, Berlin.
Enkel kalkulator Casio fx-82ES PLUS, Citizen SR-270x, SR-270X College eller HP 30S

Målform/språk: 2 sider bokmål, 2 sider nynorsk og 2 sider engelsk

Antall sider: 7 (inkl forside)

Antall sider vedlegg: 0

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Bokmål

Eksamen består av to oppgaver. Begge skal besvares. Ved sensur teller oppgave 1 og 2 henholdsvis 40% og 60%.

Oppgave 1 (40%)

a) Forklar hvorfor likevektspris og kvantum i et perfekt frikonkurransemarked maksimerer samfunnsøkonomisk overskudd (social surplus).

b)
   i) Definer begrepet eksternalitet og gi eksempler på eksternaliteter.
   ii) I tilfellet med en negativ eksternalitet, vis og forklar hvorfor et uregulert marked kan gi for stor produksjon og et effektivitetstap.

c)
   i) Definer begrepet kollektive goder (public goods) og gi eksempler på kollektive goder.
   ii) Kan vi stole på at det private uregulerte markedet vil realisere effektiv mengde av det kollektivt gode? Begrunn svaret.

Oppgave 2 (60%)

Du skal betrakte et tilfelle hvor utslipp fra forurensende bedrifter er uniformt spredt, det vil si hvor skadekostnaden er uavhengig av lokaliseringen til den enkelte forurensende bedrift. Marginal skadekostnad er gitt ved $MD = \beta Q$, hvor $\beta > 0$ og konstant. Aggregert marginal kontrollkostnad er gitt ved $MCC = \alpha R$, hvor $\alpha > 0$ og konstant. Q og R er henholdsvis totalt utslippsnivå og totalt antall utslippsreduksjoner summert over alle forurensende bedrifter.

a) Gi en tolkning av marginal skadekostnad og marginal kontrollkostnad. Bestem realisert utslippsnivå og illustrer grafisk tilhørende skade- og kontrollkostnad ved fravær av offentlig regulering av utslipp (business as usual).

b) Anta at du er en samfunnsplanlegger som skal bestemme tillatt utslippsnivå. Utled og tolk betingelsen som bestemmer optimalt tillatt utslippsnivå. Illustrer grafisk. Sammenlign dette utslippsnivået med nivået ved 'business as usual' og forklar hvorfor de avviker fra hverandre.

Anta at to bedrifter forurenser, bedrift 1 og 2. Marginal kontrollkostnad for bedrift 1 og 2 er gitt ved $MCC_1 = \alpha_1 R_1$ og $MCC_2 = \alpha_2 R_2$, hvor $\alpha_1 > \alpha_2 > 0$. Anta at bedrift 1 og 2 har identiske utslippsnivå ved 'business as usual'.

c) Utled og tolk betingelsene som beskriver hvordan du vil allokere utslippsreduksjonene mellom bedrift 1 og 2 for å nå målsettingen fra b) til lavest mulig kontrollkostnad. Illustrer grafisk.

d) Forklar og vis grafisk hvordan en avgift per enhet utslipp påvirker den individuelle bedrift sitt valg av utslippsnivå. Hvordan må skattesatsen settes for å sikre kostnadseffektive utslippsreduksjoner?

e) Forklar og vis grafisk hvordan handel med utslippstillatelser (kvotehandel) kan bidra til kostnadseffektive utslippsreduksjoner.

f) Hvilken type regulering vil du velge – avgift eller kvotehandel? Diskuter.

g) Anta nå at du har ufullstendig informasjon om aggregert marginal kontrollkostnad. Hvordan vil dette påvirke valget mellom avgift og kvotehandel? Diskuter og illustrer grafisk.

Nynorsk

Eksamen består av to oppgåver. Du skal svare på begge. Ved sensur teller oppgåve 1 og 2 høvesvis 40% og 60%.

Oppgåve 1 (40%)

a) Forklar kvifor likevektspris og kvantum i ein perfekt frikonkurransemarknad maksimerer samfunnsøkonomisk overskot (social surplus).

b)
   i) Definer omgrepet eksternalitet og gi eksemplar på eksternalitetar.
   ii) I tilfellet med ein negativ eksternalitet, vis og forklar kvifor ein marknad utan reguleringar kan gi for stor produksjon og eit effektivitetstap.

c)
   i) Definer omgrepet kollektive godar (public goods) og gi eksemplar på kollektive godar.
   ii) Kan vi stole på at den private marknaden utan reguleringar vil realisere effektiv mengde av eit kollektivt gode? Grunngje svaret.

Oppgåve 2 (60%)

Du skal betrakte et tilfelle kor utslipp frå bedrifter som forureinar er uniformt spreidd, det vil si kor skadekostnaden er uavhengig av lokaliseringa til den enkelte forureinande bedrift. Marginal skadekostnad er gitt ved $MD = \beta Q$, kor $\beta > 0$ og konstant. Samla marginal kontrollkostnad er gitt ved $MCC = \alpha R$, kor $\alpha > 0$ og konstant. Q og R er respektive totalt utslippsnivå og total mengde utslippsreduksjonar summert over alle forureinande bedrifter.

a) Gi ei tolking av marginal skadekostnad og marginal kontrollkostnad. Kva er realisert utslippsnivå og tilhøyrande skade- og kontrollkostnad i tilfelle utan offentlige reguleringar av utslipp (business as usual)? Illustrer grafisk.

b) Anta at du er ein samfunnsplanlegger som skal bestemme tillatne utslippsnivå. Utled og tolk føresetnaden som bestemmer optimalt tillatne utslippsnivå. Illustrer grafisk. Samanlikn dette utslippsnivået med nivået ved 'business as usual' og forklar kvifor dei avvik frå kvarandre.

Anta at to bedrifter forureinar, bedrift 1 og 2. Marginal kontrollkostnad for bedrift 1 og 2 er gitt ved $MCC_1 = \alpha_1 R_1$ og $MCC_2 = \alpha_2 R_2$, kor $\alpha_1 > \alpha_2 > 0$. Anta at bedrift 1 og 2 har identiske utslippsnivå ved 'business as usual'.

c) Utled og tolk føresetnadene som beskriver korleis du vil allokere utslippsreduksjonane mellom bedrift 1 og 2 for å nå målet frå b) til lavast mulig kontrollkostnad. Illustrer grafisk.

d) Forklar og vis grafisk korleis ein avgift per eining utslipp påverkar den individuelle bedrift sitt val av utslippsnivå. Korleis må skattesatsen setjast for å sikre kostnadseffektive utslippsreduksjonar?

e) Forklar og vis grafisk korleis handel med utslippsløyva (kvotehandel) kan bidra til kostnadseffektive utslippsreduksjonar.

f) Kva for ein type regulering vil du velje – avgift eller kvotehandel? Diskuter.

g) Anta nå at du har ufullstendig informasjon om samla marginal kontrollkostnad. Korleis vil dette påverke valet mellom avgift og kvotehandel? Diskuter og illustrer grafisk.

English

The exam consists of two problems. Both should be answered. By censoring problems 1 and 2 are weighted by 40% and 60%, respectively.

Problem 1 (40%)

a) Explain why the equilibrium price and quantity in a perfect competitive market equal the price and quantity that maximizes social surplus.

b)

i) Define the term externality and provide examples of externalities.

ii) In case of a negative externality, demonstrate and explain why an unregulated competitive market may produce an inefficiently high level of output and an efficiency loss.

c)

i) Define the term public goods and provide examples of public goods.

ii) Can we rely on the private market to provide the efficient level of a public good? Justify your answer.

Problem 2 (60%)

Consider a case where emissions from polluting firms are uniformly mixed, that is, the damage cost is independent of the location of the individual polluting firm. The marginal damage cost is given by $MD = \beta Q$, where $\beta > 0$ and constant. Aggregate marginal control cost (i.e., marginal cost of reducing emissions) is given by $MCC = \alpha R$, where $\alpha > 0$ and constant. Q and R are total emission level and total number of emission reductions aggregated over all individual firms.

a) Give an interpretation of the marginal damage cost and the marginal control cost. Determine the emission level and illustrate graphically the corresponding control and damage cost in absence of government regulation of emissions (business as usual).

b) Assume you are a social planner and are about to determine the allowable emission level. Derive and interpret the condition for the optimal allowable emission level. Illustrate graphically. Compare this emission level with the 'business as usual' level and explain why they differ.

Assume that there are two polluting firms, 1 and 2. The marginal control cost for firms 1 and 2 are given by $MCC_1 = \alpha_1 R_1$ and $MCC_2 = \alpha_2 R_2$, where $\alpha_1 > \alpha_2 > 0$. Assume that the 'business as usual' emission levels are identical for firms 1 and 2.

c) Derive and interpret the conditions that describe how you will allocate the reduction responsibilities across the two firms in order to reach the target set in b) at a lowest possible control cost. Illustrate graphically.

d) Explain and demonstrate graphically how a tax per unit emission will affect the individual firm's choice of emission level. How should the tax rate be set in order to achieve cost effective emission reductions?

e) Explain and demonstrate graphically how trade in emission allowances (quota trading) can result in cost effective emission reductions.

f) What policy would you choose – taxes or quota trading? Discuss.

g) Assume now that you have incomplete information about the aggregate marginal control costs. How will this affect your choice of policy – taxes versus quota trading? Discuss and illustrate graphically.

Comments on answer to the exam in SØK1101 spring term 2014

Candidate: 10121

The exam consists of two problems. Problem 1 is on competitive markets, market failures, and efficiency. Problem 2 is on optimal emission targets, cost effective emission reductions, and regulation. The present set of answers is evaluated to grade A. Although there are some shortcomings in the answer to some of the sub-questions, the candidate demonstrates a high degree of independence in most cases.

Problem 1

This problem is relatively easy and all students should be able to answer it at least in a satisfactory way. It is weighted 40%.

a) Although this was considered a plank exercise, many answers to this question suffered from shortcomings. It is nice that this candidate demonstrates the market equilibrium and defines the terms consumer-, producer-, and social surplus. However, the candidate fails to explain why the private marginal willingness to pay (PMWP) and the private marginal cost of producing the good (PMC) just equals the social marginal willingness to pay (SMWP) and the social marginal cost of production (SMC), respectively, in a perfect competitive market. Unfortunately this applies to most candidates to this exam. An excellent performance should present the assumptions behind a perfect competitive market – including the assumptions of private goods and well-defined and protected property rights – and explain why the assumptions ensure that PMWP=SMWP and PMC=SMC and hence, that the social surplus is maximized in equilibrium. Private goods and well-defined and protected property rights means that all goods have characteristics that permit exclusive individual return/utility on the part of the owner. Hence, no externalities or public goods exist.

b) i) An externality is an effect of one economic agent on another that is not taken into account by normal market behavior. That is, the effect is not reflected in the market price. This candidate mentioned this point. This is important because if the effect was reflected in the market price, then there would not be any efficiency loss involved. The candidate provides some examples, but it would have been nice to also see a short explanation how these situations create external costs. For instance, in what way are ‘accidents from car traffic’ an externality? One can argue that the individual driver will take into account that the risk of a collision increases if he/she increases speed because the cost of damages to his/her car and/or the cost of personal injuries to him/her are private costs that are internalized in the private decision. However, it is reasonable to believe that the individual driver ignores the fact that the risk of collision increases for all if he/she increases speed, unless this risk is reflected in the market prices. In this way ‘accidents from car traffic’ can be seen as an example of a negative externality.

ii) The figure presented and the graphical explanation why an efficiency loss occurs is good and demonstrates understanding and independence. The candidate also gains credit for mentioning the Coase theorem in the section “Addition to #1B”. Unfortunately, although the Coase theorem is highly relevant here because in some cases private negotiations may solve the externality problem without public regulations, many students do not mention it at all. However, the answer provided by this candidate would be further improved if the candidate had highlighted the underlying problem in case of negative externalities, namely the lack of well-defined and protected property rights. Take for instance a production process causing environmental damaging emission to air that impose a cost to the society due to some negative health effects. Because there are no private property rights defined to the air, the unregulated producer aiming at maximizing private profit will fail to take this cost into account when determining its output level. Unfortunately, most students fail to relate the problem of externalities to the assumptions behind a perfect competitive market.

c) i) A pure public good is *non-rival* and *non-excludable* in consumption. As explained in a clear way by this candidate *non-excludable* means that nobody can be excluded from the benefits the good confers, whether they contribute to its provision or not, whereas *non-rival* means that one individual’s consumption of the good does not diminish the amount available to others. The candidate mentions the climate as an example and explains well why the climate is a public good. Other examples include national defense, street light, firework (private or public), recreational areas (if not crowded), clean air, and clean water.

ii) The definition of public goods implies that everyone consumes the same quantity of the good. Due to non-excludability individuals can benefit from the good even without contributing to its provision. It is nice that this candidate argues along these lines and identifies the problem of free riding. The answer could be further improved with a discussion of the corresponding difficulties in securing financing of the good. However, a large fraction of the students failed to even mention the free rider problem and seen in that context, this candidate answers the question in a very good way.

Problem 2

This problem is weighted 60%.

a) Emissions impose a damage cost on the society, e.g., negative health effects, biodiversity loss, damage to recreational areas and so forth. The marginal damage cost (MDC) measures the increase in damage cost of an additional unit emission. The control cost is the cost of reducing emissions: changing the input mix, reducing quantity produced etc. The marginal control cost (MCC) measures the increase in control costs when emissions are reduced by an additional unit. It is very nice that the candidate gives examples of damage and control costs; many students forget to do so. MDC and MCC are illustrated graphically in a correct way. The business as usual emission level is correct and so are the corresponding damage cost and control cost. What is missing in this answer is a short presentation of the objective of the firms: In an unregulated market firms follow their self-interest and minimize costs by choosing the business as usual emission level.

b) The answer to this question is very good and the candidate demonstrates high degree of independence. The decision problem of the social planner is presented and solved and a graph is presented and thoroughly explained to illustrate the main points. Very well done.

c) Again it is nice to see that the candidate presents and solves the decision problem of the social planner. The graph and the corresponding explanation demonstrate good intuition and understanding. Very well done.

d) Again the candidate presents and solves the decision problem of the firm. The solution is well demonstrated and explained graphically. However, the candidate makes a mistake when referring to the areas in the graph at page 20: The total cost at R* should be b+T. Nevertheless, the overall impression is that the candidate understands the topic very well. Because both firms reduce their emission level until their marginal control cost equals the tax rate, uniform tax rates will ensure $MCC_1=MCC_2$. This is very well explained by the candidate.

e) The graph presented and corresponding explanation gives a good answer to the question. It could have been mentioned that the government can allocate quotas for free or by auction prior to quota trading, or the role of payment in this stage could have been discussed when answering question f). The underlying assumption of a perfect quota market is not mentioned, although it is a necessary assumption for emission reductions to be allocated in a cost effective way: With a perfect market all firms face the same quota price and hence $q=MCC_1=MCC_2$.

f) A very good answer to this question should provide a *discussion* of taxes versus quota trading by explaining their arguments and not simply list up bullet points (as many students unfortunately do). The discussion should be along the following criteria: target effectiveness; cost effectiveness; incentives to invest in advanced control technology; distribution (polluter pays principle); and political feasibility. This candidate presents advantages and disadvantages of the two along these criteria. However, some of the points could be explained further. For instance, why is it claimed that quota trading does not generate income to the state? Here it would have been nice to separate between cases where quotas are distributed for free or by auction in the step prior to quota trading (see also my comment to question e) above). Auctioning provides income to the state. Auctioning will also strengthen the incentive to invest in new technology.

g) Surprisingly, although we had analysed the role of asymmetric information about marginal control costs (see Perman et al. chapter 7.3.3.1), very few students were able to mention the main points and even fewer were able to offer a proper analysis. Incomplete information about the aggregate marginal control cost adds another dimension to the choice between emission taxes and quota trading. The intention was for the students to demonstrate graphically the efficiency loss due to incomplete information in case of taxes and in case of quota trading using a figure similar to figures 7.3-7.6 in Perman et al. When the marginal damage cost is steep relatively to the marginal control cost ($\beta > \alpha$), e.g. toxins and thresholds, quota trading is preferred. When the marginal damage cost is less steep relatively to the marginal control cost ($\beta < \alpha$), e.g. stock pollution like CO2, taxes are preferred.

This candidate, as most candidates, failed on this question. However, because questions a)-f) are answered in a highly competent and satisfactory way, the overall impression is that this candidate understands the economics of pollution targets and regulations very well and is able to perform an independent analysis of these issues.

#1A

Sosial surpluss SS is given by the sum of the producers surpluss PS and the consumers surpluss CS. That is:

$$SS = PS + CS$$

SS: sosial surpluss.

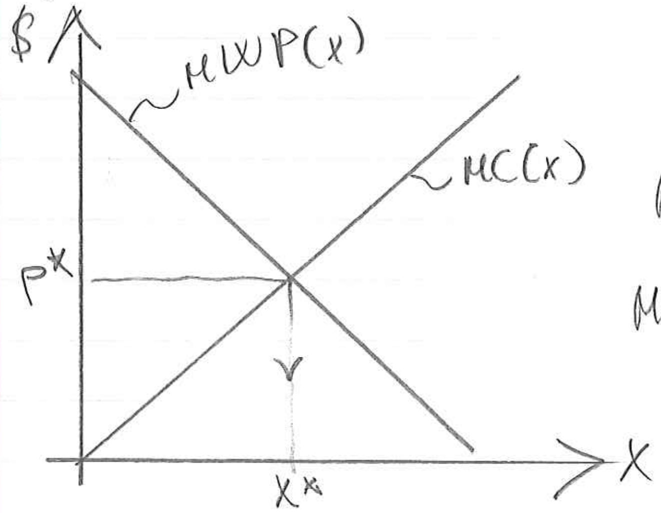
PS: Producers surpluss. - An economical measure of the satisfaction of the producer, given by analysing the difference between the producer marginal costs and the market price.

CS: Consumers surpluss. - An economical measure of the satisfaction of the consumer, given by analysing the difference between the consumers marginal willingness to pay, and the market price.

Generally the producers marginal costs is given as a function which increases with production, MC(x). The consumers marginal willingnes to pay MWP(x) is given as a function decreasing with production.

Mark: We could also denoted MWP = D - demand and MC = S - supply.

Graphically this is given as:



X - produced quantity
$ - price
MC(x) - Marginal control costs.
MWP(x) - Marginal willingness to pay.

The graph shows how MC increases with X and MWP decreases with X.

For a perfect competative market, with perfect information, no distribution costs etc, the marginal willingness to pay MWP(x) will exactley equal the marginal control costs MC(x). That is, the price the consumer is willing to pay exactley equals the price the producer demands. The price is denoted in the graph as P* - the market price, and the quantity is denoted as X*.

Thus as we see, for a perfect competitive market, the equilibrium price and quantity P* and X* is given by

$$\boxed{MC(X^*) = MWP(X^*)}$$

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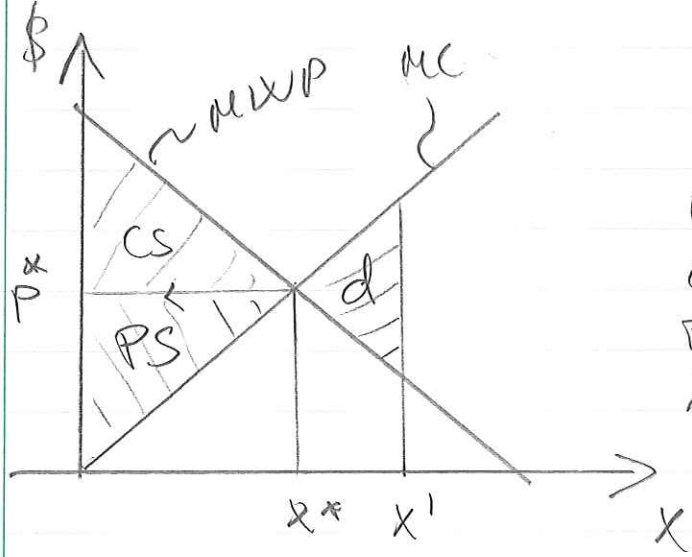
If we than return to the sosial surpluss, the first order criterion for maximization is given derivation.

$$\max_x \{SS(x) = PS(x) + CS(x)\}$$

$$\Rightarrow \boxed{MWP(x) = MC(x)}$$

Thus as we see, the first order criterion for maximizing the sosial surpluss equals the criterion which gives the equilibrium price and quantity in a perfect competitive market.

This can ones more be seen graphically:



$ - price
MC - marg cost
MWP - marg will to pay
CS - consumers surpluss
PS - producers surpluss
x - quantity.
d - efficiancy loss

The graph shows how the sum of PS and CS is maximized for the equilibrium prize and quantity.

It also shows how there would be a effisiancy loss d if the production were higher than optimal X' > x*. The reason for this is that there would be a missmatch between marginal costs and marginal willingness to pay (supply and demand). The MWP would be lower than the MC, resulting in an effisiancy loss given by d. The efficiancy loss would be subtracted from the sosial surpluss, making it smaler than optimal. That is:

$$SS^* = CS + PS$$
$$SS' = CS + PS - d$$

$$\Rightarrow SS' < SS^*$$

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#1B

(i)

An externality is defined as the effect of one economical agent on another, that is not taken into account by normal market behaviour. That is, the effect is not reflected on the market price.

Externalities can be both positive and negative. Examples of negative externalities are noise, pollution, and accidents from car trafic. (These are consumer-consumer externalities, as they are inflected by the consumer on the consumer.)

#1B

(ii)

An unregulated free market will often fail to initialize externality costs from their production. This will result in the sosial marginal costs SMC being higher than the producer marginal costs MC. The difference SMC − MC equals the damage costs from externalities DC.

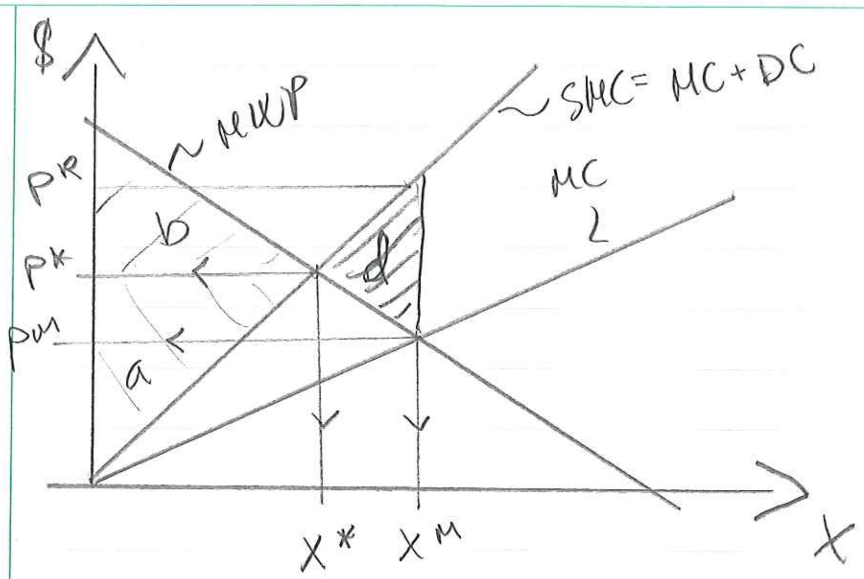
The market will determine the equilibrium price and quantity according to the criterion given in #1A, that is:

$$MWP(x^m) = MC(x^m)$$

However, as SMC > MC, this will result in the quantity x^m being higher, and the market price P^m being lower than what is optimal.

The producer will pay less for a good than the costs of producing it. The extra costs will be enflicted on the sosiety, giving an efficiancy loss which reduces the social surplus.

The graph on the next page illustrates this.



* Thus it decreases towards zero for $x^M \to x^*$ and $P^R \to P^M$ which is logical.

The graph shows the MWP, and the two different costs. As we see, the free market equilibrium gives a larger quantity, and a lower market price than optimal. $P^M < P^*$, $x^M > x^*$

The real costs of producing a quantity of x^M is denoted as P^R. As we see, the first order criterion for maximizing social surpluss is violated; $MWP(x^M) < SMC(x^M)$, and we get an efficiancy loss denoted as d on the figur, which is to be subtracted from the social surpluss

That is: $SS^* = a + b$
$SS^M = a + b - d$. $\}$ $SS^* > SS^M$

The efficiancy level d is in this figur given by:

$$d = \frac{1}{2}(P^R - P^M)(x^M - x^*) \; *$$

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#1c

(i)

A public good is defined as a good that is non-excludaple, and non-rival.

Non excludable means that it is impossible to exclude individuals from enjoying the benifits of the good, regardless of if they payed for it or not.

Non-rival means that one individuals consumption of the good does not destroy other individuals possibility to consum.

Climate is an example of a public good, as it can not be "used up", and the benifits of a better climate benifits all (non-rival). Moreover it is impossible to exclude someone from the benifits of a beter climate, even if they did not pay for abatement.

Another example of an non-rival, non-excludable public good would be public fireworks.

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#1C

(ii)

The private market can not be relied on to provide the efficiant level of a public good. Moreover the precense of public goods may be one of the reasons why markets fail.

The reason for this is the so called free-rider instentive. As no one can be excluded from public goods, we may easily get a situation where some individuals free ride on others. The enjoy the benifits of the public good, without paying for it themselves. This may forinstance be the case for distribution of pollution abatement between countries.

The free rider instentive makes one agent take a to large share of the costs of the good, and the efficiant level will not be obtained.

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Addition to #1B

Inefficiancies caused by externalities is due to the absence of property rights. According to the Coase theorem it does not matter who is assigned property rights, as long as some on is, the efficiant sollution can be obtained on basis of negotiation.

The rason for the negotiation is that one pary wil be willing to pay more, (typically the marginal willingness to pay equals the damage costs) to reduce production, than this other party demands in compensation.

Thus assigning property rights might be a sollution to the problem.

Another possible sollution is trough a tax equal to the damage cost.

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#2A)

Marginal damage cost is the the damage costs of emitting one more unit of pollution to the environment The marginal damage costs may be the costs of environmental damages, health effects from pollution, global warming etc. As we see also in this case MD is increasing with increasing level of emission. In this equation

$$MD = \beta \cdot \varphi \;;\; \beta > 0,$$

β denotes a constant in the form $\frac{kr}{unit}$, which accounts for the damages pr unit emission. The area under the marginal damage cost curve φ is the total damage costs. $TDC = \int_0 MD(\varphi)\, d\varphi$.

Marginal control costs is the costs of reducing the emissions by one more unit. The marginal control costs may be the costs of investing in new pollution reducing technology, reducing production, more advanced control systems etc. The equation for MCC yelds.

$$MCC = \alpha \cdot R \;;\; \alpha > 0$$

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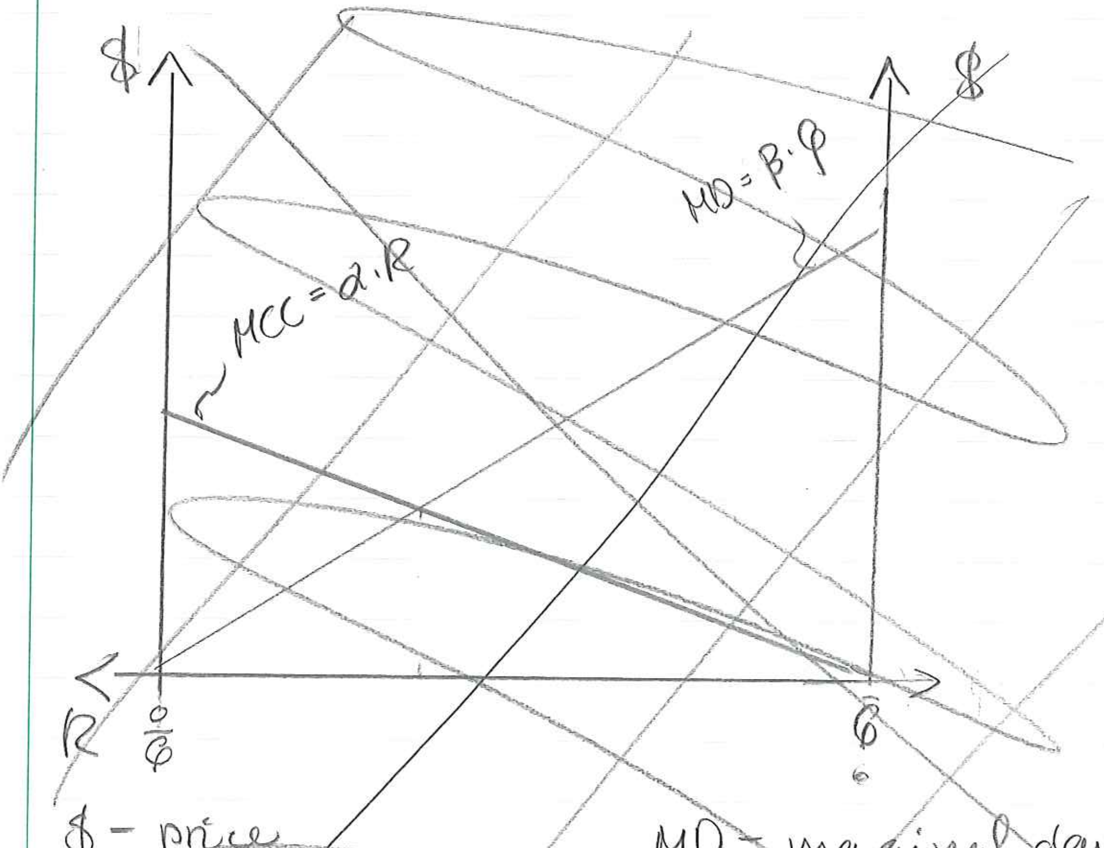
As we see the MCC is increasing with increasing reduction. Here the reduction parameter equals

$$R = \bar{\varphi} - \varphi$$

Where $\bar{\varphi}$ is the emission with zero abatement and φ is the emission level after reduction. Same φ as in the $MD = \beta\varphi$ equ. α is a positive constant, in the form $\frac{kr}{unit}$, which accounts for the cost pr unit reduction.



\$ - price MD - marginal damage costs

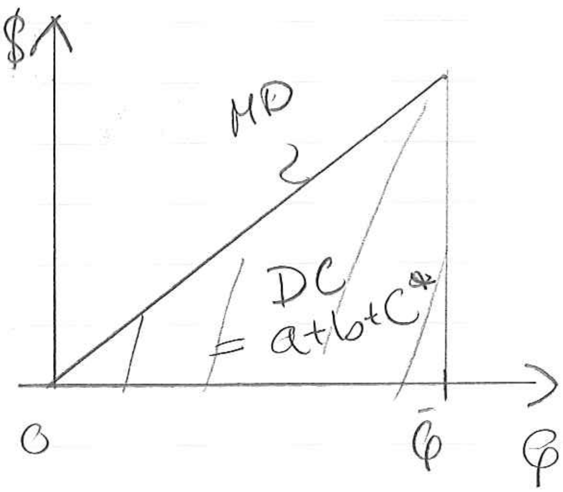
R - reduction

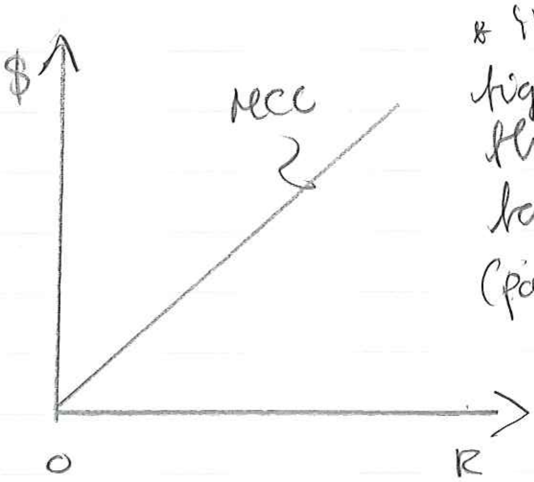
φ - emission level MCC - marginal control costs.

In the absence of governmental regulation the polluting firms will not initiate the externalities of the damage costs, hence they will not reduce their emissions. Thus we have:

$\varphi = \varphi_{max} = \bar{\varphi}$ $\quad MD(\varphi) = \beta \cdot \bar{\varphi}$

$R = \bar{\varphi} - \bar{\varphi} = 0$ $\quad MCC(R) = \alpha \cdot 0 = 0$





* in the figure in the next task. (page 15)

The graphs show how MD increases with φ, and MCC increases with R. For zero abatement (buisnis as usual) R=0 and $\varphi = \bar{\varphi}$. Thus

Total control costs $CC = 0$

Total damage costs $DC = \bar{\varphi} \cdot MD(\bar{\varphi}) \cdot \frac{1}{2} = \boxed{\frac{\beta}{2} \bar{\varphi}^2}$

As we see the damage costs are huge. This is not an efficiant solution. The answer could also be justified by a graph showing MD and MCC in the same drawing, as is done on the next question.

#2B

The sosial planner wil try to minimize the total emission costs. Where the total emission costs are given by the total damage costs of emitting the pollutant, pluss the total control costs of reducing to the given emission level. That is:

$$TC(\varphi) = DC(\varphi) + CC(R)$$

The minimization problem for the sosial planner is:

$$\min_{\varphi, R} \{ DC(\varphi) + CC(\bar{\varphi} - \varphi) \}$$

The first order criterion for this is given by derivation. That is

$$MD(\varphi) = MCC(\bar{\varphi} - \varphi) = MCC(R)$$

Thus the sosial planner wil solve for the optimal alowable emission level, to obtain minimum emission costs.

This is shown graphically on the next page:

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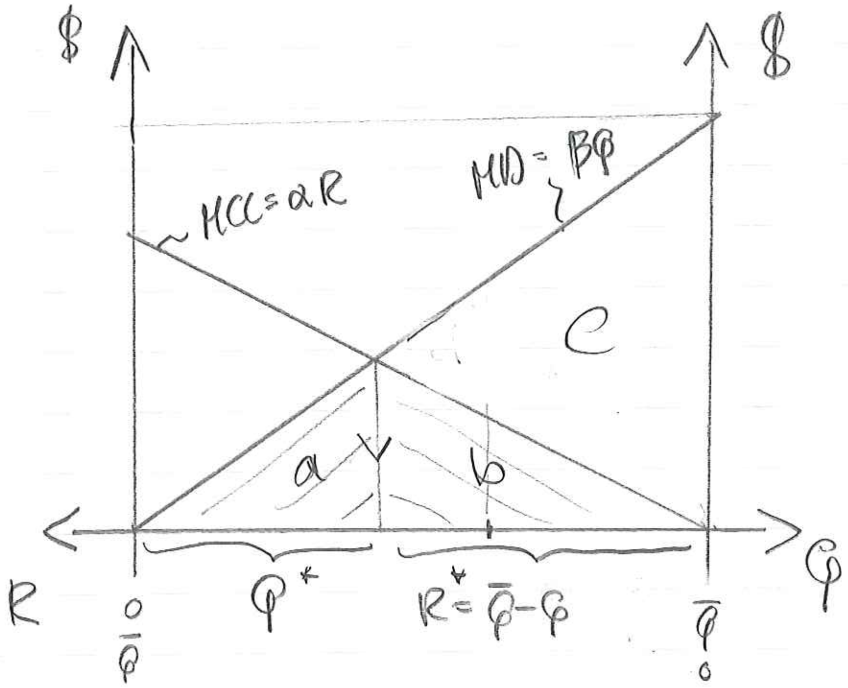

The graph shows the optimal emission level φ^*, and the optimal reduction level R^* in one figur. As we see, the first order criterion MCC = MD is satisfyed and the solution is optimal.

The total emission costs equal:

$TC^* = a + b$.

The graph also shows the total costs in the case of zero abatement (fom A), as we see this gives a total cost of

$\overline{TC} = a + b + C$, which is C, larger than the optimal solution.

The reason for the difference is that the efficiency criterion is not satisfyed when the abatement is zero.*

Moreover the large damage costs in A is clearly not optimal. The social planner could reach the optimal level of φ^* and R^* by imposing a tax rate on emissions, such that

$$MC(R^*) = MD(\varphi^*) = t^*,$$

However that would demand perfect information of the cost functions.

* The marginal costs of reducing emissions is zero, while the marginal damage costs from emission is at its maximum. This is clearly not optimal.

The optimal emission level is:

$$\beta\varphi = \alpha \cdot R = \alpha(\bar{\varphi} - \varphi)$$

$$\beta\varphi = \alpha\bar{\varphi} - \alpha\varphi$$

$$\varphi^* = \boxed{\frac{\bar{\varphi}}{\alpha + \beta}}$$

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#2c

The definition of cost efficiant emission reduction allocation is the allocation of emission reduction between firms that minimizes the total control costs, while still reaching the targets for emission reduction.

This gives the minimization problem:

$$\min_{R_1, R_2} \{CC_1(R_1) + CC_2(R_2)\}$$

subject to $R_1 + R_2 = R$

The first order criterion is again given by derivation:

$$MCC_1(R_1) = MCC_2(R_2)$$

subject to $R_1 + R_2 = R$

Thus cost efficiant emission reduction occures when the MCC's are equal. As the firms have different MCC functions, the efficiant allocation will clearly not be an equal distribution of reduction. Rather it will be cost efficiant to let the low cost firm (firm 2) take the largest share of the reduction.

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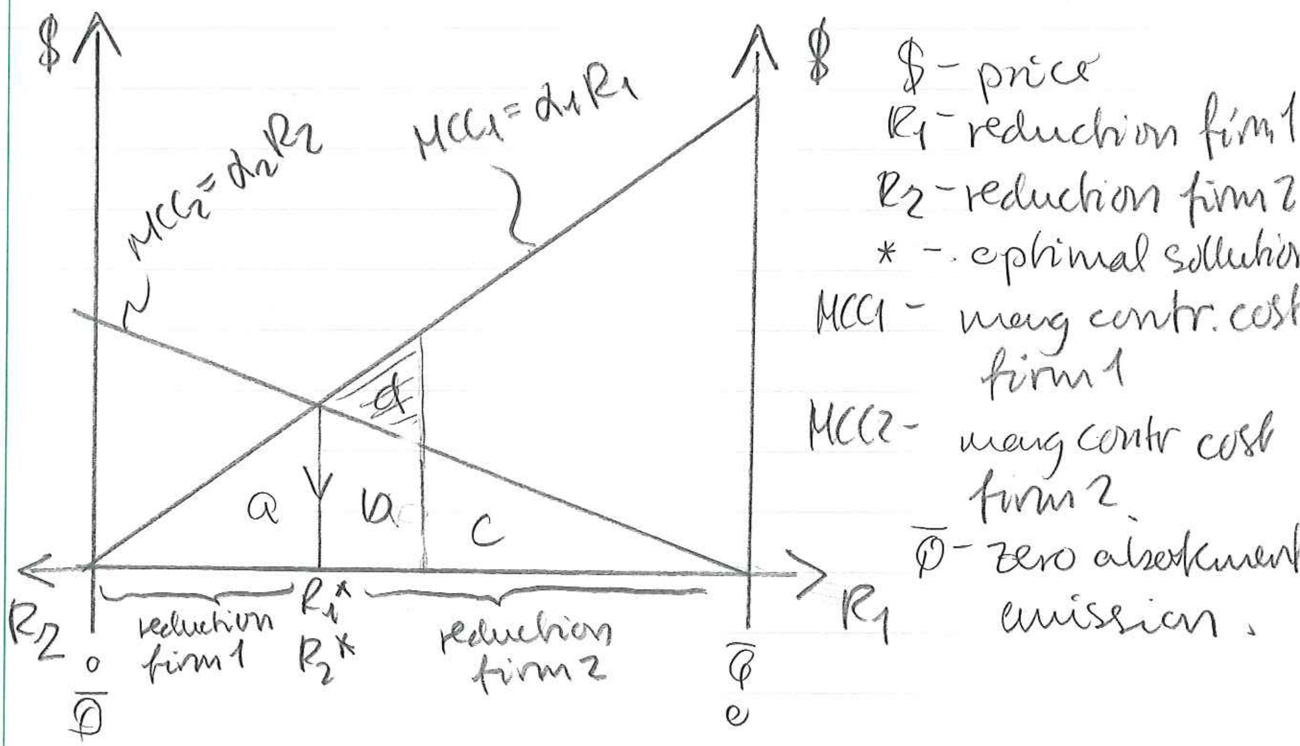
Graphically this is illustrated as follows:



The graph shows marginal control costs for the two firms as a function of reduction. 2 from right to left. 1 from left to right.

As wee see the optimal sollution yelds a larger reduction for firm 2 as predicted.

The graph also shows the total control costs, which are minimized; a+b+c. In addition it shows the extra costs, marked as (d) if the allocation were an equal distribution. Than CC_2 would be reduced to c, but CC_1 would increase to a+b+d. The total costs would increase, and the sollution would not be cost efficient.

#2D

A tax will make each firm pay a total of: the control cost of reducing $CC(R)$, pluss a tax burden equal to the remaining part of the emissions $t\cdot\varphi = t(\bar{\varphi} - R)$.

Each firm will try to minimize its costs according to the following minimization:

$$\min_{R} \{TCF(R) = CC(R) + t\cdot(\bar{\varphi} - R)\}$$

Again the first order criterion is given by derivation:

$$MCC(R) = t$$

That is, each firm will reduce it emissions in order to reduce its total costs, as long as the marginal cost of emitting one more unit of pollution is below the tax rate.

Thus each firm will reduce its emissions until $MCC_i(R_i) = t(\bar{\varphi} - R_i)$. This is illustrated graphically on the next page both for the individual firms, and for the two firm system.

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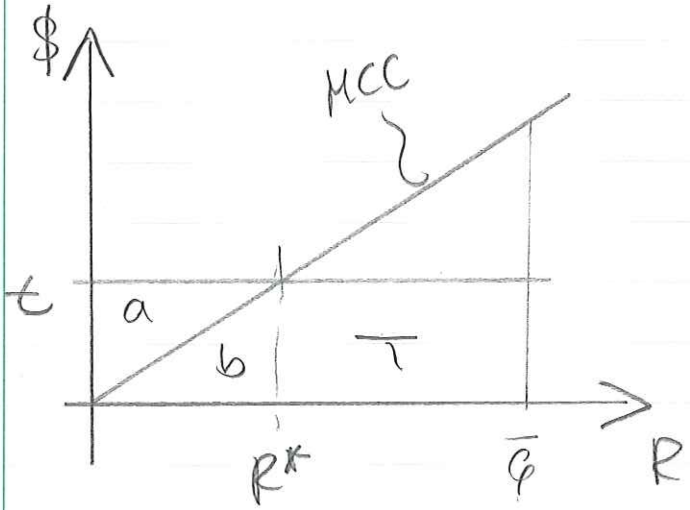

$ - price

t - tax rate

R - reduction

MCC - marginal control costs.

The graph shows how the individual firm reduces its emissions after its own cost minimizing criterion.

From a total cost at zero reduction of:

TCF = a + b + T.

To a total cost at R = R* of:

TCF = a + T.

For the two firm system, each firm will reduce costs after their own cost minimizing criterion. That is reduce emissions until $MCC_i(R_i) = t$. Thus for

$t = MCC_1 = MCC_2 = t^*$, we will satisfy

the criterion for cost efficient emission reduction allocation. The tax rate should be chosen such that:

$$t = MCC_1 = MCC_2 = t^*.$$

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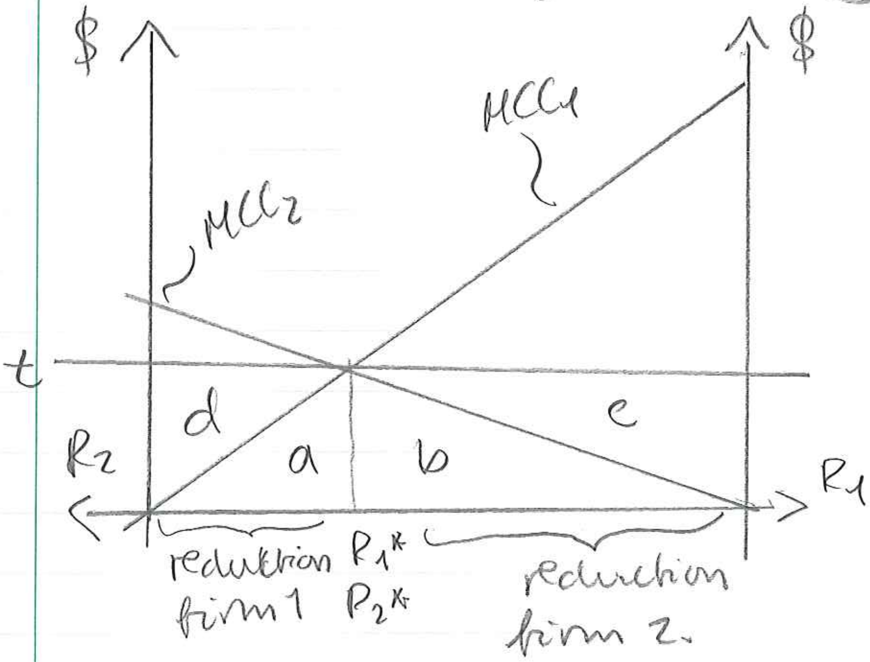
This is shown graphically:



Firm 1

No reduction:

$CC_1 = 0$

$Tax_1 = a+b+c+d$ } $TOT = a+b+c+d$

After reduction:

$CC_1 = a$

$Tax_1 = b+c$ } $TOT = a+b+c$

Firm 2:

No reduction

$CC_2 = 0$

$Tax_2 = a+b+c+d$ } $TOT = a+b+c+d$

After reduction:

$CC_2 = b$

$Tax_2 = a+d$ } $a+b+d$

Thus each firm reduces its costs. Moreover the solution is cost efficient, and reaches the reduction targets.

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#3E

Quota trading

- The low cost firm, firm 2 will have instentive to sell quotas (so that they must reduce more) as long as the quota price is below the firms marginal cost of reducing one more unit, MCC_2.
- The high cost firm, firm 1 will have instentive to buy quota (so that they can reduce less) as long as the quota price is below their MCC, MCC_1.

Thus:

Firm 1 will buy quota until $MCC_1 = q^*$
Firm 2 will sell quota untill $MCC_2 = q^*$

Where q^* is the optimal quota price. This will lead to

$$MCC_1 = MCC_2$$

Which satisfies the first order criterion for efficiant emission reduction allocation, and we will have the cost efficiant sollution.

Graphically this is illustrated on the next page.

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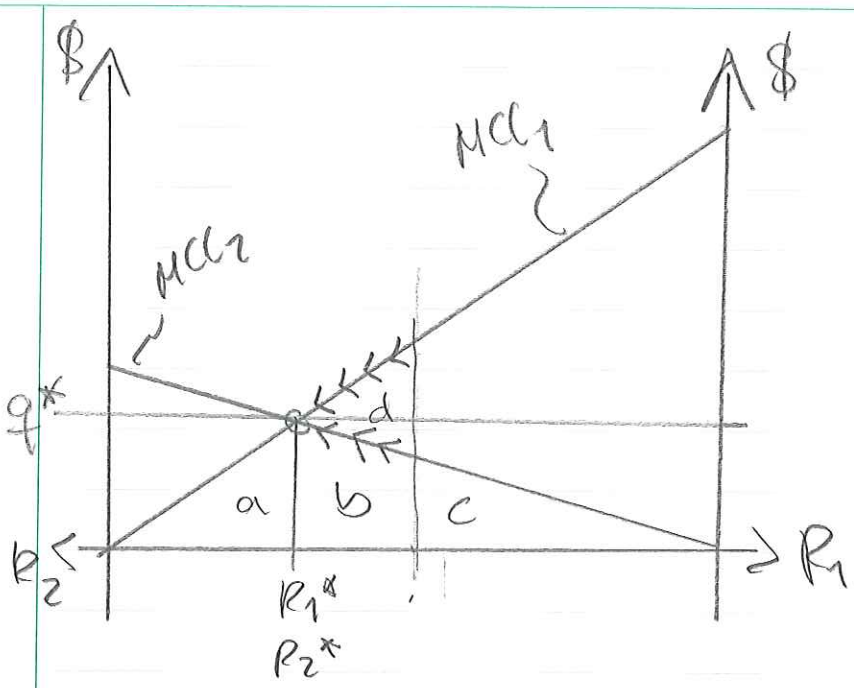

Notation on the graph is the same as befor.

We see that by quota trading we reach the efficiant allocation, and the reduction target.

From an equal distribution of quotas, where the extra costs are marked as d, we reach the target at the lowest possible control costs a+b+c.

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#2F

Taxes vs quota trading

Taxes give the firms insentive to reduce emissions in order to reduce their tax burden. This gives insentive to invest in environmentally friendly technologies, and may in the long run result in emissions being reduced below the target level. This is positive.

Taxes generates income for the state, which is positive, and can be used for wellfear, or other goods.

Taxes require perfect information for the state regarding the cost functions of the firms, which may be challenging.

Taxes may be politically difficult due to strong and powerfull industrial organisations.

Quota trading gives a weaker insentive to invest in environmentally friendley technology than taxes. The reason for this is that the high cost firm has insentive to invest in order to reduce the ammounth of quotas it buys from the low cost firm. Thus, in

The long run, the total emissions will not be reduced below target value.

Quota trading does not generate income to the state

Quota trading does not require perfect information

Quota trading may be more politically feasible

On basis of the possibilities for taxes to reduce emissions below target value, and the fact that taxes generate income to the state I would suggest taxes.

Taxes is cost effective if the information is perfect, gives strong insentive to invest in environmentally friendley technologi, and is in line with the "polluters pay" prinsipal.

However, as we will se in the next task, the choise depends on the degree of information about the marginal control costs of the firms.

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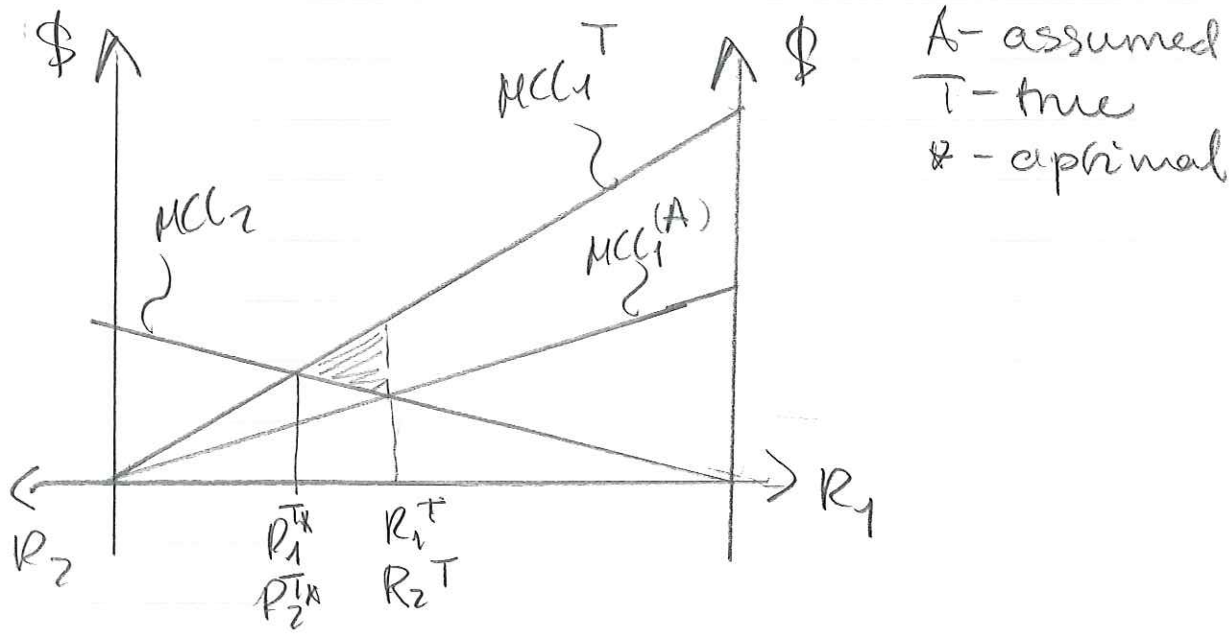
#2a

Letts say that the incomplete information is regarding the MCC of firm 1, and that this is believed to be smale (less steep)) than what is the true case.

The government will chose tax rate in order to achieve the cost minimizing criterion $MCC_1 = MCC_2$. However if $MCC_1^{(A)} < MCC_1^{(True)}$, the assumed optimal reduction done by firm 1 wil be larger than the true case, resulting in an efficiancy loss.

This is shown graphically:



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The graph shows the extra costs due to the imperfect information. Thus the tax case with imperfect information will lead to an un-optimal sollution. It will be target, but not cost effective.

Quota trading does not relly on the governmental information on the cost functions. It will still give the target and cost efficiant sollution, and thus quota trading should be prefered over taxes if information is imperfect.

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