NTNU
Det skapende universitet

Institutt for samfunnsøkonomi

Eksamensoppgave i SØK1101 – Miljø- og ressursøkonomi /

Environmental and resource economics

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Tlf.: 73 59 19 39

Eksamensdato: 31.05.2013

Eksamenstid (fra-til): 09.00 – 13.00

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 Citizen SR-270x, HP 30S eller SR-270X College

Annen informasjon: Eksamensoppgaven består av 2 oppgaver med delspørsmål som alle skal besvares.

Sensurdato: 21. juni 2013.

Målform/språk: Bokmål, nynorsk og engelsk

Antall sider: 4

Antall sider vedlegg: 0

Eksamen består av to oppgaver. Begge skal besvares.

Oppgave 1

Betrakt to forurensende bedrifter, 1 and 2, som hver har et forurensende utslipp lik $\overline{Q}$ enheter, slik at totalt utslipp er lik $2\overline{Q}$ enheter. Marginal kontrollkostnad (marginal control cost) for bedrift 1 og 2 er gitt av henholdsvis $MCC_1 = AR_1$ og $MCC_2 = BR_2$, hvor A og B er positive konstanter og $B > A$. R_1 og R_2 er antall enheter utslippsreduksjoner gjennomført i bedrift 1 og 2.

a) Myndighetene bestemmer at totalt utslippsnivå skal reduseres med $\overline{Q}$ enheter for å nå ønsket utslippsnivå. For å nå dette målet, krever myndighetene at hver bedrift reduserer sine utslipp med $\overline{Q}/2$ enheter. Illustrer grafisk tilhørende total kontrollkostnad.

b) Definer begrepet kostnadseffektiv utslippsreduksjon (cost effective emission reductions). Vil like utslippsstandarder som i a) sikre en kostnadseffektiv utslippsreduksjon? Begrunn svaret. Bruk figur(er) til å illustrere svaret.

c) Hvordan bør utslippsreduksjonen allokeres mellom bedriftene for å sikre kostnadseffektivitet?

d) Anta nå at bedriftene blir pålagt en utslippsavgift per enhet utslipp. Forklar og illustrer grafisk hvordan en bedrift tilpasser seg en utslippsavgift. Illustrer også bedriftens tilhørende kontrollkostnad og skattekostnad.

e) Hvordan bør utslippsavgiften utformes for å sikre en kostnadseffektiv fordeling av utslippsreduksjonene?

f) Anta i stedet at myndighetene betaler en subsidie per enhet utslippsreduksjon. Forklar og illustrer grafisk hvordan en bedrift tilpasser seg en slik subsidie. Illustrer også bedriftens tilhørende kontrollkostnad og mottatt subsidiebeløp. Sammenlign resultatene med hva du fant i d). Hvilket av de to politikkalternativene foretrekker bedriftene? Hvilket av de to politikkalternativene ville du anbefalt myndighetene? Begrunn svarene.

Oppgave 2

a) Diskuter kort ulike fortolkninger av begrepet bærekraftig utvikling.

Du skal nå betrakte en ikke-fornybar ressurs som skal allokeres over to perioder. Beholdningen av ressursen på starttidspunktet er $\overline{X} = 30$ enheter. Marginal betalingsvillighet (marginal willingness to pay) er gitt av $P(X_i) = 15 - 0.5X_i$, hvor X_i er antall enheter som utvinnes/konsumeres i periode i, $i = 1,2$. Marginal utvinningskostnad (marginal extraction cost) er konstant og lik 3.

b) Bestem utvinningen i de to periodene slik at nåverdien av netto inntekt for de to periodene maksimeres. Sett diskonteringsrenten lik 0.03. Illustrer og forklar grafisk. Vil du si at fordelingen mellom de to periodene er rettferdig? Begrunn svaret.

c) Hva er markedsprisen i periode 1? Hva er den marginale brukerkostnaden (marginal user cost) i periode 1? Forklar hvorfor utvinning i periode 1 resulterer i en positiv marginal brukerkostnad.

d) Hva er markedsprisen i periode 2? Hva er den marginale brukerkostnaden i periode 2?

e) Basert på resultatene ovenfor, hva kan du si om sammenhengen mellom variasjon i markedspris, marginal brukerkostnad og mengde konsumert over tid?

Eksamen består av to oppgåver. Begge skal besvaras.

Oppgåve 1

Betrakt to bedrifter, 1 and 2, som hver har et forurensende utslipp lik $\overline{Q}$ enheter, slik at totalt utslipp er lik $2\overline{Q}$ enheter. Marginal kontrollkostnad (marginal control cost) for bedrift 1 og 2 er gitt av henholdsvis $MCC_1 = AR_1$ og $MCC_2 = BR_2$, kor *A* og *B* er positive konstantar og $B > A$. R_1 og R_2 er einingar utsleppsreduksjonar gjennomført i bedrift 1 og 2.

a) Myndighetene bestemmer at totalt utslippsnivå skal reduserast med $\overline{Q}$ einingar for å nå ønsket utsleppsnivå. For å nå dette målet, krev myndighetene at kvar bedrift reduserer sine utslepp med $\overline{Q}/2$ einingar. Illustrer grafisk tilhørande total kontrollkostnad.
b) Definer kva vi forstår med kostnadseffektiv utsleppsreduksjon (cost effective emission reductions). Vil like utsleppsstandardar som i a) sikre ein kostnadseffektiv utsleppsreduksjon? Grunngje svaret. Bruk figur(ar) til å illustrere svaret.
c) Korleis bør utsleppsreduksjonen allokerast mellom bedriftene for å sikre kostnadseffektivitet?
d) Anta nå at bedriftene blir pålagt ein utsleppsavgift per eining utslepp. Forklar og illustrer grafisk korleis ein bedrift tilpassar seg ein utsleppsavgift. Illustrer også bedrifta sin tilhørande kontrollkostnad og skattekostnad.
e) Korleis bør utsleppsavgifta utformast for å sikre ein kostnadseffektiv fordeling av utsleppsreduksjonane?
f) Anta i staden for at myndighetene betalar ein subsidie per eining utsleppsreduksjon. Forklar og illustrer grafisk korleis ein bedrift tilpassar seg ein slik subsidie. Illustrer også bedrifta sin tilhørande kontrollkostnad og mottatt subsidiebeløp. Samanlikn resultata med dei du fann i d). Kva for eit av dei to politikkalternativa føretrekk bedriftene? Kva for eit av dei to politikkalternativa ville du anbefalt myndighetene? Grunngje svara.

Oppgåve 2

a) Diskuter kort ulike fortolkningar av omgrepet bærekraftig utvikling.

Du skal nå betrakte en ikkje-fornybar ressurs som skal allokerast over to periodar. Behaldninga av ressursen på starttidspunktet er $\overline{X} = 30$ einingar. Marginal betalingsvilje (marginal willingness to pay) er gitt av $P(X_i) = 15 - 0.5X_i$, kor X_i er einingar som utvinnes/konsumerast i periode i, $i = 1,2$. Marginal utvinningskostnad (marginal extraction cost) er konstant og lik 3.

b) Bestem utvinninga i dei to periodane slik at nåverdien av netto inntekt for dei to periodane maksimerast. Sett diskonteringsrenta lik 0.03. Illustrer og forklar grafisk. Vil du si at fordelinga mellom dei to periodane er rettferdig? Grunngje svaret.
c) Kva er marknadsprisen i periode 1? Kva er den marginale brukarkostnaden (marginal user cost) i periode 1? Forklar kvifor utvinning i periode 1 resulterer i ein positiv marginal brukerkostnad.
d) Kva er marknadsprisen i periode 2? Kva er den marginale brukarkostnaden i periode 2?
e) Basert på resultata ovanfor, kva kan du si om samanhenga mellom variasjon i marknadspris, marginal brukarkostnad og mengde konsumert over tid?

The exam consists of 2 problems. Both should be answered.

Problem 1

Consider two polluting firms, 1 and 2, each of which emits $\overline{Q}$ units of pollution so that a total of $2\overline{Q}$ units are released into the environment. The marginal costs of pollution control for firm 1 and 2 are given by $MCC_1 = AR_1$ and $MCC_2 = BR_2$, respectively, where *A* and *B* are positive constants and $B > A$. R_1 and R_2 are the number of emission reductions made by firm 1 and 2, respectively.

a) The government determines that total emissions must be reduced by $\overline{Q}$ to achieve the social desirable level of pollution. Assume that the government requires for each of the polluters to reduce emissions by $\overline{Q}/2$ units. Illustrate graphically the corresponding total control cost.
b) Define the term 'cost effective emission reductions'. Does the policy of equal emission reductions in a) ensure cost effective emission reduction? Why, or why not? Use figure(s) to illustrate your point.
c) How should the total emission reduction be allocated across the firms in order to ensure cost effectiveness?
d) Assume now that an emission tax is levied on each unit of pollutant emitted into the environment. Explain and illustrate graphically how the individual firm adjusts to an emission tax. Illustrate also the firm's corresponding control cost and tax payment.
e) How should the emission tax be set to ensure a cost effective allocation of emission reductions?
f) Assume instead that the government pays a subsidy for each unit of reduced emissions. Explain and illustrate graphically how the individual firm adjusts to an emission-reduction subsidy. Illustrate also the firm's corresponding control cost and received subsidy payment. Compare your result with your answer in d). Which of the two policies is preferred by the firms? Which of the two policies would you recommend for the government? Explain your answers.

Problem 2

a) Discuss shortly different interpretations of the term sustainable development.

Consider now a depletable resource stock of size $\overline{X} = 30$ units to be allocated between two periods. The marginal willingness to pay is given by $P(X_i) = 15 - 0.5X_i$, where X_i is the number of units extracted/consumed in period i, $i = 1,2$. The marginal extraction cost is constant and equal to 3.

b) Determine the extraction in the two periods so as to maximize the present value of the net benefit for both periods. Set the discount rate equal to 0.03. Illustrate and explain graphically. Is this allocation fair? Why, or why not?
c) What is the market price in period 1? What is the marginal user cost in period 1? Explain why extraction in period 1 results in a positive marginal user cost.
d) What is the market price in period 2? What is the marginal user cost in period 2?
e) Based on the results above, what can you say about the relationship between variations in the market price, the marginal user cost, and the quantity consumed over time?

Comments on answer to the exam in SØK 1101 spring term 2013

The exam consists of two problems. Problem 1 is on cost effective emission reductions, and effectiveness and distributional aspects of economic policies to reduce emissions. Problem 2 considers sustainable development and extraction of a non-renewable resource. The present set of answers is evaluated to grade A. However, it is a weak A as some of the sub-questions could have been more thoroughly answered. Because the major questions are answered in a highly satisfying way, the set of answers in total demonstrates a high degree of independence.

Problem 1

a) This is a plank exercise. The answer provided is rather brief (e.g., the curves in the figure lack proper explanation and are not denoted), but this is unfortunately a characteristic to most of the responses to this exam. The figure is ok and further explanation is provided in the answer to question b).
b) The definition of the term is satisfying and it is good that the condition for cost effectiveness is included. The answer explains well why the distribution in a) is not cost efficient, and it is nice that a graphically illustration of the difference in total control cost in a) and b) is included.
c) The answer is graphically correct, but the candidate could have added explicitly that the firm with the highest marginal abatement cost should be allowed to reduce emissions less and the firm with the lowest marginal abatement cost should be required to reduce more, compared to the uniform allocation of emission reductions in a).
d) The particular figure provided in this answer is necessary for a high evaluation here. The objective of the firm – to minimize total costs (control and tax) – is well explained and illustrated graphically. It is good that a comparison with the case without a tax is provided.
e) The figure and text illustrate well that the tax rate should be set equal for all so that the marginal control costs are equalized across firms. This is the correct answer to this question.
f) The figure and text illustrate very well how the firm adjusts to a subsidy of emission reductions. The corresponding control cost is illustrated correct in the figure as the area below the MCC-curve from $\bar{Q}$ to Q_S. The subsidy payment is, however, illustrated wrong graphically. The correct payment is $s(\bar{Q} - Q_S)$, which equals area $f + g$ in the figure. However, the answer demonstrates very well how the distributional effect of a subsidy and tax differs. The discussion provided is short, but the points made are highly relevant.

Problem 2

a) The answer to this question is incomplete. It is nice that the answer defines the terms strong and weak sustainability in terms of the total capital stock. However, a notion on how we can understand sustainability, i.e. as non-declining consumption over time, and a presentation of the link between capital, production, and consumption, would have improved the answer.
b) Here, the condition for dynamic efficiency is correct (the readers should be aware that several responses to this exam failed to discount future marginal net benefit). Some verbal explanation of this condition would have improved the answer, but the math included and the figure is correct. The discussion of fairness and the link made to sustainability in question a) is very good and demonstrates independence in an excellent way.
c) Correct. The answer provides a nice explanation of the relationship between the marginal user cost and resource scarcity. Many of the responses failed to on this part of the question c).
d) and e): Several responses to this exam failed to answer these two questions properly. The present response is excellent: It is all about increased resource scarcity over time.

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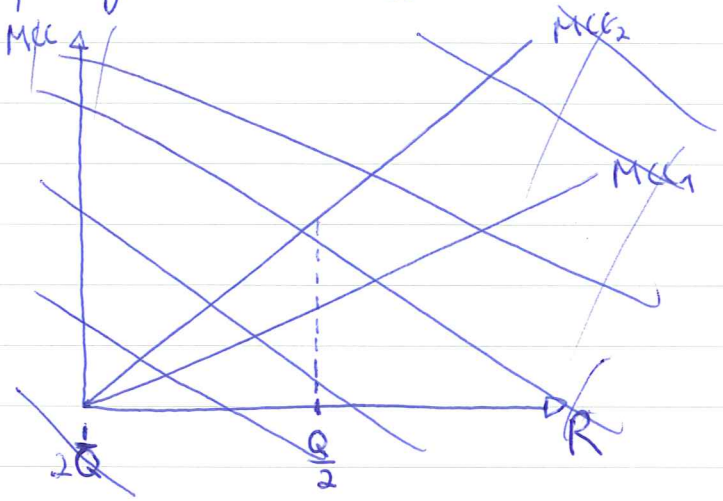
Problem 1)

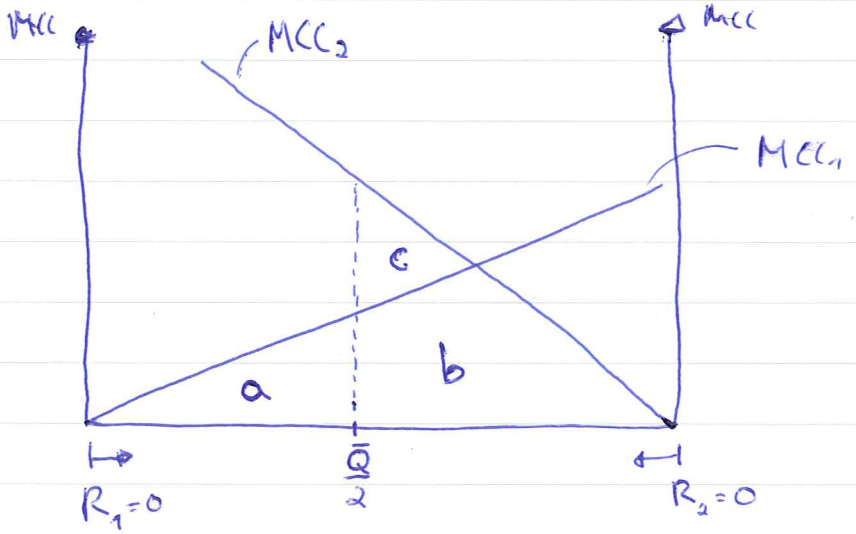
Total emissions: $2\bar{Q}$

$MCC_1 = A \cdot R_1$ $\quad B > A$

$MCC_2 = BR_2$

a) reduction of $\bar{Q}$ → social desirable level of pollution
→ equally distributed $\frac{\bar{Q}}{2}$





Total control cost are a + b + c

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1) b) cost effective emission reduction:

For a given emission reduction level, the cost shall be minimized to the lowest possible level (effektiv). This can be achieved if the reductions take place at the firms with the lowest control/reduction cost. It is effective if the marginal control costs of all firms are equal:

$$MCC_1 = MCC_2 = MCC_3 = \dots = MCC_i$$

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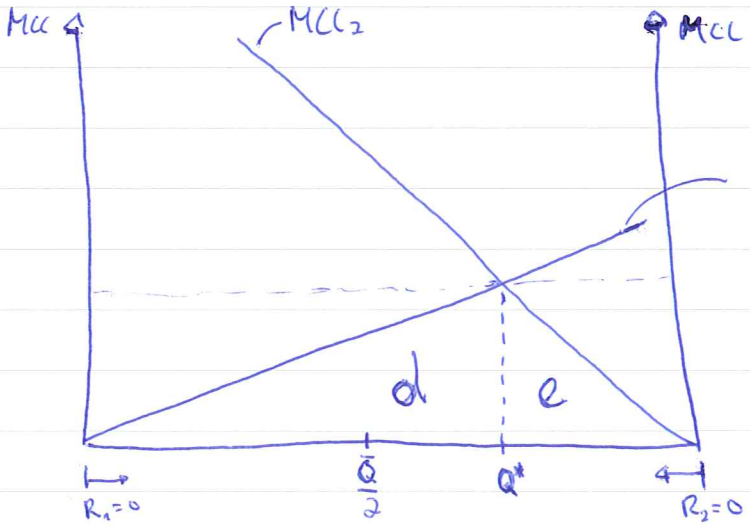
The policy of equal emission reduction does not ensure cost effective r. reduction because the marginal control cost are not equal in $\frac{\bar{Q}}{2}$. That means that the marginal cost to reduce an additional emission unit is smaller for Firm 1 than for firm 2. The total cost could be reduced by letting the reduction alone by firm 1.

cost effective emission reduction would be: $MCC_1 = MCC_2$



contd 1b)

Total cost in cost effective emission reduction:

$d + e$

which equals

$a + b$ (from graph in 1a)

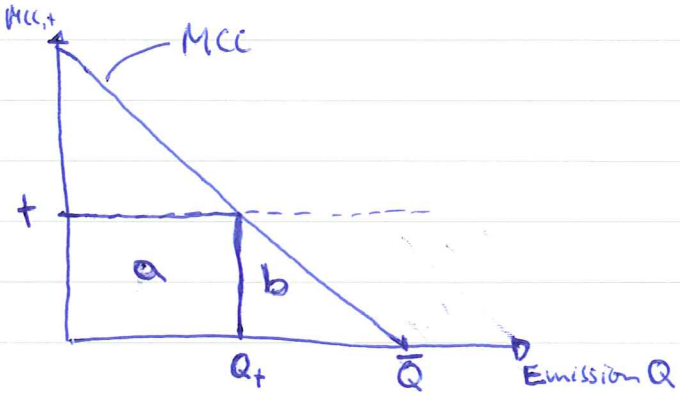
Total cost by $\frac{\bar{Q}}{2}$ distribution are higher by

c

1c) As shown in 1b), cost effectiveness can be achieved by allocating Q^* to firm 1 and $\bar{Q} - Q^*$ to firm 2.

Firm 1 has total cost of d (see graph in 1b) and firm 2 has total cost of e.

1d) individual firm with tax on emission



Without tax: company pollutes on emission level $\bar{Q}$

→ No control cost

cont'd 1d)

With tax:

At point $\bar{Q}$, the marginal cost of tax per additional emission is higher than the marginal reduction cost. It is cheaper for the firm to reduce emission than to emit.

This goes to the point Q_+ where: $MCC = t$

A further reduction of emission is more expensive than to pay the tax for each emission.

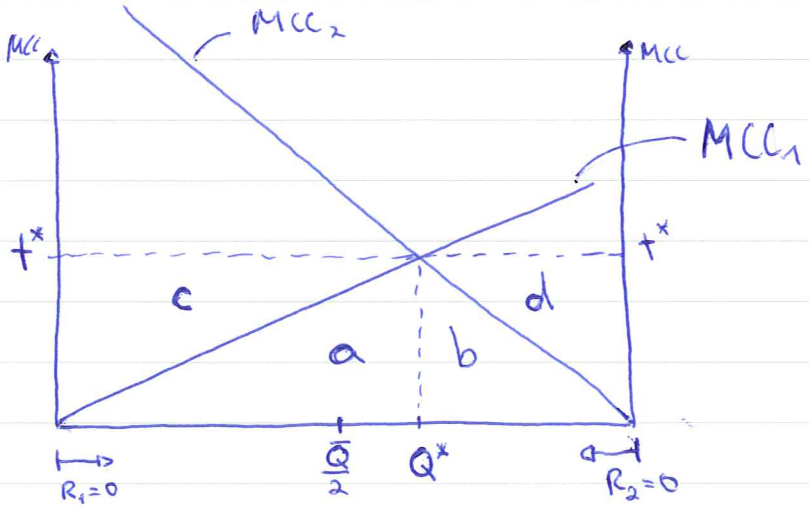
Total cost with tax:

$a + b$ (in graph of 1d)

a: Tax payment

b: Control cost

1e)



if emission tax is: $t^* = MCC_1 = MCC_2$

than it is cost effective as shown in 1b & c)

It minimizes the total cost of reduction emission

Total cost for firm 1:

$a + b + d$

a: Control cost

b+d: tax payment

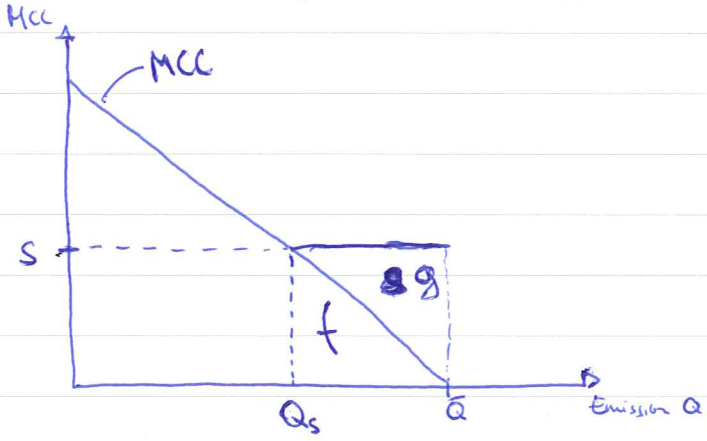
Total cost for firm 2:

$$b + a + c$$

b: control cost

a+c: tax payment

1f) individual firm: subsidy



control cost: f

subsidy payment: g

at $\bar{Q}$: the firm gets the incentive to reduce emissions because the payment by the state for a marginal reduction is higher than the marginal control cost.

at Q_s: the firm reduces its emission to this point because MCC = s. A further reduction of emissions leads to higher cost, since MCC > s

In Q_s: Control cost = f

Subsidy payment = g

cont'd 1f)

Comparison to 1d: tax payment (polluter pays)

With tax payment and control cost, the company has higher total cost compared to the subsidy case. Here, the company gets money for reducing emission and thus can cover its control cost with this payment. The total cost are zero.

Consequently, firms prefer subsidies ~~for~~ than taxes since it is cheaper for them.

From the government perspective, it is therefor more interesting to introduce taxes which are an income for the state. These payments can be used to avoid market- inefficiencies such as externalities in other markets or invest in projects ~~that~~ against environmental pollution.

A subsidy is ~~for the~~ an expense for the government and thus not so interesting.

Fagtrykk Trondheim AS 11.2012

2) weak sustainability (Hartwin rule):
The total natural stock value shall be non-declining.
If there is the possibility of substitution between natural resources and capital (human, physical), than the ~~total~~ natural stock value is non-declining.
€

Example: Norway is extracting oil from natural resources and is selling it. If the money is saved for future generation, than we can observe a non-declining value of stock.

Strong sustainability:
The value of the natural stock shall be non-declining. If ~~there possibility is not a~~ natural resources are not substitutable with capital, than ~~natural resource~~ the value of natural resource stocks is only non-declining if natural resources are substituted with natural resources.

Environmental sustainability:
It deals with the natural materials/flows/resources such as wood. The stock shall be non-declining which means harvesting should not exceed the growth rate in order to be sustainable

2) b) $\bar{X}=30$ $\quad x_1 + x_2 = 30$

MWP: $P(x_i) = 15 - 0{,}5x_i$

$MC = 3$

$r = 0{,}03$

dynamic efficiency:

$$PVNB_1 = PVNB_2$$

$$12 - 0{,}5x_1 = \frac{12 - 0{,}5x_2}{1{,}03}$$

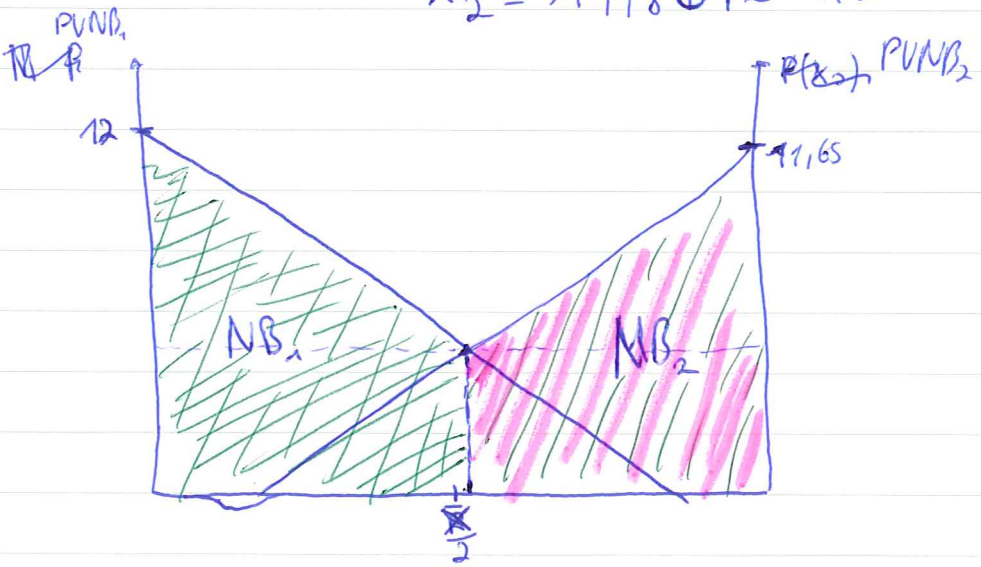
$$12{,}36 - 0{,}515x_1 = 12 - 0{,}5 \cdot (30 - x_1)$$

$$0{,}36 - 0{,}515x_1 = -15 + 0{,}5x_1$$

$$1{,}015x_1 = 15{,}36$$

$$x_1 = 15{,}133 \approx 15{,}1$$

$$x_2 = 14{,}867 \approx 14{,}9$$



cont'd 2b)

Net benefit: $NB_1 = (12 - 0{,}5x_1) \cdot x_1 + \frac{1}{2} \cdot x_1 \cdot (12 - (12 - 0{,}5x_1))$

area under the curves

$= 4{,}45 \cdot 15{,}1 + \frac{1}{2} \cdot 15{,}1 \cdot 7{,}55$

$= 67{,}2 + 57 = 124{,}2$

$NB_2 = \frac{(12 - 0{,}5x_2)}{1{,}03} \cdot x_2 + \frac{1}{2} \cdot x_2 \cdot \left(11{,}65 - \frac{(12 - 0{,}5x_2)}{1{,}03}\right)$

$= 4{,}42 \cdot 14{,}9 + \frac{1}{2} \cdot 14{,}9 \cdot (11{,}65 - 4{,}42)$

$= 65{,}858 + 53{,}86$

$= 119{,}72$

$NB_1 > NB_2$

Although the present value of the net benefit are maximized for both periods, the net benefits in each period are different. The consumption of the resource and consequently the net benefit in period 1 are higher than in period 2. This is not fair. In order to increase fairness and achieve weak sustainability, one could take a part of the money in the first period, put it on a bank, so that the people in period 2 have the same NB

↳ $NB_1 = NB_2$

It would be $NB_1 - \lambda = NB_2 + \lambda \cdot (1{,}03)$

payment $\lambda \approx 2{,}21$

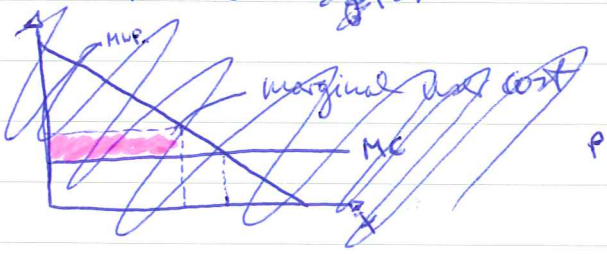
2c) market price Period 1:

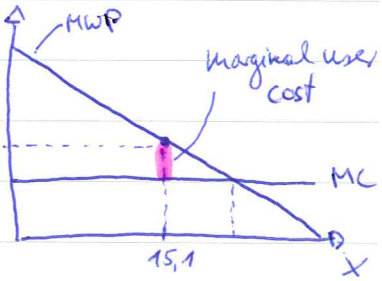
$P(15,1) = 15 - 0,5 \cdot 15,1 = 7,45$

Marginal user cost: $7,45 - 3 = 4,45$

Because of the scarcity which only allowes a resource extraction of 15,1 in period 1, the price is higher than marginal cost. The additional cost is covered by the consumers.

If the resource is not scare, the consumption would be at the point where MC = MB and the price would be equal to the cost (3).





2d)

market price period 2:

$P(14,9) = 15 - 0,5 \cdot 14,9 = 7,55$

Marginal user cost: $7,55 - 3 = 4,55$

The marginal user cost in period 2 is even higher because of the reduction of consumption (14,9) which is due to the resource scarcity.

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2e)

If there is a variation in the market price, it is because the quantity consumed over time ~~variate~~ variates. For example, if the quantity consumed over time is reduced ~~and the~~ - the resource is more scarce - than the market price will increase and then the marginal user cost will increase too.

If the quantity consumed over time increases to 48*, then the marginal user cost would be zero and the price equals marginal cost (3).

*48 because state efficiency

$MC = MWP$

$15 - 0{,}5x = 3$

$0{,}5x = 12$

$x = 24$

→ two periods = 48