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Center for
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Research - Oslo

Report 1998:1

Emission Trading under the Kyoto Protocol

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ISSN: 0804-4562

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6 July 1998

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Acknowledgements

This study explores a possible development and performance of an international trading regime for greenhouse gas emission quotas. The Nordic Ad hoc Group on Energy-related Climate Issues at the Nordic Council of Ministers has financed the study. The authors want to thank Jørgen Abildgaard, Camilla Rosenhagen, Olle Björk and Jon D. Engebretsen for comments to the draft of this report and our colleagues Knut H. Alfsen, Lasse Ringius and Asbjørn Torvanger as well as Knut Thonstad in the Norwegian Ministry of Finance for valuable inputs and discussions.

The draft of this report was written before the third Conference of the Parties to the Framework Convention on Climate Change in Kyoto. In this revised version the numerical calculations take the emission limitations specified in the Kyoto Protocol as the starting point. However, we have not thoroughly discussed the consequences of some of the important aspects of the Kyoto Protocol, such as the inclusion of all six groups of greenhouse gases and removals by sinks. Furthermore, available data for emissions of other greenhouse gases than CO_2 are very limited. The numerical estimates of the cost reduction potential and quota price following from emission trading must therefore be regarded as very uncertain.

1 Executive summary

On 11 December 1997, delegates to the third conference of the Parties to the UN Framework Convention on Climate Change agreed upon the Kyoto Protocol. The protocol sets binding emission targets for developed nations (Annex B countries).[1] The Protocol states that Annex B countries may participate in emission trading. The rules for emission trading are to be discussed at the fourth Conference of the Parties in November 1998.

The aim of the report is to discuss the potential gains from emission trading and to raise some crucial questions. The advantages in the form of reduced abatement costs are a basic features of emission trading. The numerical example presented shows that the total costs of the Kyoto Protocol could be reduced by approximately 95% through emission trading. From the Nordic perspective it is important to note that Denmark and Norway and to some extent also Sweden are probably among the Annex B countries benefiting most from this trading. Finland will not benefit to the same extent from this trading because of lower estimated abatement costs in this country.

Emission trading is a policy option also in the domestic arenas. The Kyoto Protocol allocates emission limitations (quotas) to each of the Annex B countries. The governments of these countries might consider allocating these quotas further to domestic enterprises as emission permits. If such allocation takes place new markets for greenhouse gas (GHG) emission quotas and permits might emerge domestically as well as internationally. The costsaving potentials are probably significant also with domestic emission trading. Here, however, emission taxes could be implemented and give a correspondingly cost-effective solution. It is in that respect important to underline that the protocol does not set restrictions on national choice of policy instruments.

The report emphasizes that emission trading at the national and international levels must be discussed separately. The Nordic governments, for example, will find several good reasons for supporting emission trading at the international level, although emission trading in greenhouse gases may not be the preferred policy instrument *domestically*. The Nordic countries have already implemented domestic taxes on CO_2-emissions. This tax policy could be sustained while the Nordic governments support and take part in emission trading at the international level.

Even though we realize that international emission trading can significantly reduce the Nordic countries implementation costs and may be a necessary condition to ensure that a high number of countries ratify the Kyoto Protocol, some undesirable side effects cannot be ignored. According to projected emission levels in the future, the protocol gives at least some of the countries in transition to a market economy (the EIT countries) emission limitations above their business-as-usual (BAU) emissions. Free emission trading among Annex B countries would then *reduce* total abatement compared to a situation where the quotas are non-tradeable. We will refer to this as the ‘hot air’ problem in connection to emission trading.

[1] Annex B countries are the countries listed in Annex B in the Kyoto Protocol (the OECD countries (except Korea, Mexico and Turkey), EU, which is a Party to the Convention, contries that are undergoing a process of transition to a market economy, and Liechtenstein and Monaco).

1.1 The gains from trade

Figure 1.1 shows the calculated distribution of costs of the Kyoto Protocol.[2] The European Union (EU) has distributed its quota to the member countries in accordance with the internal EU distribution plan agreed upon in June 1998. [3]

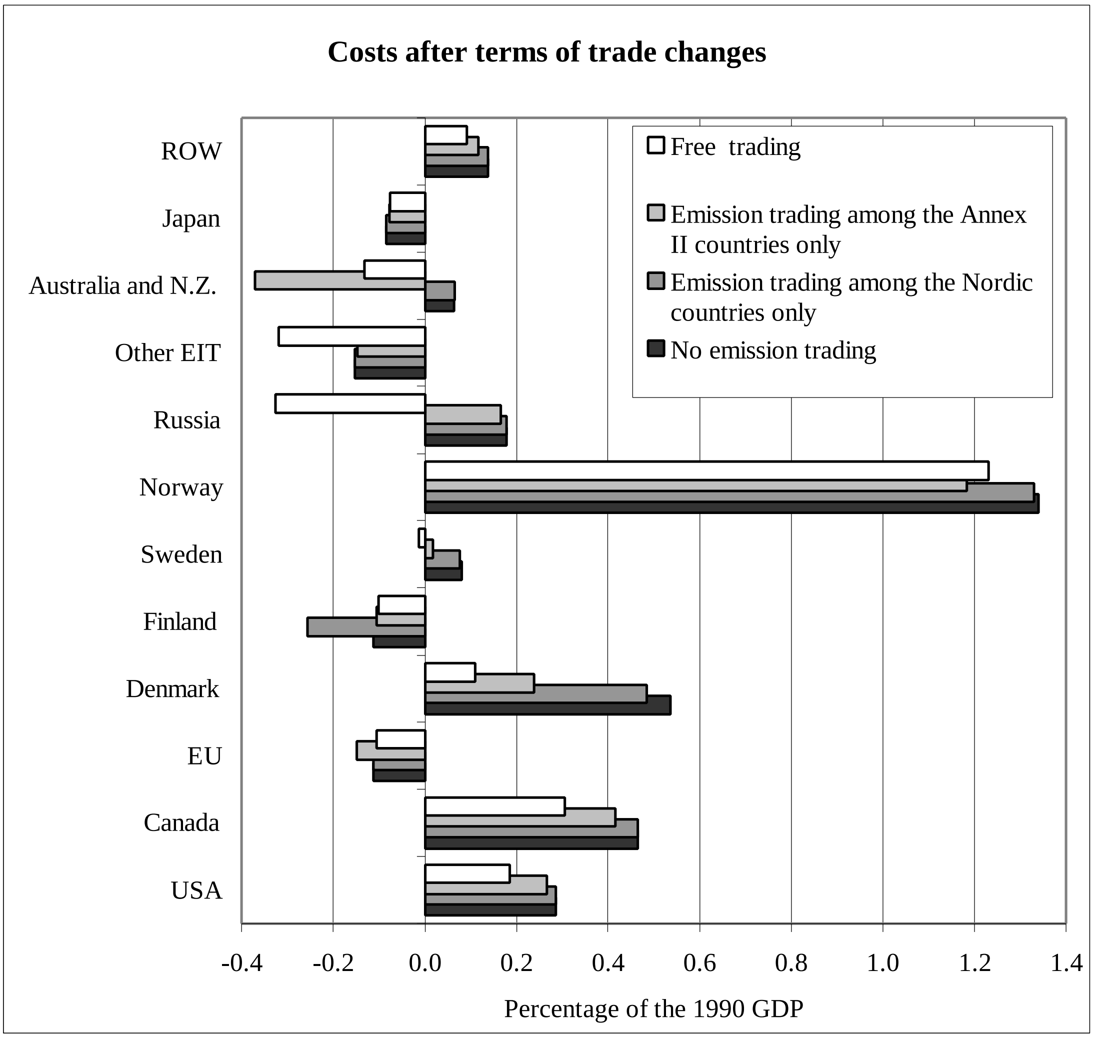


Figure 1: Costs of implementation of the Kyoto Protocol. Both terms-of-trade changes due to price changes in the energy markets and benefits from revenue recycling are taken into account. The internal EU distribution plan agreed upon in June 1998 is internalized (see footnote 3).

Four cases are analyzed in the report. In the first case no emission trading is allowed. In the second case only the Nordic countries are allowed to trade with each other. In the third

[2] The numerical examples are produced by simulation of a model developed at CICERO. An earlier version of the model is described in detail in Holtsmark (1997). Cf. Ringius, Torvanger and Holtsmark (1998) for another application of the model.

[3] The quotas of Denmark, Finland and Sweden are 79, 100 and 104 percent of their respective 1990 emissions. The fact that Denmark has to reduce the emissions substantially between 1990 and the first commitment period, while Finland and Sweden only should stabilise or increase the emissions in this period, explains to a large extent why Sweden and Finland according to the simulations experience small or even negative costs, while Denmark experiences substantial net costs.

scenario, the trade region is extended to include the entire Annex II countries. [4] Finally, we look at the case where emission trading is free within Annex B. In the last case the total costs of the Annex B countries are reduced by approximately 95% compared with the case without trade.

Especially Denmark, Norway, Canada, USA, Australia and the EIT countries will receive significant benefits from emission trading. This is related to both especially high or low abatement costs in these countries as well as either a strict or flexible emission target. Countries with more average abatement cost patterns will not benefit to the same extent from emission trading. The emission targets of Australia and Russia are for example likely to give these countries some flexibility and the possibility to attain gains from quota sale.

A basic result of the presented model simulations is that the EIT countries are large quota sellers, while in general the traditional market economies as a group are buyers of quotas. Hence, if there are no limitations on the trading, an outcome could be reduced abatement efforts in the traditional market economies. Significant 'no regret' options for emission reductions in the EIT countries mean that these countries experience net benefits even in a situation of no emission trading.

1.2 Long-term impacts of emission trading

It is important to recall that the global emission reductions that will be achieved by the Kyoto Protocol are very limited. The emissions are likely to continue to grow in the rest of the world (non-Annex B countries) as long as new renewable energy production loses in the competition with fossil fuels. Therefore, a crucial question is how a climate agreement should be designed in order to encourage the technological development within new renewable energy production.

Emission trading reduces the costs of abatement, which again will reduce the demand for non-polluting or emission efficient technologies. Hence, emission trading could reduce the R&D incentives in these areas, and consequently the long-term environmental impacts of the agreement.

1.3 Policy recommendations

- The report recommends a controlled introduction of emission trading through different phases. Possible undesirable side effects will then probably be detected in time to be corrected.
- In the first phase some restrictions on trade is recommended. The parties should be restricted to sell only a certain share of their quotas. The restriction on trade must be seen in relation to the compliance and sanction mechanisms that will be applied.
- At the end of the first phase, the Conference of the Parties (COP) should review experiences from transboundary emission trading between governments of Annex B parties. On the basis of this review the COP can decide whether the restrictions on the emission trading should be relaxed.

[4] Annex II countries are the countries listed in Annex II in the Climate Convention (the OECD countries as of 1992 and EU).

- The report recommends that an international institution is designated to approve all quota-sales. All transfers of emission quotas across borders should be followed by a report to the designated institution. These reports must contain a plan from the seller of quotas, specifying how the corresponding increased need for abatement measures will be designed and implemented.
- In the national arena, there is a choice between carbon taxes and allocation of tradeable emission permits. The Nordic countries' governments should investigate further these two alternatives. However, due to the attained experience with carbon taxes this is probably the preferred policy instrument in these countries.
- If several governments in the first phase introduced emission-trading systems in the national arenas, in the second phase they should consider whether these markets could be integrated. Transboundary trade with both government and business could then emerge. The national government, however, should be responsible for the national compliance. At this stage the non-Annex B countries could be invited to accept emission limitations in order to be able to join the quota market.

1.4 Overview of the report

In chapter 3 the proposed stepwise introduction of emission trading is further elaborated. Chapter 4 describes how a trading regime works and could be constructed. Chapter 5 discusses advantages and disadvantages of emission trading both at the national and the international level.

Chapter 6 discusses the potential gains from emission trading in the light of other empirically based studies. Chapter 7 presents some numerical examples to illustrate how emission trade could affect the different countries total abatement costs and costs related to terms of trade changes that follows when several countries implement measures simultaneously. Chapter 8 provides a short look at other studies and experiences with emission trading.

2 Norsk sammendrag

11. desember 1997 ble delegatene til klimakonvensjonens tredje partsmøte enige om teksten i Kyoto-protokollen. Protokollen setter bindende utslippsrestriksjoner for alle Anneks B-landene.[5] Protokollen fastslår også at Anneks B-landene kan handle med utslippskvoter. Regler og retningslinjer for slik handel vil bli diskutert på det neste Partsmøtet i Buenos Aires i november 1998.

Målet for denne rapporten er å diskutere den potensielle nytten av handel med kvoter samtidig som det blir reist noen kritiske spørsmål. Et viktig trekk ved kvotehandel er gevinstene i form av reduserte kostnader ved utslippsreduksjoner. Det numeriske eksempelet som presenteres i kapittel 7 i rapporten viser at de totale kostnadene av Kyoto-protokollen kan reduseres med omkring 95 prosent gjennom handel med kvoter.

I et nordisk perspektiv er det viktig at Danmark, Norge og til en viss grad Sverige sannsynligvis er blant de Annex B- landene som vil tjene mest på slik handel. Finland ligger imidlertid ikke i samme grad an til tjene på handel med kvoter. Dette skyldes at de estimerte kostnadene ved å redusere utslippene er lavere i Finland enn i de andre nordiske landene.

Handel med utslippskvoter er også aktuelt på det nasjonale plan. Kyoto-protokollen fordeler utslippsrettigheter (kvoter) til alle Anneks B-landene. Myndighetene i disse landene kan så vurdere om de ønsker å distribuere sine kvoter videre til nasjonale aktører i form av nasjonale kvoter. Dersom de velger å gjøre det, kan markeder for omsettbare kvoter oppstå nasjonalt så vel som internasjonalt.

Potensialet for kostnadsreduksjoner er sannsynligvis stort også når det gjelder innenlandsk handel med kvoter. På det nasjonale plan kan en imidlertid oppnå en tilsvarende kostnadseffektiv løsning ved å innføre avgifter på utslipp. Det er i den forbindelse viktig å understreke at Kyoto-protokollen ikke legger noen restriksjoner på de enkelt lands valg av nasjonale virkemidler.

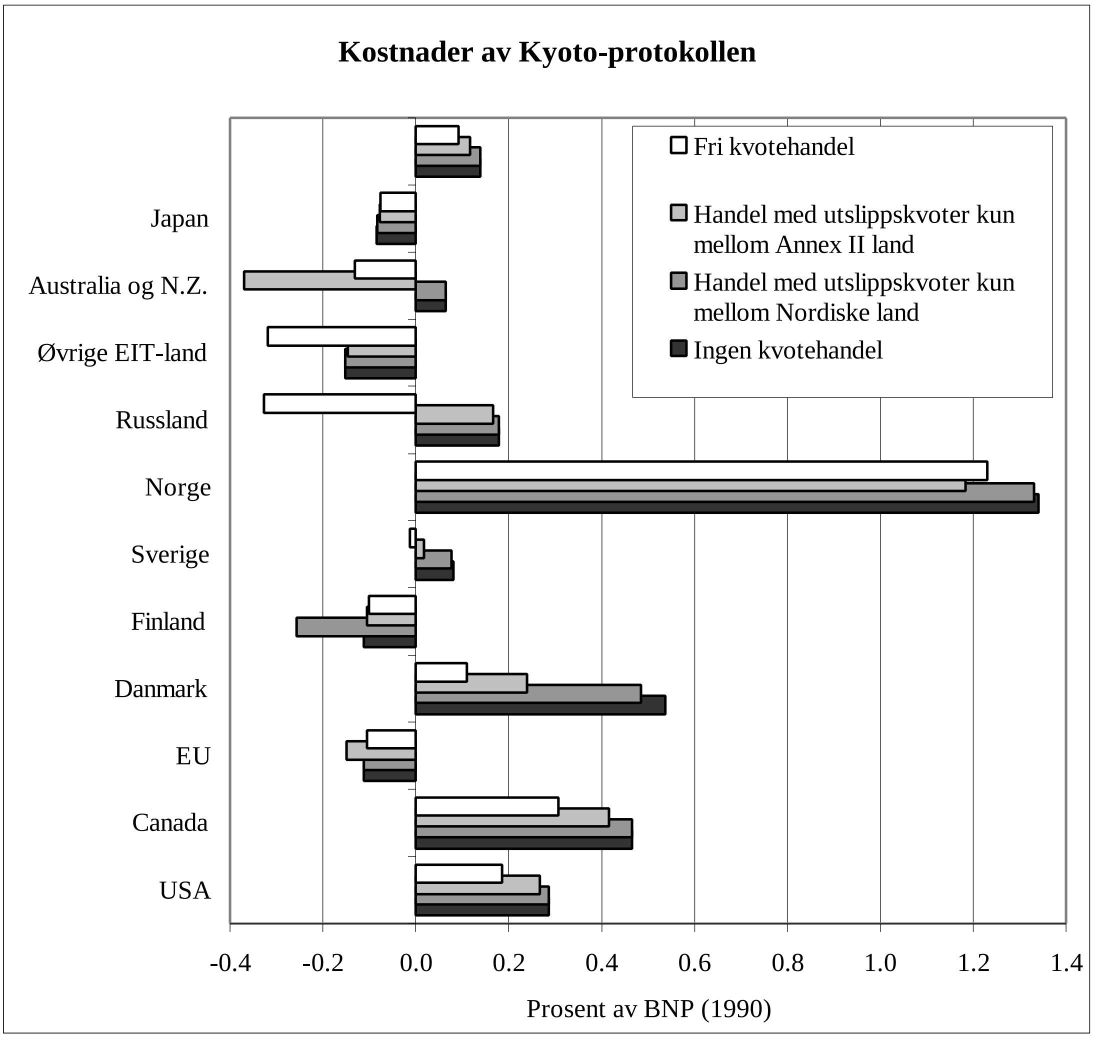
Handel med kvoter på nasjonalt og internasjonalt nivå bør i stor grad diskuteres hver for seg. Det er lett å se at de nordiske landenes myndigheter vil ha mange grunner til å støtte handel med kvoter på internasjonalt nivå, selv om handel med kvoter ikke gjennomføres på nasjonalt nivå i disse landene. De nordiske landene har allerede innført karbonavgifter innenlands. Denne avgiftspolitikken kan opprettholdes samtidig som de nordiske lands myndigheter støtter og deltar i handelen på internasjonalt nivå.

Selv om det er åpenbart at kvotehandel både kan redusere de nordiske landenes kostnader betydelig og være helt nødvendig for å få tilstrekkelig antall land til å ratifisere protokollen, er det enkelte uønskede effekter som ikke kan overses. Kyoto-protokollen tillater sannsynligvis noen land å slippe ut mere klimagasser enn det en kan anslå at deres "business as usual" (BAU) utslipp vil bli. Dette gjelder noen av landene med overgangsøkonomier (EIT-landene). Ubegrenset kvotehandel blant Anneks B landene vil da helt klart *redusere* de samlede utslippsreduksjoner sammenlignet med en situasjon hvor kvotene ikke er omsettelige. Vi omtaler dette som "hot air"- problemet i forbindelse med kvotehandel.

[5] Annex B land er de som er listet opp i Annex B i Kyoto protokollen (OECD-landene (untatt Korea, Mexico og Tyrkia), EU, som er en egen part til klimakonvensjonen, land med overgangsøkonomier og Liechtenstein og Monaco).

2.1 Gevinster av kvotehandel

Figur 2.1 viser den beregnete fordelingen av kostnader av Kyoto-protokollen.[6] Det er lagt til grunn at EUs samlede kvote er fordelt til medlemsstatene i overensstemmelse med den interne EU-fordelingen som det ble enighet om i juni 1998.[7]



Figur 2: Kostnader av implementering av Kyoto protokollen. Både bytteforholds-gevinster som følge av prisendringer i energimarkene og gevinster av proveny-resirkulering er tatt hensyn til. Den interne EU-fordelingen vedtatt i juni 1998 er lagt til grunn (se fotnote 7).

Fire situasjoner er analysert. I den første tillates ikke kvotehandel. I den andre tillates kun de nordiske landene å handle med hverandre. I den tredje situasjonen utvider vi handelsregionen

[6] Beregningene er utført med en modell utviklet ved CICERO. En tidligere versjon av modellen er nærmere beskrevet i Holtsmark (1997). Se også Ringius, Torvanger and Holtsmark (1998) for en annen anvendelse av denne modellen.

[7] Kvotene for Danmark,Finland og Sverige er 79, 100 og 104 prosent av de respektive 1990-utslippene. Det faktum at Danmark må redusere utslippene betydelig fra 1990 til den første forpliktelsesperioden, samtidig som Finland og Sverige bare må stabilisere eller svakt kan øke utslippene i denne perioden, forklarer for en stor del hvorfor Danmark i henhold til beregningene må regne med betydelige nettokostnader som følge av Kyoto-protokollen, mens Finland og Sverige er antatt å slippe billigere fra det.

til å omfatte alle Annex II landene. [8] Til slutt analyseres en situasjon hvor kvotehandel kan skje uhindret innen Annex B. I det siste tilfellet reduseres totalkostnadene til Annex B-landene med omkring 95 prosent sammenlignet med situasjonen uten handel.

Spesielt Danmark, Norge, Canada, USA, Australia og EIT-landene vil få spesielt store gevinster av kvotehandel. Dette skyldes at disse landene enten har spesielt høye eller lave reduksjonskostnader eller en tøff/fleksibel utslippskvote. Land med mer gjennomsnittlige kostnader ved utslippsreduksjoner vil ikke i samme grad få nytteeffekter av handel. De relativt romslige utslippskvotene til Russland og Australia vil for eksempel trolig gi disse landene en stor grad av fleksibilitet og mulighet til å tjene på kvotesalg.

Et grunnleggende resultat er at EIT-landene selger kvoter, mens de tradisjonelle markedsøkonomiene i tilfellet med fri handel samlet sett kjøper kvoter. Hvis det ikke settes begrensninger på handelen, kan derfor resultatet bli reduserte utslippsreduserende tiltak i de tradisjonelle markedsøkonomiene. Store såkalte ”ikke-angre-tiltak” i EIT-landene er forklaringen på at EIT-landene er anslått å oppleve netto gevinst av en klimaavtale selv uten kvotehandel.

2.2 Langsiktige konsekvenser av kvotehandel

Det er viktig å være klar over at de globale utslippsreduksjonene som følger av Kyoto-protokollen er svært begrenset. Utslippene vil sannsynligvis fortsette å øke i de land som ikke inngår i Anneks B-gruppen så lenge ny fornybar energiproduksjon taper i konkurransen med fossile brensler. Et sentralt spørsmål er derfor hvordan en klimaavtale bør utformes for å oppmuntre til teknologisk utvikling innen ny fornybar energiproduksjon.

Kvotehandel reduserer kostnadene ved utslippsreduksjon, som igjen vil redusere etterspørselen etter ikke-forurensende eller utslippseffektive teknologiske løsninger. Kvotehandel kan derfor komme til å redusere motivene for å satse på forskning og utvikling på disse områdene og kan følgelig også svekke den langsiktige miljøeffekten av en avtale.

2.3 Anbefalinger - tiltak og virkemidler

- Rapporten anbefaler en kontrollert, gradvis innføring av kvotehandel gjennom ulike faser. Mulige alvorlige sideeffekter vil derved kunne oppdages i tide til å bli korrigert.
- I den første fasen anbefales visse begrensninger på handelen. De enkelte lands regjeringer bør tillates bare å selge en viss andel av sine kvoter. Størrelsen på denne andelen bør sees i forhold til de kontroll- og sanksjonsmekanismene som vil bli brukt.
- Ved slutten av første fase bør partskonferansen (COP) vurdere erfaringene fra mellomstatlig kvotehandel mellom Annex-B land. På bakgrunn av denne vurderingen kan COP avgjøre hvorvidt begrensningene på kvotehandelen kan gjøres mer romslige.
- Rapporten anbefaler at en internasjonal institusjon tillegges ansvaret for å godkjenne alt salg av kvoter. Alle overføringer av utslippskvoter over landegrenser bør følges opp med en rapport til ovennevnte institusjon. Disse rapportene må inneholde en plan fra landet som selger kvotene om hvordan det økte behovet for utslippsreduksjoner vil bli planlagt og gjennomført.

[8] Annex II land er de som er listet opp i Annex II i klimakonvensjonen (OECD-landene pr. 1992 og EU).

- På de nasjonale arenaer står valget mellom karbonavgifter og fordeling av omsettelige kvoter for CO_2-utslipp. De nordiske landenes myndigheter bør utforske disse to alternativene videre. I forhold til erfaringene en allerede har med karbonavgifter er dette sannsynligvis det virkemiddelet som bør foretrekkes i disse landene.
- Hvis mange land i den første fasen innfører kvotehandelssystemer på de nasjonale arenaer bør en i andre fase vurdere om disse markedene kan integreres. På denne måten kan det utvikles mellomstatlig handel både med myndigheter og næringsliv som aktører. De nasjonale regjeringer bør likevel være ansvarlig for at den samlede nasjonale målsettingen nås. På dette stadiet kan land utenfor Annex B inviteres til å akseptere utslippsbegrensninger for å være i stand til å slutte seg til kvotemarkedet.

2.4 Oversikt over rapporten

Kapittel 3 utdyper blant annet den foreslåtte gradvise innføringen av kvotehandel. Kapittel 4 beskriver hvordan markeder for kvotehandel kan bygges opp og fungere. Kapittel 5 diskuterer fordeler og ulemper ved kvotehandel både på nasjonalt og internasjonalt nivå.

Kapittel 6 diskuterer potensiell nytte av kvotehandel i lys av andre empirisk baserte studier. Kapittel 7 presenterer noen numeriske eksempler for å illustrere hvordan kvotehandel kan påvirke de ulike landenes totale reduksjonskostnader og kostnader relatert til endringer i handelsregimer som følger når mange land gjennomfører tiltak samtidig. Kapittel 8 gir en kort gjennomgang av andre studier og erfaringer med kvotehandel.

3 Introduction

3.1 Historical background

For more than one decade at least parts of the international community have realized the need for a climate convention that limits the global emissions of greenhouse gases (GHGs). A number of intergovernmental conferences focusing on climate change were held in the late 1980s and early 1990s. Together with increasing scientific evidence, these conferences helped to raise international concern about the issue and the question whether an international law could be established. The Intergovernmental Panel on Climate Change (IPCC) released its First Assessment Report in 1990. It had a powerful effect on both policy-makers and the public and provided the basis for negotiations on the Climate Change Convention.

In December 1990, the UN General Assembly approved the start of treaty negotiations. The Intergovernmental Negotiating Committee for a Framework Convention on Climate Change (INC/FCCC) met for five sessions between February 1991 and May 1992. Negotiators from 150 countries finalized the proposal for the UN Framework Convention on Climate Change (FCCC) in June 1992 just before the Rio "Earth Summit". 154 states (plus the EC) signed the Convention in Rio. Later on the Convention has been ratified by more than 160 states and should now be considered as international law.

In March 1995 the first conference of the parties (COP-1) to the Convention took place in Berlin. The key action of the COP-1 was the adoption of the decision, the so-called “Berlin-Mandate”, that concludes “that the present commitments under the Convention, notably the commitments of developed countries to take measures aimed at returning to their level of GHG emissions of 1990 by the end of the century, are not adequate”.

The Berlin Mandate established a process that would enable the Parties to take appropriate actions for the period beyond 2000, including strengthening of developed countries’ commitments, through adoption of a protocol or another legal instrument. Most important was the setting of quantified limitation and reduction objectives (QELROs) within specified time frames. The Berlin Mandate furthermore stated that there should be no new commitments for developing countries.

At the third conference of the Parties (COP-3) the delegates agreed upon the *Kyoto Protocol*. The protocol sets differentiated binding emission limitations for developed nations (Annex B-countries) for the commitment period 2008-2012. The specific emission limits vary from country to country. The different Parties’ emission limitations are listed in appendix B.

The combined result of individual country targets is estimated to result in an overall reduction in Annex B countries’ GHG emissions by 5,2 % from the 1990 levels by the commitment period 2008-2012 (averaged across the period). The emission targets include all six groups of GHGs not included in the Montreal Protocol. There are, however, several important aspects of the protocol that remain to be negotiated. Among them are the rules for emission tradeing. The Protocol states that “Parties included in Annex B may participate in emission trading for the purpose of fulfilling their commitments …… Any such trading shall be supplemental to domestic actions for the purpose of meeting quantified emission limitations and reduction commitments…” (article 16 bis). The rules and guidelines are to be discussed at the fourth Conference of the Parties (COP-4) in November 1998.

3.2 Basic concepts

In the two subsections below we explore the distinction between emission *quotas* and emission *permits* and *abatement costs* and *protocol costs* as we use these basic concepts in this report.

3.2.1 Quotas and permits

It is our perception that it is especially important to emphasize and clarify the difference between domestic emission trading between enterprises within the different countries, and transboundary emission trading between governments. In accordance with most literature we use the term emission *quotas* for the national emission limitations specified in a protocol. The term emission *permits* are used for emission limitations allocated by a national government to domestic enterprises. In accordance with these definitions there could be an international market for emission *quotas*. In this market governments could be buying and selling quotas. At the same time there could be different national markets for emission *permits*. The participators are here domestic enterprises.

National markets for emission permits could be integrated with the international market for emission quotas. In that case the governments should allow national emitters to exchange their permits with the international tradeable quotas their receptively governments hold and hence trade directly on the international market.

3.2.2 Abatement costs and protocol costs

A country's efforts in order to reduce its emissions of greenhouse gases will normally decrease the net national income in the country. The reduced national income is called the *abatement costs*. The abatement costs could be low or even zero for small emission reduction levels. If the national economic policy in the first place is inefficiently designed the abatement costs could in some cases be zero or even negative because emission reductions in such cases could be achieved just by the implementation of a more efficient economic policy in the country under consideration.

A climate protocol specifying national emission quotas will have a number of economic consequences in addition to the costs each country with a quota will experience when taking action to reduce the national emissions. International trade patterns will be affected. Hence the prices in these markets will be altered. Especially significant price changes are likely to occur in the energy markets. Large fossil fuel exporters will for example probably experience reduced income if a strong climate agreement is implemented.

Such changes represent costs that come in addition to the *abatement costs* mentioned in the above paragraph. We could talk about *protocol costs*, which therefore have a broader meaning than the costs connected only to national abatement efforts. It is however important to have in mind that some countries' protocol costs will be lower than their abatement costs because the terms of trade changes give them a net gain. Fossil fuel net importers will for example probably experience considerably terms of trade gains.

3.3 Emission quotas and trading

The Kyoto Protocol sets quantified emission limitations for all Annex B countries relative to their 1990 levels. This correspond to an allocation of *quotas* to the Annex B countries, where the amount of quotas is equal to the amount of emission following from the emission limitations set out in the protocol.

In this report we will clarify the concepts related to quota trading, and discuss advantages and disadvantages. We analyze emission trading both at the international and the national levels. The Annex B countries' governments might consider whether they in their domestic arena should allocate their quotas to domestic business. If such allocation takes place emission trading could be a policy option also in the domestic arenas. We emphasize however that emission trading at the international and national levels has to be discussed separately. Governments could find several good reasons for supporting emission trading at the international level although they do not see tradeable emission quotas as their first choice in their domestic climate policies.

The advantage in the form of reduced total abatement costs is a basic feature of emission trading at both levels. In the case of greenhouse gases, the potentials for reduced abatement costs through emission trading is also large according to several empirically based investigations. The numerical example presented in chapter 7 estimates for example that the total abatement costs of the Kyoto Protocol could be reduced by 95% through emission trading. Other studies referred to in chapter 6 provide similar estimates. Similar cost saving potentials could be found by domestic emission trading. Implementation of emission taxes could, however, be implemented and nationally give a corresponding cost-effective solution.

Emission trading may not be the preferred policy instrument at the national level. A prerequisite for emission trading to take place is that emission quotas are allocated. In the domestic arena, the allocation of GHG-emission quotas has not taken place in any countries so far. At this level emission taxes is also a good alternative to the allocation of domestic emission permits. We emphasize that not least the Nordic countries have attained experience with carbon taxes. Further refinements of these climate policy measures are coupled with less degree of uncertainty compared with the design and implementation of national systems for allocation of tradeable permits. We discuss this further in section 5.3.

In the international arena, the situation is quite different. The Kyoto Protocol implies that emission quotas is the main instrument at the international level. The question now is to what extent these quotas should tradable. Quota trade can significantly reduce the countries' cost of the protocol. There are, however, arguments for keeping the quota trade within limits.

Firstly, completely free trade could mean a less effective agreement due to low degrees of compliance. We discuss this further in section 5.2. Secondly, the long-term impact of emission trading on technological development is an uncertain factor. One can sometimes miss a realistic approach to what could be achieved by a climate agreement limiting only the Annex B countries to small emission reductions. The effect on global emissions of greenhouse gases will be very limited, because the developing countries are in a phase of their economic development with high growth in GHG emissions. Due to the leakage effect a climate protocol could furthermore aggravate this emission growth. [9] The effect on emission reduction in the long term through an accelerated technological development including new renewable energy might therefor turn out to be more important than the short-term emission reductions.

A main result of emission trading is likely to be a net transfer of emission quotas from the EIT-countries to traditional market economies, cf. chapter 7. Hence, emission trading will reduce the pressure on industries in the traditional market economies to reduce their emissions of greenhouse gases. In chapter 5 we discuss whether this could delay the important technological development, for example new renewable energy.

[9] See section 4.3 for an explanation of the concept 'leakage effect'.

3.4 Phases in the development of GHG trading markets

Although one should be aware of possible undesirable side effects of emission trading, it can not be ignored that emission trading might significantly reduce the abatement costs. Consequently the parties could have increased willingness to ratify the Kyoto Protocol if emission trading is allowed. On the other hand, since some undesirable side effects of emission trading might not be known at the present stage or their degree of seriousness is not well known, a stepwise approach to emission trading should be considered. Table 3.1 sketches three possible main phases in the development of a global emission-trading regime.

In the *first phase* the Kyoto Protocol enter into force. The protocol could at this stage allow limited trade in emission quotas between Annex B governments. For example, each government could only be allowed to sell a certain share of its quotas to other governments. The Kyoto Protocol states (article 16 bis) that quota trade should be “supplemental” to domestic actions. The Protocol may therefore, at least initially, also restrict the purchase of quotas.

The Kyoto Protocol (article 4) states that a group of countries can pool their target and be in compliance as long as total emissions for all countries included in the “bubble” does not exceed the sum of the individual’ emission targets. This implies that EU can allocate the total amount of quotas of all EU members according to the allocation rule EU chooses.

At the national level the governments in the Annex B countries choose policy instruments within their countries. Some countries will probably develop plans for gradually increasing their CO_2-taxes and other taxes on GHG emissions and thereby cost-effectively bring the GHG-emissions in accordance with the national commitments within the specified timeframes. Other governments will design national systems for allocation of tradeable emission permits.

At the end of the first phase, the Conference of the Parties (COP) should review experiences from transboundary emission trading between governments of Annex B parties. On the basis of this review the COP should decide whether emission trading should be expanded or be completely free.

If several governments in the first phase introduced emission-trading systems in the national arenas, one should in the *second phase* consider whether these markets could be integrated. Each national government could let permit holders exchange domestic permits against the international quotas. The national governments will however be responsible for the national compliance, whether they have allocated quotas to national business or not. Hence, the national governments must be free to choose whether their domestic permit holders should be allowed to participate in the international quota market. At this stage the non-Annex B countries could be invited to accept emission limitations in order to be able to join the quota market.

Table 1: Possible phases in the development of a global market for GHG emission quotas

	National level	International level
Phase 1	The Annex B governments are free to use taxes or quotas in their domestic policies • Some governments may allocate national permits to business, and introduce domestic emission trading. • Other governments will use emission taxes and not allocate permits.	• The Kyoto Protocol enter into force. • An international institution is designated to approve, register and control the emission trading. • Limited trade in GHGs between governments. • An EU-quota is allocated to the member countries.
Phase 2	• National governments are free to choose whether domestic business should be free to take part in the international quota market. Governments are nevertheless responsible for national compliance. • Non-Annex B governments having accepted national emission limitations may allocate the national permits to business, and introduce domestic emission trading.	• Free trade in GHGs between Annex B governments and business. • Non-Annex B countries are invited to accept emission limitations in order to join the quota market.
Phase 3	• Free trade in GHGs involving both Annex B parties and non-Annex B parties having accepted national emission limitations. Both governments and business could take part in the trade.	

In addition, in *phase 3* the emission trading in the preceding phases should be evaluated. Important objects for evaluation will be the parties having sold quotas and their degree of compliance. The evaluation will constitute the basis when deciding whether the emission trading market should be further developed and expanded. If the experiences are promising a global market involving both governments and business in both Annex B and non-Annex B countries could emerge in this phase.

4 Design of a trading regime

The construction of a global climate policy could be seen as a two-level game. The national arenas constitute the bottom level of the game, where the governments, business companies and the public are the participants. The international climate negotiations constitute the top level of the game.

The goal of the negotiations (the top level of the game) is to find a solution that fits well into likely solutions at the bottom level of the game. Moreover, it is here important to keep in mind that, on the bottom level of the game, different countries will find different solutions suitable for them. One of the challenges is, however, to agree upon a common solution at the top level of the game.

The two main market-based policy instruments in greenhouse gas abatement are:
a) emission taxes, and
b) allocation of quotas.

At the national level, governments are free to choose different strategies. At the international level (the top level of the game) there has been little controversy around quotas as the basic instrument. Hence, at this level the discussion has concentrated around the question of what countries should have emission limits, how ambitious they should be, whether the limits should be differentiated, and whether the emission quotas could be traded.

The discussions at the national level are far more open. Several countries (Denmark, Finland, Netherlands, and Norway) have implemented CO_2-taxes, whereas allocation of tradeable CO_2-permits has so far not taken place in any countries. [10] Under the Kyoto Protocol it is likely that some countries will fulfill the commitments by the use of emission taxes, while other governments will allocate permits.

Governments who choose to allocate emission permits domestically have to choose whether this should be done through direct distribution of permits or by auctions. Auctions will generate public income, but might be a less politically feasible solution. Furthermore, they have to decide whether the permits should be tradeable.

4.1 What is emission trading?

Trade can only take place if there is a good to be traded. A basic prerequisite for emission trading to take place, is that a number of emitters by some sort of a legal instrument are restricted to keep their emissions within certain limits. The emission quotas or permits are the goods being the object to trade.

Emission trading means that the emitters keeping emission quotas or permits exchange these assets against an economic compensation. The essential point is that they have common interests through cost-saving if their marginal costs are different. [11] If such differences exist, it is in both emitters' interests to make a deal where the emitter with high marginal abatement costs receives quotas or permits from the emitter with low marginal abatement costs, followed by an economic compensation going the opposite direction.

[10] Voluntary agreements are often seen as a separate alternative to emission quotas. We concider, however, that a system with voluntary agreements on emission reductions in reality is a non-tradeable permits-system. The only difference from an ordinary emission-permit systems is that the size of the permits are the outcome of negotiations between business and government.

[11] The marginal abatement cost is the costs related to reducing the emission by an additional unit greenhouse gases.

There might be very large cost saving potentials connected to such trade. In the numerical example presented in chapter 7 of this report the total abatement costs are reduced by approximately 95% if there is free trade among the Annex B countries. Other studies shortly mentioned in chapter 6 points in the same direction. All emitters taking part in the emission trading are likely to obtain a part of the economic gains from the trade, cf. the discussion in the appendix.

4.2 Who trades?

We have used government-government emission trading as a starting point for our analysis. Quite independent of to what extent the COP-4 reaches consensus on rules for intergovernmental emission trading at the international level, some governments might prefer to open up for emission trading domestically. A prerequisite for emission trading is that the emitters are subject to emission limits. Hence, domestic emission trading requires permits to be allocated to individual, domestic emission sources such as industries, companies or households.

It might be important to underline that the Kyoto Protocol do not force any government to introduce emission trading domestically. Governments will be free to use other instruments than tradeable permits, for example CO_2-taxes, in their *domestic* climate policy whether or not emission trading takes place at the international level.

If, on the other hand, a number of countries allocate tradeable permits domestically, emission trading might follow new pathways. Governments might decide to allow individual emission sources such as industries and companies that are subject to emission limits, to participate in the international emission trading system. The governments should then allow national emitters to exchange their permits with the international tradeable quotas the government holds and hence trade directly on the international market.

A further remark on the question of who is taking part in national emission markets is needed. As underlined above, only individuals, households, firms or governments who possess emission quotas or permits, could take part in emission trading. It is however obviously not reasonable to allocate emission permits to every single household and firm in a country. The administration costs would then be unacceptable large. In the case of CO_2, a better strategy is to allocate the permits to the companies selling and distributing oil, coal, and gas. Because there is a simple relationship between the amount of fossil fuels sold and the final emission of CO_2, the companies could be allowed to sell certain amounts of fossil fuels measured in CO_2-units. If permits are distributed in that way, these companies will be the participants in an emission trading system.

4.3 Inclusion of non-Annex B parties in the trading system

The Kyoto Protocol does not set any limitations on the emissions from the developing countries (non-Annex B countries). Hence, the protocol puts limits on a diminishing part of the world's emissions of greenhouse gases. This problem is pressing not least because the policies and measures implemented in the Annex B countries in order to fulfill their commitments in turn might lead to increased emissions in the non-Annex B countries.

This so-called leakage effect of a climate agreement with limited participation is partly brought about by reduced demand for fossil fuels in the Annex B countries, falling prices and consequently increased consumption of fossil fuels in the non-Annex B countries. Furthermore, in the long term it is likely that one will experience a movement of energy intensive and polluting industries from countries implementing policies and measures to those not taking steps to limit their emissions of CO_2 and other greenhouse gases.

The opportunity to take part in an emission trading system could provide the non-Annex B countries with an incentive for accepting emission caps. When an international quota market is established, there might be willingness in the developing countries to accepting emission limitations and thereby join the quota market, cf. table 3.1 and the discussion of phases in 3.4. If invitations are accepted, it could reduce the leakage problem.

The point is that a prerequisite for taking part in a market for emission permits is an emission limit. A country with considerable possibilities for low-cost emission reductions could therefore find it beneficial to accept an emission limit in order to be allowed to sell emission quotas on the international market. In total, this could be beneficial to this country if the cost of reaching the initial emission limit is less than the net gains the country will have from participation in the emission trading market. It is, however, important to ensure that the developing countries receive quotas that are below their BAU emissions in order to ensure that no “hot air” trading occur (see discussion about “hot air” in section 5.2.2).

4.4 What is traded?

In the previous sections we discussed what is meant by emission trading, and who the trading partners could be. In this section we discuss the definition of the traded commodity. A prerequisite for a successful trading regime is that the traded commodity, (or commodities if there are several types of quotas), is/are clearly defined. Furthermore, the trading regime should be designed such that the total abatement achieved after trade has occurred are in compliance with total abatement following from the initial distribution of the emission limitations (or emission caps) across Parties. A quota must be clearly defined with regard to emission measurement and the time period the quota is valid for. It can also be valuable to specify the country of origin of the quotas. These aspects will be further discussed below.

The amount of tradeable quotas distributed across the countries, which have binding emission caps, depends on the rules for trading. If there are no restrictions on trade, the distribution of tradeable quotas should correspond to the distribution of emission limitations. In an initial phase of a trading regime, where there might be restrictions on trade, only a certain percent of the Parties’ emission limits could be defined as tradeable quotas.

4.4.1 One quota or several quotas?

A quota system could comprise several types of quotas – one quota for each GHG, where the emissions are measured by tonnes of the corresponding GHG - or one type of quota could cover a basket of all the different GHGs. The quantified emission limitations specified in the Kyoto Protocol are related to a basket of GHGs. The emissions reductions of the different GHG in the basket are interchangeable. The emissions from the different cases are measured by a common measure; *CO_2–equivalents.*[12]

[12] GWPs (Global Warming Potentials) has been introduced as a tool for policymakers to compare the impact on the climate of emissions of the different greenhouse gases. GWP is an index which defines the cumulative radiative forcing between the present and some chosen later time horizon caused by an unit mass gas emitted now, expressed relative to the reference gas CO_2. By the use of GWP one can translate GHGs into CO_2-equivalents. Although it is not explicitly stated in the Kyoto Protocal, it is consensus on choosing a time horizon of 100 years.

The impact of trade restrictions on abatement: A numerical example

For simplicity we assume that the country in our example only emits two types of GHGs; Methane and CO_2. We will in the following compare three different situations for international trade:

*Situation A***:** One quota for a basket of GHG. No restriction on trade

Situation B: Separate quotas for all gases. Only international trade with CO_2 quotas is allowed but the protocol allows for national exchange of emissions from the different gases

Situation C: Separate quotas for all gases. Only trade with CO_2 quotas is allowed.

Assume that a country in *situation A* finds it optimal to sell quotas corresponding to 20 tonnes of CO_2 equivalents. This is met by an increase in national abatement of CO_2 by 10 tonnes and abatement of Methane by 10 tonnes of CO_2 - equivalents to ensure compliance.

Given the same international price of CO_2 quotas in *situation B* as the price of quotas measured in CO_2 - equivalents in *situation A*, the country will in *situation B* find it optimal to sell *CO_2-quotas* corresponding to 20 tones CO_2-equivalents. Since the national abatement costs are the same whether trade of both types of quotas are allowed or not, the country will increase abatement of CO_2 by 10 tonnes and Methane by 10 tonnes of CO_2 equivalents in order to be in compliance with the climate agreement. Hence, the restrictions on trade will not alter the country's optimal distribution of abatement across gases compared to *situation A.*

The restrictions on trade in *situation B* did not imply restrictions on the distribution of abatement across gases within each country or on trade in CO_2 quotas. This imply that the international price on CO_2 quotas and the total trade measured in CO_2 equivalents, and the distribution of abatement across countries and across gases will be identical in the two situations.

Furthermore, if the country wanted to cheat by reporting more abatement of methane than it had carried out, this could as well be done in a regime where trade was restricted to only CO_2 quotas as in a regime with no restrictions on trade. However, in *situation C* the country could not meet the sale of CO_2 quotas by increased abatement of methane. This would thus reduce the countries' incentive to report fictive reductions of methane .

Emissions of some types of GHGs are more difficult to monitor than others. Anthropogenic emissions of CO_2 are relatively easy to monitor because the emissions are almost directly linked to the use of fossil fuels and land use changes. [13] Especially CO_2 emissions from combustion of fossil fuels are easy to monitor. Observing, for instance, the reductions of nitrous oxide (N_2O) and methane (CH_4) emissions is more complicated than for CO_2 since the emissions are more technology-specific, and varies with, among other things, the combustion conditions.

Controlling and verifying emissions will have to rely on measurements and site inspections. Monitoring problems can make it difficult to verify that countries are in compliance with their emission limitation levels, because they can sell quotas well in excess of what is met by increased national abatement (see section 5.2.1 for a further discussion about cheating). Mullins and Baron (1997) suggest (before the Kyoto meeting) that, due to monitoring problems, trade could, at least initially, be limited to trading only emission of CO_2. However,

[13] A minor part (2 %) of the antropoghenic emissions of CO_2 is caused by cement production. (1991/1992 figures from World Resources Institute (1996)).

restricting trade to only CO_2 emissions would imply that the Kyoto Protocol would have to specify separate quotas CO_2 in order to secures that emission reductions of CO_2 could not be exchanged with emission reductions of other GHGs. This is illustrated by a numerical example in the text box.

A system with separate non-interchangeable quotas for the different GHGs will increase the cost of the climate agreement because it prevents countries from distributing abatement cost effectively across gases both nationally and internationally. It is therefore a trade-off between reducing the possibilities for cheating (or miscalculating) and increasing the cost–effectiveness in the design of a trading regime. Since the Kyoto Protocol sets emission limitations for a basket of gases it is probably unlikely that separate quotas for the different GHGs gases will be assessed in the discussion for the rules for a global trading regime at the next COP-4.

4.4.2 Time period

A quota could define the right to a certain amount of emissions in a fixed year or over a certain time period, or a quota could specify repeated emissions over subsequent periods (years).[14] The emission targets specified in the Kyoto Protocol are to be reached over a five–year commitment period. That is, the average emissions per year during the commitment period can not exceed the emission limitations specified in the protocol. The choice of a *commitment period* opposed to a certain *target year* increases the flexibility of the protocol. This flexibility should also be accounted for in a trading regime. The quotas should therefore be *period-specific,* which means that they give the right to a certain amount of emissions during a commitment period. The holder of the quota could then choose at what time, during the commitment period, the emission should occur.

The Kyoto Protocol accepts banking of emission reductions which implies that if a country's emissions during one commitment period is less than its assigned amount, the difference can be added to the assigned amount for that Party for the subsequent commitment periods. This flexibility should also be reflected in the design of the tradeable quota market. To the same extent as countries are allowed to bank emission reductions across periods, they should be allowed to bank quotas across periods.

4.4.3 Country-specific quotas

It has been argued, *inter alia* by Mullins and Baron (1997), that it may be necessary to identify the country of origin of the quotas in order to facilitate *accounting* of emissions for determining compliance. However, a system where all trade in quotas have to be reported to an international agency, identifying buyers, sellers and the amount traded could equally well facilitate the *accounting* of emissions. A system for identification of the quotas' country of origin would in that case be unnecessary.

However, country-specific quotas are one method for preventing countries from selling more quotas than they intend to compensate by increased abatement nationally. If the holders of quotas must, to some extent, be responsible for the country of origin's compliance there will be different prices on the quotas from different countries of origin depending on the countries' compliance. This could prevent countries from cheating because that could, if verified, cause a fall in the price of their quotas for future budget periods.

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[14] Quotas, which give the right to repeated emissions over subsequent periods, can for instance specify an entitlement to emit a certain amount of CO_2 in each of the subsequent budget periods specified in a climate protocol. Hagem and Westskog (1996) studies how quotas which give the right to repeated emissions can reduce the adverse effect of market power, compared to quotas that define the right to a certain amount of emissions in a fixed year or over a certain time period.

Non-compliance will not necessarily be a result of planned cheating. The country not being in compliance will nevertheless be punished through a fall in its quota prices in the future *if* the buyers of quotas must, to some extent, be responsible for the country of origin's compliance. However, this system may lead to limited trade because the quota buying country will need to collect information about the selling country before trade can take place and consequently the transaction costs of the system are increased.

An alternative way of limiting non-compliance is to require that all transfers of emission quotas across boarders have to be approved by an international institution (as we suggested in section 3.4). The punishment for not being in compliance can be restrictions on trade in future commitment periods.

5 Discussion of the performance of a trading regime

The previous chapter provided an overview of the basic structure of markets for emission trading. The goal of this chapter is to discuss the main advantages and disadvantages of emission trading in its different forms. The aim of the chapter is to clarify and break down this discussion as much as possible. Technical terms are therefore kept to a minimum.

In the discussion, we must distinguish clearly between transboundary emission trading between governments and domestic emission trading between companies and institutions within the different countries. [15] This distinction is fundamental because the arguments for and against emission trading are not the same whether we discuss the first or the second mentioned types of emission trading. One reason for this partitioning of the discussion is that these two types of emission trading have to be evaluated against different backgrounds. When discussing *transboundary* emission trading between governments the question at stake is to what extent the Kyoto Protocol should allow the quotas to be traded.

When discussing *domestic* emission trading, the starting point of the discussion is quite different. The Kyoto Protocol has allocated greenhouse gas quotas to all Annex B countries. The governments now have to decide whether their national quotas should be allocated further domestically. An alternative is to use another market-based instrument like emission taxes right from the beginning. Hence, at the domestic level allocation of quotas and emission trading has to be discussed critically in relation to emission taxes. That discussion is quite different from the discussion at the international level, where quotas already are allocated.

Although we emphasize the difference between international and domestic emission trading, some arguments are nevertheless common. The cost-saving potential that could be exhausted by emission trading is one example of this. We take that quite general discussion applicable to both types of emission trading in an appendix to the report. Section 5.1 discusses whether some large participants in the quota markets, by strategic behavior, will reduce the cost-effectiveness of quota markets. Transboundary emission trading is discussed in further detail in section 5.2, while domestic emission trading vs. taxes is discussed in section 5.3.

5.1 Inefficiency due to market power and transaction costs

The potential for reductions in total abatement costs through emission trading is the main argument for allowing such trade. In this section we will discuss some factors that reduce the cost-saving potential of quota trading. Tradeable quotas have been much studied in the literature and researchers foresee numerous obstacles to such trade.

Tietenberg (1985) gives a thorough analysis and review of the literature on tradeable quota systems. A theoretical feature of a perfectly competitive market of quotas is that cost-effectiveness is achieved regardless of the initial allocation of quotas. This implies that the allocation of quotas across countries following from the Kyoto Protocol does not influence the cost-effectiveness of a tradeable quota regime. A perfectly competitive market for quotas minimizes the *total cost* of the sum of abatement, for all possible distributions of quotas, and hence economic costs, across the participating countries. However, several factors might

[15] As mentioned in the previous chapter transboundary emission trading could also take place between companies or other institutions in the different countries.

reduce the cost-effectiveness of a tradeable quota scheme. One is that some large agents through strategic behavior are able to influence the price, i.e. take advantage of their market power. Another factor is transaction costs. Both of them will be discussed in this section.

5.1.1 Market power

In a competitive market, the agents are by definition "price-takers", which means that they can not, by their behavior, influence the prices. However, if an agent is a large seller/buyer of quotas, she knows that her supply/demand for quotas will have an influence on the market price. Some large countries, for example the USA and Russia, might dominate the international quota market. The international quota market will therefore probably not be competitive. A large seller of quotas will sell too few quotas and a large buyer of quotas will buy too few quotas compared to a cost-effective distribution of abatement across agents.[16]

It is not possible to say generally whether the Nordic countries will loose or gain if there are countries with market power in the quota market. That depends on whether the large agent, are sellers or buyers of quotas. A large buyer would give likely quota buyers, as Denmark and Norway, advantages through its effort to keep the quota price low. According the distribution of quotas given by the Kyoto Protocol and the projected emissions in the future (discussed in section 7), USA will be a large buyer of quotas and Russia will be a large seller of quotas. A further development of the numerical model is, however, necessary before we could be able to estimate these two countries possibilities to influence on the quota price.

Hahn (1984) shows that the efficiency loss from market power in a tradeable quota market depends on the initial allocation of quotas. Hence, there is no longer separability between considerations of equity and efficiency in the quota system, as we would obtain in a competitive market of quotas.

As already mentioned, market power is only a problem if there are some large seller/buyers of quotas. If all participants in the quota market are trading small amounts of quotas relative to the total amount of quotas traded, they are all "price–takers" and the problem of market power would disappear. An increasing number of small countries participating in quota trade would reduce the problem of market power. In a worldwide trading regime it is therefore less possibilities to exercise market power than in a regime with trade only between a limited number of countries.

The problem with market power is also an argument for letting each producer and importer of fossil fuels to a country operate in the tradeable quota market rather than countries, as this will surely increase the number of participants in the quota market. There are, however, two main reasons why this would not necessarily eliminate the problem of market power. Firstly, many of the importers and producers of fossil fuels would probably have the possibility of acting strategically in the quota market as well. Many of them have large global market shares. The market power problem could be reduced, but it would probably not disappear. Secondly, if a government has the ability to act strategically when it is trading in the quota market, it can still be acting strategically if its importers and producers of fossil fuels instead are traders of quotas. By regulation of the national fossil fuels taxes it can affect the supply or demand of quotas in the international market of tradeable CO_2-quotas, and hence be able to exercise market power as before.

[16] In a study by Westskog (1996) it is shown that with some allocation rules set up by Western European countries to involve Former Soviet Union and Eastern Europe with no obligations to reduce CO_2-emissions in the trading of quotas, the efficiency loss from market power can amount to a 10% increase in the total costs of reducing CO_2-emissions.

The problem of market power is probably more relevant for domestic trade in quotas, especially within small countries, than in a global trading regime (or in a trading regime among Annex B countries). The problem of market power should therefore be taken into consideration when the Nordic governments choose among national policy instruments in a possible initial phase of a trading regime (see table 3.1). The number of potential quota traders will probably be small in all Nordic countries. It will be a very costly system, in terms of transaction costs, if quotas were allocated to all emitters of GHGs. This would for instance imply that all households had to ensure that they had a sufficient amount of quotas before they could drive their cars or heat their houses. This would be a very costly system both because it is time consuming for the consumers and it would be costly to monitor. Quotas would therefore most likely be distributed to national energy suppliers. However, since there are a limited number of national energy suppliers within the Nordic countries, the problem of market power may arise.

Although the cost-effectiveness of the quota market can be reduced due to some agents exercising market power, it is not a fundamental disadvantage. The main part of the cost-saving potential of emission trading is probably nevertheless going to be exploited.

5.1.2 Transaction costs

Transaction costs can also reduce the cost-effectiveness of a tradeable quota market. Stavins (1995) identifies three sources for transaction costs in tradeable permit markets:

- The cost of providing information about trading partners
- The expenses incurred in connection with trade negotiations, for instance the cost of time, fees for brokerage and legal and insurance services
- The authorities' monitoring and enforcement costs

The magnitude of these transaction costs will depend on the structure of the market and the extent to which transactions require approval by the authorities. Under a well-functioning market, the agents do not have to search for trading partners. All agents will know the market price for quotas and the price conveys all the information the agents need for their decisions. However, at least in an initial phase of a tradeable quota regime, where perhaps only a limited group of countries negotiate trading, the transaction costs may be significant.

Increasing the number of potential traders and establishing formal trading exchanges could significantly reduce the transaction cost. A trading regime may, however, increase the monitoring and enforcement costs of the Kyoto Protocol. As discussed in section 5.2.1, we recommend that an international institution should be designated to approve all quota-trade (at least in an initial phase). Such a system will imply some costs. However, the cost of this monitoring system will probably be of minor importance compared to the potential gains from trade.

This leads to the conclusion that transaction costs may be significant in an initial phase of a trading regime, but these costs will probably be of minor importance when the trading regime is well established.

5.2 Transboundary emission trading – will it benefit the environment?

The appendix A provides a numerical example in order to explain the cost saving potentials of emission trading. Section 5.1 discussed to what extent the cost saving potentials could be reduced if there are one or a few very dominant participants in the emission trading market and if there are high transaction costs. In this section we will draw the attention to factors that can reduce a tradeable quota regime's ability to combat global warming. Firstly, we will discuss to what extent quota trading might aggravate problems with compliance. Secondly, we will discuss the implications of the fact that some countries may receive quotas well in excess of their business as usual emissions. Thirdly, we will discuss whether emission trading might reduce the climate agreement's ability to stimulate research and development on new renewable energy.

5.2.1 Emission trading and compliance

Problems regarding monitoring and compliance are fundamental for any climate treaty. Whether or not emission trading is taking place, the treaty requires monitoring of the emission reduction efforts in the different countries and there has to be some sort of sanction mechanism.

Nevertheless, monitoring and sanction mechanisms *might* be of greater importance if emission trading is allowed. Emission trading can increase the potential economic gains from non-compliance and the environmental consequences of non-compliance could be enhanced. Let us illustrate this using the numerical example in the appendix assuming that only country A, the quota seller, is a cheater. After the trading agreement is signed, country A is committed to reduce its emissions more than in the case without trading, while country B could reduce its emissions less.

If there is no effective sanction mechanism in place, country A will neglect its emission reduction commitments. Consequently, the total emission reduction will be limited to three million tonnes of CO_2. If emission trading had not been allowed the total emission reduction would at least have been five million tonnes of CO_2. Furthermore, if country A as a cheater is completely rational, it will have incentives for selling more quotas than the two million tonnes assumed initially. This number was calculated on the basis of planned compliance. If non-compliance is no longer a part of the plan, further quota sale is going to take place. The result could be that no emission reductions would take place at all.

Assuming that only country A is a cheater and a cheater completely without scruples is a simplification. It is perhaps more realistic that both countries would consider cheating if the net gains are high enough.

It is therefore not obvious that emission trading will increase the problems concerning compliance. Country B could for example be willing to cheat if emission trading is not allowed, because the gains from cheating then are large. When emission trading is allowed, country B's costs related to compliance are reduced. Hence, it could consider the costs related to loss of reputation as more costly than the abatement costs, and consequently fulfills its commitments. However, the gains from cheating for a country with high national abatement costs could also be *increased* by emission trading because the country could choose to be a *seller* of quotas which it has no intention of compensating by national abatement.

The conclusion from the general discussion above is that although emission trading increases the *potential* for cheating, it is not possible to state *generally* that emission trading will increase the problems related to compliance. Whether quota trade will enhance the problem of cheating depends on the different countries' attitude to non-compliance. The barriers to cheating are probably not equally distributed among countries.

The emission-trading pattern is likely to be dominated by an export of emission quotas from the EIT-countries to the traditional OECD-countries. It is reasonable to assume that most countries will seek to be in compliance with the protocol. However, some potentially large sellers of quotas are in a difficult economic situation. For instance Russia face severe problems with its national economy. Selling quotas could be an important source for foreign earnings. In the case of countries with large economic problems it might be too optimistic to expect that sale of quotas will be met by increased national abatement efforts. Hence, emission trading might enhance cheating and lead to less global abatement unless there is a sanction mechanism, which prevents countries from cheating. With the lack of such a mechanism limiting the amount of quotas each country is allowed to sell can reduce the problem of cheating.

5.2.2 "Hot air"

The Kyoto Protocol has probably provided some countries with emission limitations above their business as usual (BAU) emissions. The (positive) difference between the emission limitations and the BAU emissions is often refereed to as "hot air". According to the scenarios presented in chapter 7, at least Russia and probably also some other EIT-countries will have "hot air". Quota trading implies that these countries will sell these "excessive" quotas. Increased emissions from the countries buying the quotas are in this situation not met by reduced emissions from the countries that are selling their "excessive" quotas. The consequence is that total global emissions are larger than they would have been in a situation where the quotas were non-tradeable. We refer to this as the problem of "hot air" trading.

The problem of hot air trading can, in theory, be avoided by limiting trade to countries that "without doubt" have received quotas below their BAU-emissions. It is, however, important to note that it is almost impossible to prove that a country have hot air. The reason for this is that the Kyoto Protocol specifies emission targets for a time period in the future (2008-2012). Estimates for future emissions, especially from the EIT-countries, are very uncertain. Furthermore, due to the Kyoto Protocol the BAU-emissions in the first commitment period will never be observed. If one observes that emissions in the time period shortly prior to 2008 is below the emission limitations set out in the Kyoto Protocol it is more or less impossible to say whether the low emissions are due to low BAU emissions or to implemented abatement measures. It is of course in the interest of the country to claim that the emission reductions are due to implemented abatement measures if that implies that the country is allowed to trade quotas.

Furthermore, the countries that most likely have hot air (the EIT-countries) probably also have the lowest abatement costs. Excluding these countries from quota trading would therefore increase total cost of the protocol significantly. It is in other words a trade-off between some hot air trading and increased cost of the protocol.

Above we discussed the possible impact on global emissions of hot air trading for the first commitment period (2008-2012) in isolation. It is, however, important to keep in mind that the Kyoto Protocol accepts banking of quotas. This implies that if some countries have hot air in the first commitment period, and they are restricted from sale of quotas because of this, they will bank the hot air to the next commitment period.

If the countries the next commitment period have BAU emissions above the emissions limitations set for that commitment period (not yet decided), intertemporal transfer of hot air will imply that the emission from these countries would be higher than they would *have been* if banking was not accepted. Consequently, since banking *is* accepted, hot air trading in the first period will in the end not lead to higher global emissions in the long run than if trade was not allowed. (We assume that countries that have hot air in the first commitment period in some future commitment periods will have emission limitations below their BAU emissions).

5.2.3 Negative effect on technological development within energy efficiency and new renewable energy?

Although economists are able to draw relatively strong conclusions about the potentials for reduced abatement costs through emission trading, the long-term consequences are less well understood. It is important to stress that the direct emission reductions achieved through a protocol specifying emission limitations only to the Annex B countries will be unsatisfactory. The emissions are likely to continue to grow in the rest of the world. Through the leakage effect the emissions in the developing countries is even likely to be increased as a result of the implementation of abatement measures in the Annex B countries. If nothing occurs which make new renewable energy technology more competitive relative to fossil fuels, the accumulation of CO_2 and other greenhouse gases in the atmosphere will continue despite any climate protocol limiting the emissions of the Annex B countries. Hence, an essential question is whether a climate protocol will be able to encourage research and development of new renewable energy.

It is difficult to give good advises on how a climate agreement should be designed in order to promote research and development of new renewable energy production, because economic theory so far gives ambiguous advises at this point. How to encourage technological development in general is the subject of professional dispute among economists. Strong conclusions at this point will nevertheless be weakly based.

It is in spite of this reasonable to believe that a climate agreement that commits the rich countries to reduce their emissions of greenhouse gases, not least the USA and other leading economies considered to be at the ‘technology frontier’, could have an important impact on the technological development just mentioned. If countries on the technology frontier are forced to limit their use of fossil fuels, it is likely that this will stimulate relevant research and development. The result could be new technological solutions that will constitute new ‘no regret options’. In turn that could bring about reduced use of fossil fuels also in other parts of the world not being committed to reduce their emissions. Hence, although abatement measures limited to the traditional market economies will have a small immediate effect on global emission of greenhouse gases, the effect in the long term due to development of new technologies might be considerable.

A major result of allowing emission trading is probably that the EIT-countries will be net sellers of quotas, while the traditional market economies as a whole will be buyers. In other words, emission trading is likely to stimulate to increased abatement in the EIT-countries, and reduced abatement measures in the traditional market economies. The question is how this will affect the technological development.

The EIT-countries are in general probably far from the technology frontier. Hence, emission trading is likely to bring about increased abatement in countries far from this frontier and reduced abatement measures in countries at or near the frontier. To a large extent it is reasonable to say that emissions of greenhouse gases in the EIT-countries could be brought about just by investing in technology that is already well known through large scale use in the traditional market economies. Abatement measures in these countries would therefore not necessarily encourage technological development within new renewable energy, at least not at the same extent as in the traditional market economies. The result could be that emission trading could cause higher emission in the long term, compared to an agreement with the same set of national quotas not traded.

As emphasized above, we are now in an area of uncertainties. The above thoughts are to some extent speculative. The long term technological development of new renewable energy might turn out to be of greater importance to global emissions of greenhouse gases than the direct emission reductions that will follow from the Kyoto Protocol. However, how this technological development should be effectively encouraged is difficult to answer. We discussed above the possible negative impact of technological development of transferring quotas from EIT-countries to the industrialized countries. On the other hand we know that emission trading can significantly reduce the cost of a climate protocol. This implies, other things being equal, that there are more resources available for research on technological development. Consequently, we are very careful drawing strong conclusions about possible connections between emission trading and technological development.

5.2.4 Concluding remarks on emission trading and the environment

In this section we have pointed towards some factors that might cause a protocol which allow emission trading, to lead to higher emissions than if trading was not allowed. The starting point for our discussion was the differentiated emission limitations for the first commitment period agreed on in the Kyoto Protocol. However, it is important to have in mind that the Kyoto Protocol will not enter into force unless at least 55 Parties to the Convention, which accounted in total for at least 55 percent of the total CO_2 emissions for 1990 from developed countries, ratify the protocol.

Since emission trading significantly reduces the countries’ protocol costs, restriction on trade may imply that the protocol will never enter into force. Furthermore, emission trading may imply that the Parties accept higher ambition level for emission reductions in future commitment periods. If that is the case, the possible adverse effect on the environment of emission trading, as we discussed above, could be more than offset by higher ambition level for global abatement.

5.3 Domestic emission trading vs. energy taxes

As we emphasized in the introduction to this chapter, allocation of tradeable permits in the national arenas should be considered in relation to other suitable instruments, not to mention emission taxes. This section will provide input to those considerations. We will in the following discuss the differences between a national permit trading regime and a national emission tax regime with respect to cost-effectiveness, distribution of costs in theory and practice, and the performance of the two different systems under an international climate agreement.

5.3.1 Cost-effectiveness

National emissions taxes imply that national emissions of GHGs are taxed by the national governments. The emission tax will specify the amount that has to be paid per unit CO_2-equivalents emitted. The Kyoto Protocol covers the emissions of all GHGs not covered by the Montreal Protocol. The locations of the emissions of the different GHGs are not directly observable. However, anthropogenic emissions of CO_2 are directly linked to the use of fossil fuels and land use changes. To reduce emissions of CO_2 one may impose instruments (tradable permits or taxes) on the use of fossil fuels and land use changes.

Observing emissions of other GHGs, for instance, N_2O and CH_4, is more complicated since the emissions are more technology-specific, and varies with, among other things the combustion conditions. Other policy instrument (for instance direct regulations of production technologies) may then be more effective. The choice of other domestic policy instruments than permits and taxes will, however, not be discussed in this report. Tradable permits or (and) taxes will probably be the most important policy instruments since these instruments effectively reduce the emissions of CO_2, which is the most important GHG.

We know from economic theory that if the emission tax is identical for all sources of emissions, the climate policy is cost-effective. The tax system ensures that abatement is distributed cost-effectively across emitters. Hence, both a national tax regime and a national tradeable permit regime can ensure a cost-effective national distribution of abatement.

5.3.2 Distribution of cost

A tax regime can, in principle, lead to all possible outcomes for distribution of costs across the emitters, through compensating side payments. The cost–effectiveness of the tax system is maintained as long as the compensation is not linked to the emissions. Hence, an option is that the emitters pay a tax per unit emissions and is later redistributed a certain percent of the *total* tax revenue. The rule for redistributing the tax revenues determines the distribution of costs among the emitters. If the tax revenue is not redistributed to the emitters, the tax regime follows the “polluter pays principle”.

In a tradeable permit regime, where the permits are distributed directly to the emitters, for example employing “grandfathering”, the distribution of costs is built directly into the policy measure. The permit has a value, which in a tradeable permit regime is identical to the market price of the permits. The rule for allocating permits determines the distribution of cost among the emitters.

In short, (under complete information) it is possible to design a tax regime that leads to exactly the same distribution of costs among the emitters as a tradeable permit regime.

However, although the two systems, in theory, can lead to exactly the same distribution of costs across emitters, redistribution of tax revenue to the emitters is seldom used in practice. Hence the two systems will generally differ regarding the distribution of costs across emitters and the generation of public revenue (tax revenue received by the government).

5.3.3 Public revenue

At the national level, it should be considered as an important aspect of the chosen policy instrument whether it generates public revenue or not. Let us give an argument for that: All national communities have a public sector that is financed primarily by taxes on labor and capital income. If we for a moment ignore the potential benefits from these spending programs, the taxes tend to ‘distort’ economic behavior. That is, they reduce employment and investment below levels that would maximize the welfare of the households. For example, employers are likely to hire less labor if social security taxes make employees more expensive. Similarly, capital gains and corporate income taxes reduce the incentives for individual to save and for firms to invest in new production capacity.

If environmental policy instruments that generate public revenue are chosen, the revenue could be used to reduce other taxes in the economies. That would reduce the distortions in the level of employment and production. Hence, choosing environmental policies that generates public revenue has an additional advantage.

Emission taxes will generate public revenue. Permit systems could also generate revenue if the permits are allocated through auctions. In fact, if the permits are auctioned and all buyers pay the price offered for the last permit sold, the public revenue will be identical to the public revenue generated by a tax system. If on, the other hand all buyers pay the price they offer for permits during the auction, the public revenue generated will be larger than in the tax system.[17] Direct allocation of permits, for example “grandfathering”, will not generate public revenue. Hence, with respect to the generation of public revenue, emission taxes or permits allocated by auctions should be preferred.

5.3.4 National climate policy under an international climate agreement

In this section we compare the use of tradeable permits and emission taxes in the case of an international climate agreement. We will consider the advantages and disadvantages of the two different policy instruments in the possible different phases of a global trading regime explained in section 3.4.

Phase 1

We assume that international emission trading in this phase is limited. The governments can not buy/sell as many permits as they would have done in a situation without trade restrictions. The governments have to impose policy measures that ensure that they are in compliance with the agreement, given their limited possibility for trade in quotas. The Kyoto Protocol sets restrictions on the national cumulative emissions during the commitment period 2008 to 2012. If the national governments choose to use tradeable permits domestically, they could allocate permits to national emitters immediately after the Kyoto Protocol entered into force. In that case trade in the permits which give a right to emit a unit CO_2–equivalents in the period 2008-2012, could start at once and continue to the end of the commitment period (2012).[18,19]

The advantage of starting trade in permits so soon is that the emitters well in advance will get an idea of the cost of emission in the future (2008-2012). However, due to uncertainty about the Business-as-Usual (BAU) emissions, and future abatement costs, the emitters will face a great deal of uncertainty regarding the price of permits in the future and their own need for and valuation of emission permits. The price on the tradeable permits will probably change over time, as the traders receive more information. However, by using tradeable permits, the governments ensure that the target for national emissions is achieved.

If the governments instead use taxes in order to be in compliance with their commitments, they should announce to the emitters that they will face a tax on emissions from the year 2008. When the emitters know well in advance that they will face a tax, they have time to gradually adjust to the new conditions. The *level* of the emission tax that will be necessary to achieve the national emission limitations will be difficult to determine precisely due to uncertainty about the BAU emissions and future abatement costs, will. In order to meet the national targets for emissions, the tax level will probably have to be adjusted during the time period for the emission budget.

In the case of tradeable permits, the prices on permits will change over time as the emitters receive new information about relevant factors for the price (BAU emissions and abatement costs). In the case of emission taxes, the tax rate will change over time as the authorities receive new information about BAU emissions and abatement costs. Hence, both systems will imply that the emitters will face a great deal of uncertainty regarding the future cost of emissions. This uncertainty can make it more difficult for the emitters to make investment

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[17] We ignore that the buyer may act strategically during the auction.

[18] A small number of the total permits could be withhold and sold/distributed to new entries of emitting firms in the future to avoid hoarding of permits in order to prevent new entries. This policy is used in the US SO_2 allowances program, discussed in section 8.2.1.

[19] The Kyoto Protocol states that considerations of commitments beyond 2012 shall be initiated by the Parties by 2005 at the latest(article 3.9) The government can hence when such commitments are agreed distribute quotas for the subsequent time period.

and production plans, and frequent changes in the estimated costs of emissions increase the adjustment costs.

If the emitters have more information about the relevant factors for future cost of achieving the emission target than the authorities, a tradeable permit regime may imply less variation in the permit price over time than in the tax rate over time. This will tend to favor a tradeable permit regime relative to a tax system. On the other hand, the authorities may be more capable to predict the appropriate emission tax, than the emitters are to estimate the price on permits. Due to uncertainty emitters may hoard permits, which leads to limited trade in permits. This reduces the cost effectiveness of a tradeable permit regime. Furthermore, as discussed in section 5.1.1, in the Nordic countries there are relatively few emitters, which will be allocated permits. This implies that some emitters may exercise market power, which reduces the cost-savings of a trading regime.

Phase 2

Let’s now consider the national climate policy in a situation with no trade restrictions between Annex B countries. If the market for permits has been operating for some time the knowledge about abatement costs are probably better, and it is reasonable to assume that the international permit price will be relatively stable.

If the government in the Nordic countries prefer to continue to use emission taxes, it is now optimal to set the national tax rate equal to the international price on quotas. [20] The national government has to ensure, by international trade in quotas, that the national emissions following from the tax rate plus the purchase of quotas/minus sale of quotas are in compliance with the national emission limitation in the climate agreement.

If the national tax rate is set higher than the international quota price, this means that the marginal abatement cost is higher nationally than internationally. In that case it will be cost-effectively for the country to emit more, by reducing the national tax, and compensate the increased emission by purchasing quotas on the international market. If the tax rate is set lower than the international price on quotas, the country would reduce its total cost of the climate agreement by raising the tax rate, abate more nationally and sell correspondingly more quotas on the international market.

If the Nordic countries use tradeable national permits as their policy instrument, a cost-effective policy is to ensure, through international trade in quotas, that the national price of permits is identical to the international quota price. In that case the national marginal abatement cost is identical to other countries’ marginal abatement costs, which is a cost-effective climate policy for the Nordic countries. If the national permit price is *above* the international quota price, the governments should decrease the national cost of the climate agreement by buying more quotas in the international quota market. If the national permit price is *below* the international quota price, the government should sell quotas on the international market until the national permit price, and hence marginal abatement cost, is identical to the international quota price, and hence the international marginal abatement costs.

If the Nordic countries use tradeable permits as the national policy instrument, the governments can allow national emitters to exchange their permits with the international tradeable quotas their receptively governments hold and hence trade directly on the international market. The benefit of this is that the governments do not have to be involved in quota trading. However, in a well functioning international market for quotas, the transaction

[20] If the quota price fluctuates, the tax rate can be set equal to the expected average quota price over a certain time period. The intervals between tax rate adjustment can thus be longer than the intervals between changes in the international quota price.

costs are probably low, and the benefits of letting the emitters trade directly is therefore limited.

5.3.5 Conclusions regarding the choice between taxes and tradeable permits

One can not, in general, state that one of the policy tools should be preferred. Both lead to a cost-effective distribution of abatement nationally, given competitive markets. Furthermore, governmental trade on the international quota market can ensure that the national cost of being in compliance with the agreement is minimized under both systems. There are however, three main reasons why the Nordic countries probably should prefer taxes.

Firstly, emission taxes generate public revenue. With existing distortionary taxes, this gives an option for the governments to reduce the national cost of an international climate agreement through a national redistribution of taxes. Secondly, taxes are a well-established policy instrument in the Nordic countries in general and these countries have furthermore experience with CO_2 emission taxes. Tradeable permits, on the other hand, are so far not used in the Nordic countries. Initiating a tradeable permit regime may therefore involve higher transaction costs at least in an initial phase. (This is also a reason for choosing taxes rather than auctioning permits, even though the latter policy also will generate public revenue.) Thirdly, in order to reduce the transaction costs of permit trade, the permits must be allocated to national suppliers of carbon-based fuel and *large* emitters of other GHGs than CO_2, included in the climate agreement. In the Nordic countries there will only be a limited number of permit traders in such a system, which may imply that some emitters exercise market power in the national permit market in the first phase of an international GHG trading regime.

5.3.6 Combining tradeable permits and emission taxes

A combination of tradeable permits and emission taxes is another option that could be considered. Denmark, Sweden, Norway and Finland have all introduced CO_2 taxes. So far the CO_2 taxes in the Nordic countries are not equalized across all sources for CO_2 emissions. There are several exemptions from the CO_2 tax either for whole industries, for some sectors and/or for the use of fossil fuels as raw material in the process and manufacturing industries. The argument for this policy has among other things, been that a tax on the competitive industries will imply a reduction in competitiveness and one fears that the decrease in emissions nationally may be partly offset by increased emissions abroad.

This argument is no longer valid in an international climate agreement, where all countries shall be in compliance with their *national* caps for emissions. In that case, a cost-effective climate policy implies that all sectors of the economy should face the same emission tax. However, the consideration for the national industries' competitiveness can be perceived as more important than achieving a cost–effective distribution of national abatement. Taxes imply a higher financial burden on the industries than emission permits distributed freely.

Governments may fear that part of the competitive industry will move their production abroad if their cost of the national climate policy is high. The governments could for this reason prefer to distribute tradeable permits to the competitive industries and tax the emissions from the non-competitive industries and households. [21] This policy implies that the competitive industries pay less for their total emissions than the other sectors and must consequently be perceived as an indirect subsidy to the competitive industries. It should be

[21] If the allocation of permits is based on historical emissions, the use of tradable permits leads to exactly the same decisions regarding geographical allocation of production as a tax system. In order to ensure that the production is not moved abroad as a consequence of the national climat policy, the distribution of free pemits has to depend on current and future national production in the competetive industry. The use of tradable permits will in that case not lead to a cost effective distribution of national resources.

noted that if the governments want the competitive industries to pay less of the cost of the climate agreement than the other sectors of the economy, this could also be achieved through identical emission taxes across all sectors. In that case the governments must repay the tax revenue from the competitive industries to the same industry through some kind of subsidy.

In the initial phase of a global emission trading regime a combination of tradeable permits and emission taxes would probably also imply that the abatement costs differ across sectors. It is difficult to find the amount of permits distributed to parts of the industries and the national emission tax that exactly lead to the same marginal abatement cost across all sectors and ensure national compliance. As discussed above, the Nordic countries may also face the problem of market power in the permit market in this initial phase of a global trading regime.

In the second phase of the trading regime the governments should set the national emission tax equal to the international quota price. Furthermore, governments could make the national permits held by (part of) the industries interchangeable with the quotas held by the government. Hence, both the government and the competitive industries could trade on the international quota market.

Using both policy instruments is likely to increase the transaction costs. Hence, the governments should at least after a pilot phase choose one of the instruments. In the Nordic countries we will emphasize the advantages of the established system with carbon taxes.

If other Annex B countries introduce cost–effective CO_2–taxes, there is less reason for compensating the competitive industries for their CO_2–tax in order not to weaken their competitiveness. In general, there is usually not in the interest of any country that all countries subsidize their competitive industries. In order to contribute to the achievement of international cost-effective climate policy, the Nordic countries could consider to give their emitters equal economic conditions. That implies that the CO_2 tax is equalized across all sources for emissions or that the CO_2 quotas are sold/auctioned to the emitters. The tax revenue/income from the auction could be distributed back to the economy through a reduction in other taxes.

6 The cost saving potential of a global trading regime

In this chapter we will give a short overview over some important empirical studies related to the cost saving potential of emission trading with CO_2 quotas.[22] Several studies have pointed out the differences in CO_2-abatement costs across countries, and hence the scope for cost savings by an efficient distribution of abatement across countries.

There are two main methods for estimating the costs of reducing emissions of CO_2: *Bottom-up* studies and *top-down* studies. Bottom-up studies are micro-based analyses. These studies estimate the costs related to the introduction of new less polluting technologies in the production of goods and services. *Top-down* studies, on the other hand, estimate the cost of emission reductions by the use of macro-economic general equilibrium models. A typical approach is to introduce a CO_2 tax in the model, which is sufficient to achieve a certain reduction in the use of CO_2, and then calculate the cost as the resulting reduction in GDP.

The bottom-up studies tend to estimate lower abatement costs than the top-down studies. One reason for this is that bottom-up studies often find that the costs of mitigation are negative for a significant amount of emission reductions. This implies that there are several so-called "no-regrets" options for emission reductions. The top-down approach, assume on the other hand that all profitable energy saving investments have been implemented. Abatement costs are therefore usually non-negative, even for small amount of abatements. [23]

It is the *differences* in abatement costs across countries that are important for the cost saving potential of a CO_2–quota trading regime, and not the absolute *magnitude* of abatement costs. Both the top-down studies and the bottom up studies find that abatement costs related to CO_2 differ significantly across countries. UNEP (1994) employs bottom-up studies for a comparison of abatement costs in some developing countries, and Kram and Hill (1996) employ the same approach for a comparison of abatement costs in selected industrialized countries. They find that the costs of abatement differ widely among countries, both in developing and industrialized countries.

Several studies based on *top-down* models have calculated the cost saving potential for global trade in quotas. The global models for abatement costs usually divide the world into a few regions. The Edmond-Reilly model (see Barns et al. (1992)), the Manne-Richels model (see Manne (1992)) and the OECD model GREEN (see Oliveira-Martins *et al*. (1992b)) have compared the cost of achieving a global abatement target through cost-effective abatement across regions with a system of a given percentage reduction in each of the regions. Dean (1993) gives a comparison of the cost-reductions due to trade in emission quotas in the case of a two- percent annual emission reduction relative to baseline in the different models.

All models show gains from emission trade. The largest gain is found with GREEN, where the global output loss is halved from two percent to one percent of global GDP in 2020. [24] A recent study by Richels *et al*. (1996) compares the estimates of potential gain from quota trade in four global models. On average, the model's estimate that the global trade in quotas has the potential for reducing the cost of a carbon constraint by two-third.

[22] So far there is a lack of studies of abatement costs for the non- CO_2 GHGs in the litterature.

[23] In the case of existing distortionary taxes, the top-down calculations may also find that reducing emissions, through changes in the tax system, is profitable (so called "double dividend"). "Double dividend" effects are included in the numerical examples presented in the next section.

[24] The Manne-Richels model provides figures for carbon taxes in the no-trade and the trade case, but not GDP-figures.

The Kyoto Protocol accepts so far emission trading only between Annex B countries. It is therefore of interest to evaluate whether trade in CO_2-quotas only among developed countries also has a large potential for cost savings. Mullins and Baron (1997) refer to a study by Manne and Oliveira-Martins (1994) which estimates the cost reductions of trade in quotas among developed countries (Annex B Parties to the Climate Convention). The study is based on the GREEN-model. The developed countries are divided into seven regions. The study looks at a stabilization scenario at 1990 level in the year 2050 applied unilaterally with regional carbon taxes. The cost of this policy is compared to the total cost of achieving the same reduction target through tradeable quotas among developed countries. They show that a tradeable quota regime will reduce the cost by approximately 50 per cent.

Regional taxes imply that abatement is carried out cost-effectively between countries *within* regions. Hence, if marginal abatement costs vary significantly between countries within regions, the global models that divide the world into regions will underestimate the potential gains from an international trading regime compared to a situation where all countries meet their targets only through *national* abatement. In the study by Manne and Oliveira-Martins (1994) EU is one region. Barrett (1992) estimates, by the use of a *bottom-up* approach, that the cost of implementing the European Union's stabilization target for CO_2 emissions (as of 1992) is 50 times less expensive with cost-effective abatement, compared to a requirement that each member state stabilizes its own emissions.

In chapter 7 a numerical analyses of the gains from trade among Annex B countries is presented. According to these calculations, the total cost of the Kyoto Protocol can be reduced by approximately 95 per cent if there is free trade in quotas compared to a situation with no trade in quotas.

The above mentioned studies of gains from trade are all based on competitive well-functioning markets for quotas. However, quota trade may for some time, before a market is established, be based on bilateral or multilateral negotiations. This may reduce their degree of cost-effectiveness. Bohm (1997) carried out an experimental study of gains from bilateral trade among four Nordic countries. Denmark, Finland, Norway and Sweden established national negotiating teams consisting of experienced officials or experts appointed by their respective Energy Ministers. Prior to the negotiations, all the national teams estimated their negotiation–relevant *social* abatement costs, which they disclosed to an outside team of experts. In addition to the technical costs of abatement, the social abatement costs also included political considerations concerning the employment and income distribution effects. National teams negotiated bilaterally over a four–day period, communicating by fax.

A noteworthy result from this experiment is that even though the national teams did not have full information about each other’s social abatement costs, the negotiating process realized 97 per cent of the potential maximum cost savings. (The maximum cost savings is what would have been attained by a emission trading market under perfect competition). This implies that even if there is no well established competitive market for quota trade, bilateral agreement among a limited group of countries could significantly reduce the total abatement cost. However, the transaction costs – information seeking about the other countries’ abatement costs and four days of negotiations – are higher than if quotas were sold on a stock exchange.

In the experiment the national teams had quite good knowledge about each of the countries’ *technical* abatement costs since all countries had published abatement costs studies. Because of this knowledge they had a pretty good idea about which countries would be sellers and which countries would be buyers of quotas and to some extent the other governments strategic interests. This knowledge will certainly ease the negotiations. Due to several studies of abatement cost in Annex B countries, such information would probably also to some extent be available in a situation where an increased number of Annex B countries negotiated about quota trade. It is therefore possible that a large part of the potential gains from trade could be harvested also in an initial phase of a quota-trading regime.

To sum up, the literature shows large potential economic gains from emission trading, both on regional and global basis. However, it should be noted that *actual* gains from trade might differ significantly from the *potential* gains from trade. The potential gains from trade are calculated under the assumption of a well-functioning competitive market for quotas.

As discussed in section 5.1 there are several factors that might reduce the actual cost saving of a trading regime. There might, for instance, be only a limited numbers of traders. In that case, as discussed already, one faces the problem of some countries exercising market power. Furthermore in an initial phase of a trading regime there might not be a well functioning market for quotas and trade will be based one bilateral agreements which may involve high transaction costs.

7 Numerical examples related to consequences of the Kyoto Protocol

7.1 The numerical model – basic characteristics

In the following discussion we will use a simulation model developed at Center for International Climate and Environmental Research - Oslo (CICERO) to explore how some essential differences in starting points between the Annex B countries might cause considerable differences in the costs of achieving the commitments specified in the Kyoto Protocol. We will furthermore use the model in order to analyze how the distribution of costs is altered if emission trading between governments is allowed.

The core of the model and the theoretical background are described in detail in Holtsmark (1997). Cf. also Ringius, Torvanger and Holtsmark (1998). As part of the preparation of this report the model has been extended and elaborated in order to be capable for the analysis of emission trading and to take all six gases listed in the Kyoto Protocol into consideration. A market for emission quotas is built into the model. Furthermore, the model has been developed in order to be able to treat Sweden, Denmark, and Finland as separate countries. Originally, the plan was to incorporate also Iceland. Due to lack of some data Iceland is however so far not incorporated.

The Kyoto Protocol commits the Annex B countries to reduce their emissions of CO_2 and other GHGs and will therefore consequently directly affect the fossil fuel markets. That is likely to bring about considerable terms-of-trade changes as one of the results. Together with the implemented policies, these terms-of-trade changes will also affect the collection of public revenue in the different countries. These two consequences of the Kyoto Protocol are analyzed by the use of the numerical model.

Each of the countries is linked together in the model through their relations to the fossil fuel markets as well as the quota market. The model of the countries' economic structure is relatively simple. Important variables here are the fossil fuel taxes, the production and consumption of oil, coal and gas, the emissions of other GHGs than CO_2, and the amount of public revenue generated by fossil fuel taxation. Public revenues from fossil fuel taxation are incorporated in order to capture how national governments' behaviors are sensitive to the size of the benefits from revenue recycling and how these benefits adjust the distribution of abatement costs across countries.

The presented numerical examples illustrate how the distribution of gains and losses among the Annex B parties are sensitive to the different countries' links to the fossil fuel markets and their current and potential fossil fuel taxation schemes. The national governments are assumed to use an emission tax in order to be able to achieve the emission targets specified in the Kyoto Protocol. The model incorporates to what extent resource rents are transferred from fossil fuel exporting countries to fossil fuel importing countries, taking benefits from revenue recycling into account. Furthermore, the structures of the countries' energy demand, prior tax distortions and the size of the marginal excess burden of taxation in the different countries are important factors behind the models' estimates of the simultaneous abatement costs. [25]

[25] Although there is a vast amount of literature on the costs of combating greenhouse gas emissions, a large part of the literature is focused only on the measurement of the direct abatement costs. Surprisingly, most of the studies take into account neither the gains from revenue recycling nor the benefits or losses from changes in terms-of-trade (cf. Ekins (1995) and Hoeller and Wallin (1991)). Some examples of model studies taking terms-of-trade effects into account are Burniaux et al. (1992), DFAT and ABARE (1995). Unfortunately none of these studies analyzes the benefits of revenue recycling. Several other studies, for example Jorgensen and Wilcoxen (1993), emphasize on the other hand the importance of taking revenue recycling into account, but ignore the

It should be emphasized that the model used is a partial and static one, and the damage costs from climate change are not incorporated into the model.[26] The fossil fuel prices are determined within regional and global fossil fuel markets. The oil and coal markets are assumed global, while three regional natural gas markets are built into the model. One market is in North America where both USA and Canada are producers of gas with a net export of gas from Canada to USA taking place. Russia and Europe are included in a second gas market. The third gas market is found in the East-Asian/Pacific region.

7.2 Abatement costs and protocol costs

The purpose of the model simulations presented in this and the following sections are firstly to give an idea about how emission trading in different forms could alter the countries total costs, i.e. abatement costs and protocol costs, cf. definitions in section 7.3. Secondly, we also want to provide some information on possible absolute levels of the abatement and protocol costs. Although the numerical examples are useful to both these purposes, one should be careful when interpreting the results.

It is important to underline that not least the absolute level of the different countries calculated abatement costs are difficult to predict, especially when we look several years into the future. The absolute level of the abatement costs will for example depend on the technological possibilities for switching to new renewable energy sources at the actual point in time. The economic costs connected to new renewable energy are changing rapidly and are therefore hard to predict without a considerable degree of uncertainty when we look forward to the first commitment period.

The model is, as already mentioned, static. In this study we use the model to give us information about annual abatement costs in the first commitment period, which is 2008-2012. Technological development is likely to reduce the abatement costs before these points in time are reached. Other changes in the world economy might also adjust the costs. Although we are fully aware of the likeliness of such changes to take place we have not incorporated such a technological development.

Figure 7.1 presents the models estimates of the marginal abatement costs of reducing emissions of GHGs. Sweden's high, marginal abatement costs are explained by the relatively high fossil fuel taxes in this country (in 1990) and the low consumption of coal and reflects furthermore the fact that electricity is produced almost without use of fossil fuels in Sweden. The high abatement costs in Norway can be explained by similar reasons. The somewhat lower average fossil fuel taxes in Norway (in 1990) explain why the estimated marginal abatement costs are lower in Norway compared to Sweden. The model estimates the marginal abatement costs in Denmark to be higher than in Finland, although Denmark uses coal

terms-of-trade effects of several countries implementing climate policies at the same time. The contribution of our analysis is to give some indications on how the costs of the Kyoto Protocol will vary among the Annex B countries when dead-weight-loss from taxation, gains from revenue recycling and terms-of-trade effects are taken into account. This is done while taking into account the effect of all the Annex B countries implementing efficient abatement measures at the same time.

[26] Dynamic aspects of the countries' climate policies, as emphasized by for example Nordhaus and Yang (1996), are therefore not taken into account in the present analysis. Some relevant structural characteristics of the national economies that are emphasized by other studies, as for example DFAT and ABARE (1995) and Burniaux et al. (1992), are also ignored. In contrast to the mentioned studies the present study, however, analyses in further detail the countries' fossil fuel taxation policies under the implementation of the Kyoto protocol, and to what extent these taxation policies influence the distribution of costs and benefits of an agreement. Unlike the mentioned studies, the present study directs the focus towards the links between a possible climate agreement and both the current and potential fossil fuel taxation policies in the light of public budget constraints.

Some technical key features of the numerical model

- The model is of the *top-down* category.
- The different national fossil fuel consumption patterns together with the size of the fossil fuel taxes in 1990 are the main factors behind the estimated abatement costs functions in the different countries and regions. High fossil fuel taxes give rise to high, estimated abatement costs. The higher was the share of coal in countries' total fossil fuel consumption in 1990, the lower are the estimated abatement costs.
- The cost functions do not represent detailed analyses of the *technical* possibilities for emission reductions in consumption and production. Bottom-up-models with emphasis on such options are likely to give rice to abatement cost functions different from the cost functions presented in this study.
- The Annex B countries maximise country specific welfare functions subject to national CO_2-emission constraints and public budget constraints. The marginal excess burden of taxation is set to 0.10 in the US and Norway, 0.20 in Sweden, 0.10 the other OECD-countries, and 0.05 in the EIT-countries. [1]
- The governments are assumed to use fossil fuel taxes on consumption as their climate policy instrument.
- The national welfare functions measure net benefits from both private and public sector consumption of oil, coal and gas and profit in production of fossil fuels.
- The national abatement costs are equal to the reduction in consumers' surplus in fossil fuel consumption minus the benefits from revenue recycling.
- There are global markets for oil and coal and three regional markets for gas. Supply elasticities are 0.75 in the gas and oil markets and 1.0 in the coal market. The direct demand price elasticities vary between -0.21 (oil in Finland) and -0.57 (gas in the EIT-countries). The demand cross price elasticities varies between 0.0 and 0.30.
- In the cases where emission trading is allowed a quota market is also included. The quota price is endogenous and secures equilibrium in the quota market.

intensively, not least in power production. The explanation is connected to the structure and level of fossil fuel taxes in these countries in 1990. The fossil fuel taxes in Denmark were relatively high and are assumed to have led to relatively efficient use of fossil fuels. [27] The average oil tax in Finland was, on the other hand, in 1990 at a level equal to about 50% of the average oil tax in Denmark in that year, cf. appendix C.

The marginal abatement costs in Japan are relatively small at low emission-reduction levels, but increase relatively fast when further emission reductions are assumed to take place. The initial low abatement costs are due to the low fossil taxes in 1990, while the rapid increase in marginal abatement costs are explained by the assumed somewhat inelastic demand for fossil fuels in Japan. EU has implemented considerable higher oil taxes than the USA and Canada. That should lead to higher abatement costs in Europe. However, the intensive use of coal in

[27] This argument is based on the assumption that high fossil fuel taxes leads to high costs of curbing CO_2-emissions further. It is reasonable to assume that the tax already has caused an efficient use of fossil fuel. Hence, low-cost options for reduced consumption of the fuels are already exploited.

Europe draws in the other direction. Hence, the model finds that the abatement costs are relatively similar in Europe and the USA and Canada.

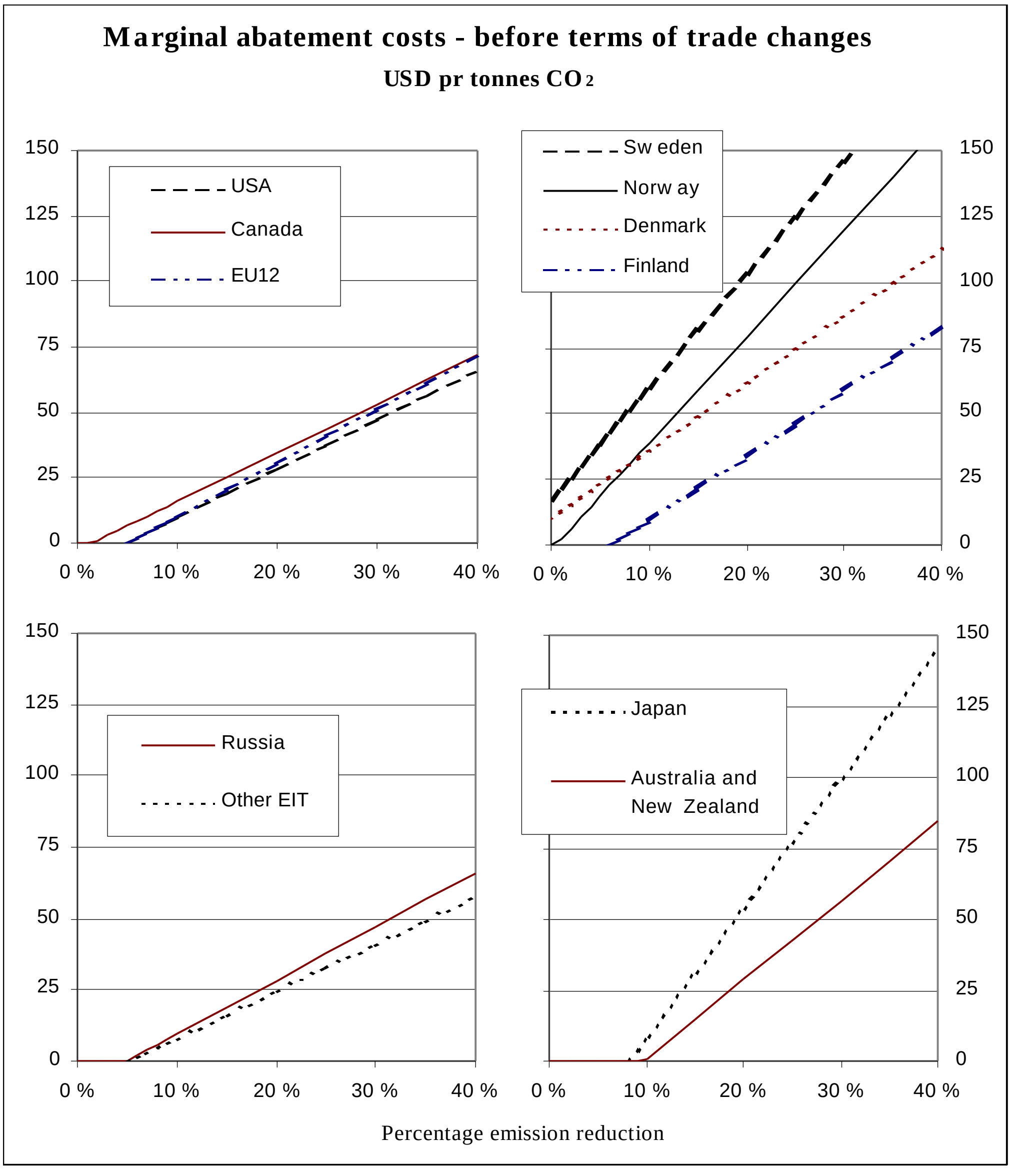

Figure 3: Estimated marginal abatement costs (USD pr. tonnes CO_2 equivalent) of reducing emissions of GHGs. Benefits from revenue recycling are taken into account, but terms of trade changes are not.

Figure 7.2 shows the models estimated *total* cost curves for the different countries, and group of countries before terms of trade-changes are taken into account. The costs are measured as income loss in percentage of the GDP in 1990. The benefits from revenue recycling are included. That means that these cost curves take into account that the use of fossil fuel taxes in the climate policy will generate public revenue, which could be reimbursed to the private sector. It is assumed that the reimbursement implies reduction of other taxes. Reduced tax rates will in general increase the efficiency of the economies and hence adjust the net cost curves downwards.

In order to understand the differences between the cost curves in figure 7.1 (marginal costs in USD pr. tonnes CO_2 equivalents) and figure 7.2 (total costs in percentage of GDP) we should keep in mind that in figure 7.1, we measure absolute costs on the vertical axes, while we measure the total costs relative to the countries' respective GDP in on the vertical axes in figure 7.2.

The change from absolute costs to costs in relation to GDP explains also to a large part why the cost curve of the USA now is elevated compared to the cost curve of EU, while it was slightly below in Figure 7.1 which measured marginal costs in absolute terms.

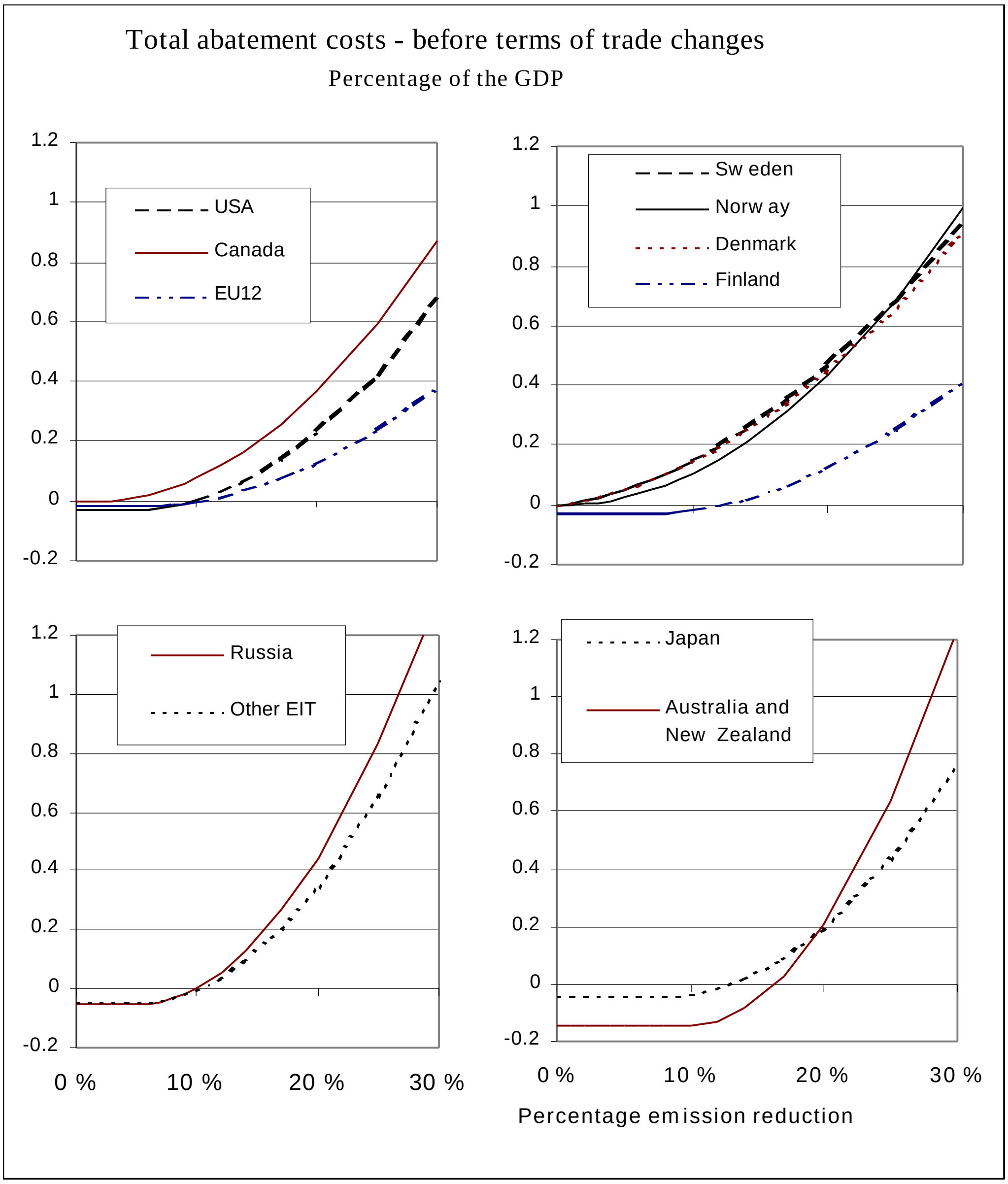

Figure 4: Estimated abatement costs. Terms of trade-changes are not taken into account, but the benefits from revenue recycling are included

A remark should also be made about the fact that the cost curves of especially EU, Japan, USA, the EIT-countries are below zero at considerable GHG emission reduction levels. In other words, the model 'finds' considerable 'no regret' options in these regions and countries.

This is due to the inclusion of benefits from revenue recycling. The revenues collected as a result of national climate policies are used to reduce other taxes and consequently the economic efficiency is increased.

7.3 Some possible consequences of the Kyoto Protocol

Based on the above-presented model, we will present numerical examples in order to illustrate some economic consequences of the Kyoto Protocol and especially how transboundary emission trading will alter the distribution of costs. The numerical examples will furthermore provide some ideas about which governments are likely sellers and buyers in the quota market and a likely level of the quota price.

When the governments are free to buy or sell parts of their emission quotas in a market, they are assumed to reduce their domestic emission to the level where the marginal abatement costs are equal to the quota price. Hence, in the case with free emission trading marginal abatement costs are equal both across gases and countries and equal to the quota price.

It is important to underline that the numerical examples do not take into account that the Kyoto Protocol states that quota import should be supplemental to domestic abatement efforts. In the actual model framework the governments simply minimize their costs, and do not take any other considerations into account. It should furthermore be remarked that the possibility for joint implementation projects through the Clean Development Mechanism (CDM) and its influence on the quota market is not taken into consideration here. If, however, emission rights could be achieved cheaply trough CDM, this could constitute a ceiling for the quota price.

Table 2: BAU emissions of CO2 (million tonnes) and other greenhouse gases (OGHG, million tonnes of CO2 equivalents) in 1990 and 2010, the Kyoto quotas and the emission reduction commitments.

	Emissions 1990 CO2	Emissions 1990 OGHG	Sum emissions 1990	BAU Emissions 2010 CO2	BAU Emissions 2010 OGHG	Sum 2010 BAU emissions	Quota	Reduction commit-ment
USA	4957.0	784.0	5741.1	6097.1	720.6	6817.7	5339.2	1478.5
Canada	462.6	103.1	565.8	550.5	110.1	660.7	531.8	128.8
EU12*	3121.5	749.9	3871.4	3304.6	592.8	3897.4	3581.4	316.0
Denmark	60.2**	19.6	79.8	66.0	17.6	83.6	63.0	20.5
Finland	53.9	10.9	64.8	63.3	12.0	75.3	64.8	10.5
Sweden	61.3	11.2	72.4	72.3	12.4	84.7	75.3	9.4
Norway	35.5	18.6	54.1	49.0	15.5	64.5	54.6	9.9
Other OECD	47.2	12.9	60.2	46.7	11.2	57.8	55.9	1.9
Russia	2388.7	594.8	2983.5	2221.5	594.8	2816.3	2983.5	0.0
Other EIT	1690.9	428.5	2065.4	1711.8	317.7	2029.5	1968.7	60.8
Australia/N.Z.	314.4	202.2	516.7	402.3	179.3	581.5	552.1	29.4
Japan	1155.0	46.1	1201.1	1325.9	41.5	1367.5	1129.1	238.4
Sum	14348.3	2981.9	17276.2	15911.1	2625.4	18536.5	16399.5	2304.2

* EU-15 minus Denmark, Finland and Sweden.
** Adjusted to account for import and export of electricity and variations in temperature. The actual emissions were 52.3 mill. tonnes CO_2.

Annex B in the protocol specifies flat rate emission reductions within the European Union member countries. However, in accordance with article 4 the EU member countries are free to redistribute the commitments between them selves. In the presented numerical examples the internal EU-distribution agreed upon in June 1998 is therefore used as our starting point. That means for example that Denmark is assumed to reduce its emissions by 21% below the 1990 level, Finland must return to the 1990-emission while Sweden is allowed to increase the emissions by 4%. The Nordic EU-countries are treated separately, while the model aggregates rest of the EU-countries to one unit (labeled EU12 in the tables).

The model provides a set of simultaneous abatement cost functions using BAU-emissions as the starting point. We therefore have to make assumptions about the countries' BAU emissions in 2010. We have used emission scenarios presented in national communications where possible. Some reported emission scenarios appear however unrealistically low. The BAU emissions of these countries are therefore adjusted upwards to what we se as a more realistic level, cf. Table 2. Where the emission scenarios are not presented in national communications, the assumed BAU-emissions are taken from Alfsen, Holtsmark and Torvanger (1998).

The Russian BAU-emissions in 2010 are assumed to be 7% lower than they were in 1990. Since the Russian emission quota is equal to the 1990 emissions, we in other words assume an amount of 167 million tonnes 'hot air' from Russia measured in CO_2 equivalents. There might turn out to be 'hot air' also in other EIT-countries, but this possibility is ruled out here due to both our assumptions about BAU-emissions in 2010 and to the aggregation of the other EIT countries to one unit.

Four cases are analyzed. Firstly, we look at the case where no emission trading is allowed to take place. Secondly, we look at a case where only the Nordic countries are allowed to trade with each other. Thirdly, we extend the trade region to include all the Annex II countries. Finally, we look at the case where emission trading is free within Annex B.

The distribution of the abatement efforts across the different gases and regions in the four cases is listed in table 7.2. One should note that in the cases where the EIT-countries are not allowed to sell emission quotas, the Russian emissions of CO_2 are estimated to be 32-33 million tonnes higher than in BAU. This is a sort of carbon leakage due to the price drop in the fossil fuel markets caused by the abatement policies in the other Annex II countries. [28]

[28] See section 4.3 for an explanation of the concept 'leakage effect'.

Table 3: Abatement of CO_2 (million tonnes) and other greenhouse gases (OGHG, million tonnes CO_2 equivalents) in the three scenarios.

	No trade		Nordic trade		Annex II trade		Free trade	
	CO_2	OGHG	CO_2	OGHG	CO_2	OGHG	CO_2	OGHG
USA	1407.2	71.3	1407.2	71.3	1080.9	55.8	747.9	39.6
Canada	119.0	9.8	119.0	9.8	81.6	6.9	50.3	4.4
EU12*	291.6	24.3	291.6	24.3	590.4	45.4	409.5	32.6
Denmark	18.1	2.4	12.1	1.7	3.7	0.6	0.7	0.2
Finland	9.5	0.9	19.0	1.8	10.7	1.0	7.9	0.8
Sweden	8.2	1.2	6.5	1.0	1.2	0.3	-0.6	0.0
Norway	7.6	2.3	6.4	1.9	3.0	0.9	1.8	0.6
Other OECD	1.5	0.4	1.5	0.4	3.9	0.9	2.7	0.6
Russia	-32.3	0.0	-32.2	0.0	-33.5	0.0	280.8	34.7
Other EIT	55.1	5.7	55.1	5.7	55.0	5.8	230.2	17.9
Australia/N.Z.	24.9	4.6	24.9	4.6	112.3	16.8	84.8	12.9
Japan	234.0	4.4	234.0	4.4	223.0	4.2	173.4	3.3
Sum	2144.6	127.4	2145.1	126.9	2132.2	138.6	1989.4	147.6

* EU-15 minus Denmark, Finland and Sweden.

Table 7.3 shows the different countries and regions import of emission quotas in the three scenarios. If emission trading is restricted to the Nordic countries, Denmark is the main buyer of quotas, while Finland is the primary seller. This result must be seen in relation to the adjusted built in internal EU redistribution of commitments in accordance with the agreement from June 1998, which commits Denmark to a 21% emission reduction relative to the 1990 emissions. Norway and Sweden are buying only small amounts of emission quotas in this situation due to the high quota price, which here is estimated to be USD 47.7 pr. tonnes CO_2 equivalent.

Together with the EIT-countries the European Union is assumed to be the main quota seller when the trading area is extended. The EU is however going to sell a larger amount of quotas in the case with the trade restricted to the Annex II area due to the higher quota price in this case. In the case with trade only among the Annex II countries, the quota price is estimated to be USD 22.4 pr. tonnes CO_2 equivalent. In the case with free trade among the Annex B countries, the quota price is estimated to be USD 13.5 pr. tonnes CO_2 equivalent.

The USA is the main quota buyer due to the high-expected emission growth in this country.

Table 4: Import of emission quotas and the quota price. Million tonnes CO_2 equivalents and USD pr. tonnes CO_2. The three scenarios.

	USA	Canada	EU12	Denmark	Finland	Sweden	Norway	Russia	Other EIT	Australia and N.Z.	Japan	**Quota price***
Nordic trade	0.0	0.0	0.0	6.8	-10.3	1.9	1.6	0.0	0.0	0.0	0.0	**$47.7**
Annex II trade	341.9	40.4	-319.8	16.3	-1.3	7.9	6.0	0.0	0.0	-99.6	11.1	**$22.4**
Free trading	691.1	74.1	-126.1	19.6	1.8	10.0	7.5	-482.8	-187.2	-68.2	61.7	**$13.5**

* The possibility of achieving quotas through investments in the CDM, might turn out be of large importance for the final quota price. The CDM as a likely ceiling on the quota price is not taken into account here.

Figure 7.3 provides an overview of the calculated costs of the Kyoto Protocol (the protocol costs). In these cost estimates both terms-of-trade changes and benefits from revenue recycling are taken into account. A first impression of the simulation is that the costs of the assumed climate protocol are relatively low in most of the countries in question, even without emission trading. We must here keep in mind that this is annual costs of emission reductions. They will therefore constitute income losses that have to be taken into account every year during the first commitment period. To some extent there will be costs also in the years prior to the first commitment period, due to a likely smoothly adjustment towards a situation with lower emissions.

According to the numerical examples, only Norway experiences net costs above 1% of the GDP. This is mainly due to the oil and gas export from this country and the calculated price drop especially in the oil market following from the implementation of the Kyoto Protocol. Not least important in this respect is the fact that a large part of the profit in this country's oil and gas production is directly allocated into public budgets. Norway has imposed especially high profit taxes in the petroleum-producing sector, but public income is also generated through direct public ownership in the production of oil and gas. Reduced oil prices in the world market will therefore bring about reduced public revenue in Norway and hence force the Norwegian government to increase existing distortionary taxes.

Having a look at the scenario where emission trading is not allowed, a noteworthy result is that among others Japan, Finland and the non-Nordic EU countries as a group will experience net gains from the implementation of the Kyoto Protocol. This is partly explained by the considerable terms-of-trade gains that these countries will experience mainly due to a drop in the producer-oil price resulting from the implemented climate policies together with the benefits from revenue recycling.

These benefiting side-effects are large enough to outweigh the implemented abatement costs. This result may however be too optimistic. The most crucial assumption in that respect is the assumed emission growth from 1990 to 2010 in the BAU-scenario. In three mentioned countries the assumed growth rates are 13.8% in Japan, 16.1% in Finland and 0.7% in the EU. Due the rapidly increasing marginal cost curves as emission reductions are increased, other assumptions with higher BAU emissions would have implied substantially increased cost estimates in these countries and group of countries.

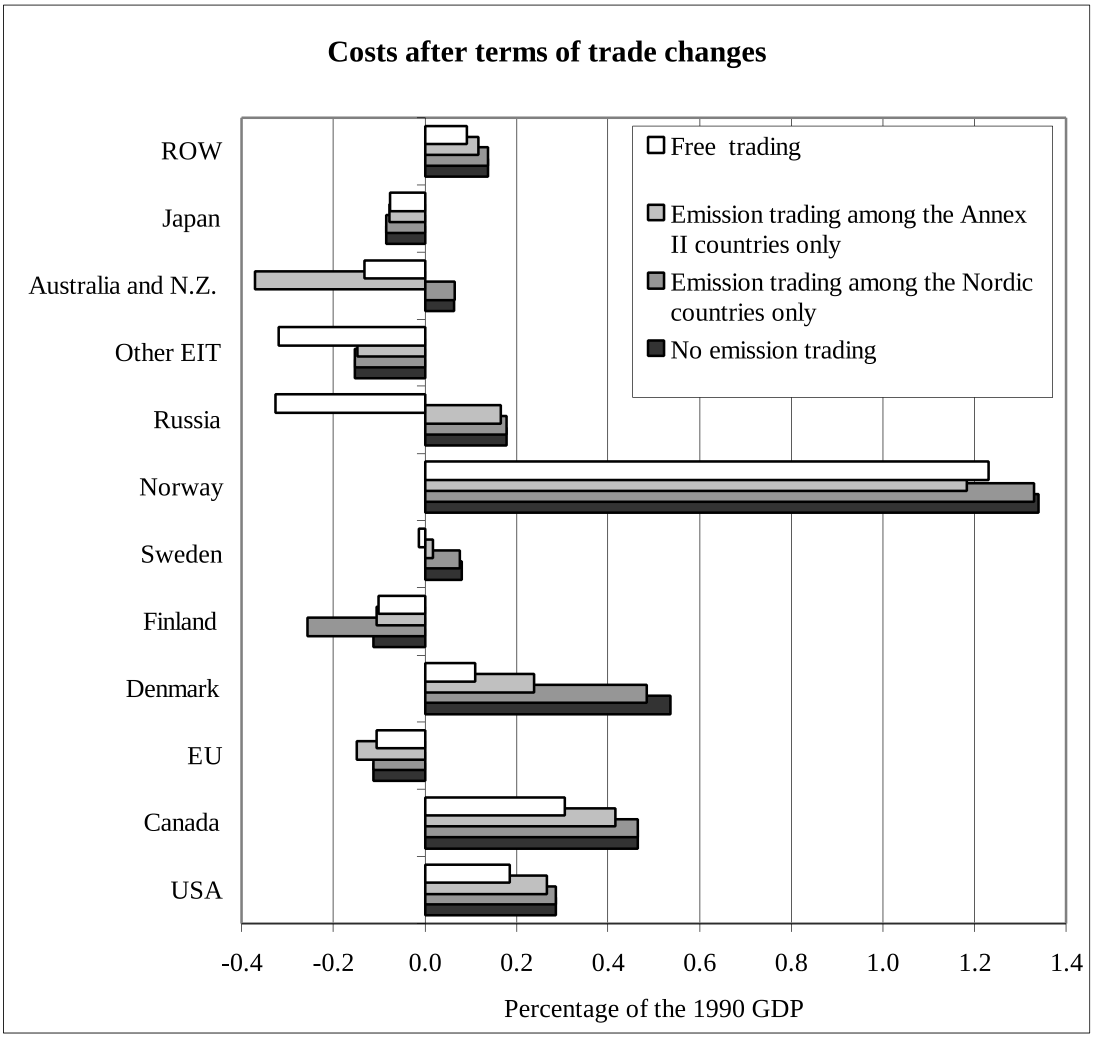

Figure 5: Costs of the Kyoto Protocol. The EU-differentiation agreed upon in June 1998 is internalized. Terms-of-trade effects are taken into account.

Although Sweden according to the simulations should expect some net costs of the Kyoto Protocol at least if there are restrictions on the quota marked, the estimated Swedish costs are small. The main explanation is the burden-sharing rule within EU, which allows Sweden to increase its emission from 1990 to the first commitment period by 4%. That implies an emission reduction from the BAU-level of 11%.

This number should be related to figure 7.1 and 7.2. From figure 7.2 we see that an emission reduction in Sweden of 11% implies abatement costs below 0.2% of GDP. The Swedish costs are nevertheless significantly smaller due to this country's gains from lower fossil fuel prices. It is here important to underline that abatement activities are expensive in Sweden. If the estimated price drop in the oil market does not take place and if the Swedish BAU-emissions are underestimated, the Swedish protocol costs would have been substantially higher.

Denmark is committed to reduce the emission to a level 21% below the 1990-level. With our assumptions about the BAU-emissions in 2010 this implies an emission reduction from BAU of 25% and consequently Denmark experiences higher abatement costs than Sweden and Finland (emission reduction from BAU of 14%).

With our assumptions, Norway and Canada are hardest affected due to these countries' role as fossil fuel producers and their relatively high estimated BAU-emission growth from 1990 to 2010.

The USA experiences relatively high costs, especially when this country is not allowed to buy quotas. This is in contrast to the relatively low marginal cost function of the USA compared to EU, cf. Figure 7.1 and 7.2. An essential factor is however the terms of trade changes and the countries' role in the fossil fuel markets, as well as the expected BAU emission growth. The USA is a considerable producer of oil, coal and gas. Hence, while Japan and the EU experience large terms of trade gains due to price drops in the oil and coal markets, the US does not experience terms of trade gains of the same order of magnitude.

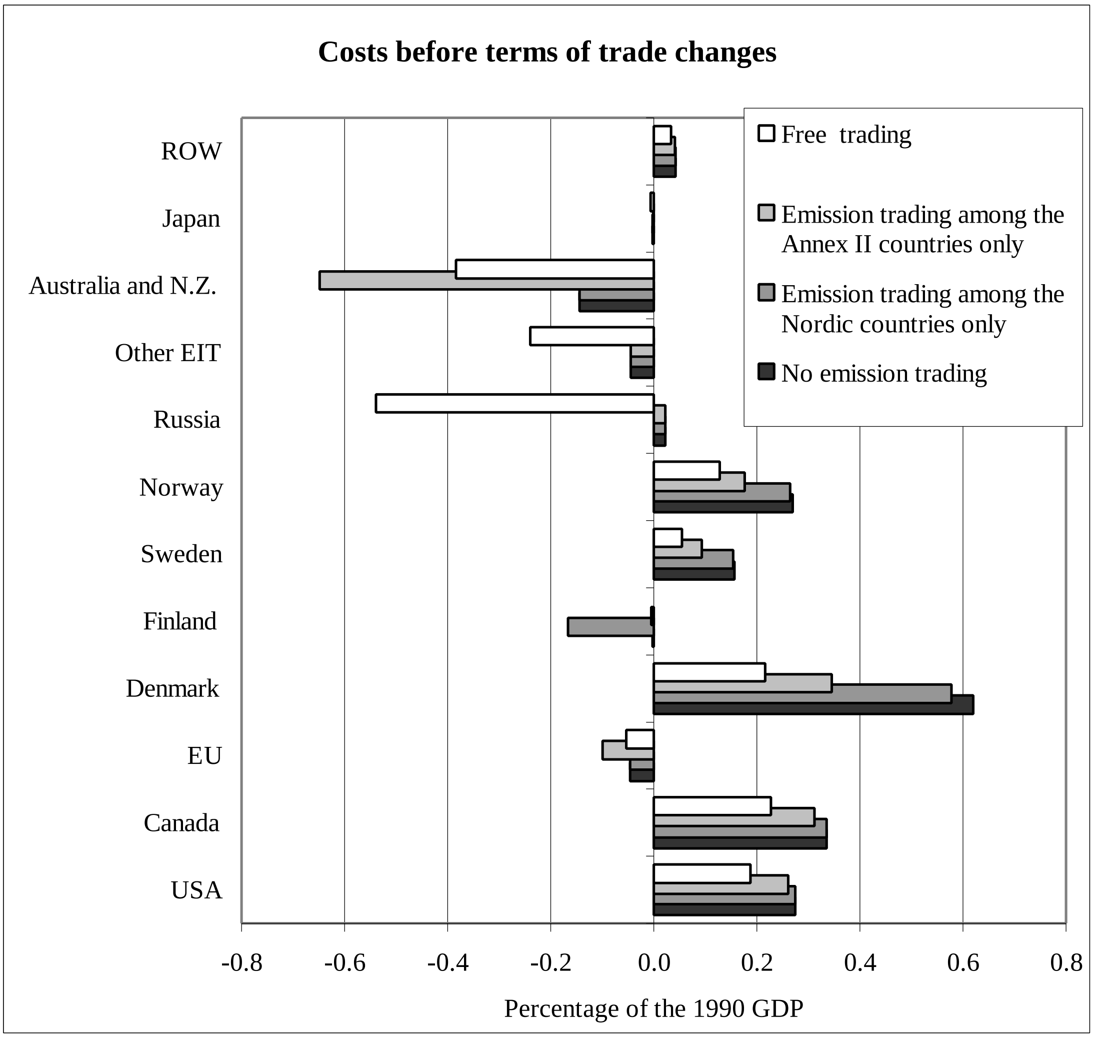

Figure 6: Costs when the terms-of-trade effects are *not* taken into account.

In the case with free emission trading, the USA is a buyer of permits. In the case where the EIT-countries are allowed to take part in the emission trading, the USA is buying emission permits equal to 13% of the initial number of permits. Hence, the US emissions in that case are estimated to be 5% higher in 2010 that they were in 1990.

Especially Denmark, Norway, Canada, USA, Australia and the EIT countries will receive significant benefits from emission trading. This is related to both especially high or low abatement costs in these countries as well as either a strict or flexible emission target. Countries with more average abatement cost patterns will not benefit to the same extent from emission trading. The emission targets of Australia and Russia are for example likely to give these countries some flexibility and the possibility to attain gains from quota sale.

Figure 7.4 shows the estimated costs when terms of trade changes are not taken into account. This diagram constitutes a good starting point for increased understanding of the estimated abatement costs in figure 7.3, which include terms of trade changes. The costs of the fossil fuel exporters are reduced while the costs of the net importers are increased if we compare with the costs including terms of trade changes. We should furthermore note that some countries according to the numerical examples would experience net gains from the Kyoto Protocol even when terms of trade changes are not taken into account. This is basically a result of income from quota sales together with the inclusion of benefits from revenue recycling.

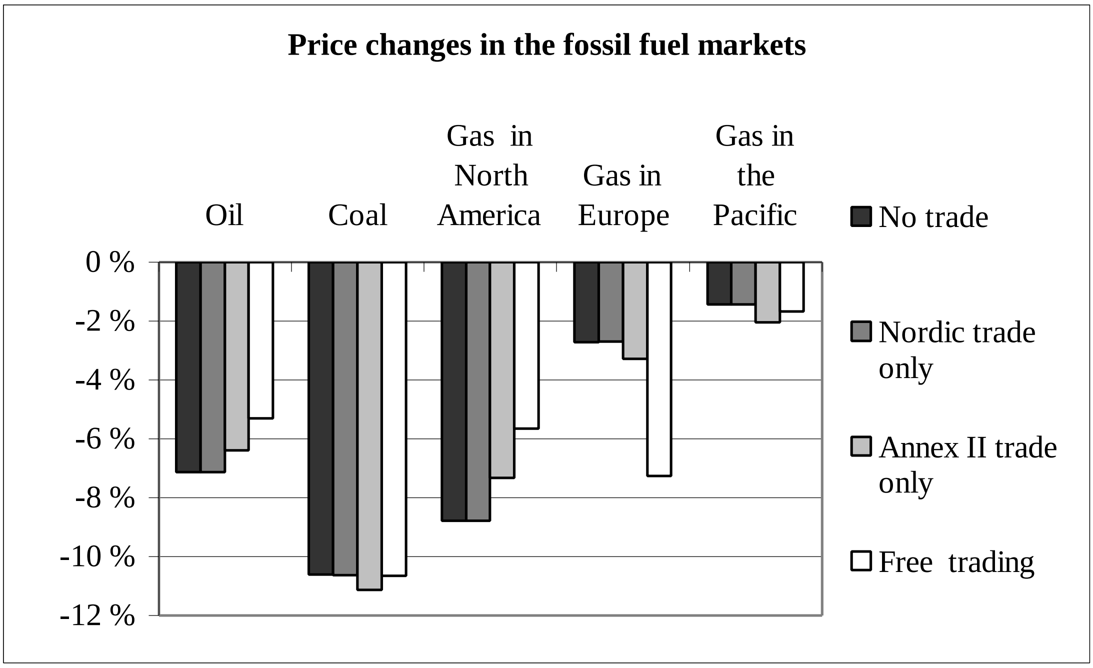

Figure 7: Estimated price changes in the fossil fuel markets.

Finland is here an interesting example. Finland's significant net gain in the case where emission trading is restricted to the Nordic countries is explained by the income from quota sales and a high quota price in this case. Finland experiences however still a slightly positive net gain also in the case without emission trading. This result is closely related to the numerical assumptions. With our numerical assumptions, this country is committed to reduce its emissions by 14%lative to the BAU emissions in 2010.

Having a look at figure 7.1 we see that in Finland abatement of this size of order to a large part could be achieved by application of no regret options (se explanation on page 43). Furthermore, even after full exploitation of the potential for no regret options, the marginal abatement costs are still small in this country. We should here be aware of the fact that no regret options are estimated to be of higher importance in Finland compared to the other

Nordic countries. The number of no regret options in Finland could of course be overestimated. In that case the model simulations draw a too optimistic picture of the costs of Finland.

Figure 7.5 provides an overview of the estimated price changes in the fossil fuel markets that are likely to follow from the implementation of the Kyoto Protocol. From a Norwegian point of view it is interesting that free emission trading is likely to enhance the price drop in the European gas market. The reason is the redistribution of abatement efforts between countries that will follow from free emission trading. The redistribution of abatement efforts will change the demand for fossil fuels.

8 Practical experiences with quota trading

In this section we will give a short overview of some relevant practical experiences with emission quota/permit trading both on an international level and on a domestic level. In this section the word emission “allowances” and “permits” are used interchangeably for domestically allocated emission rights. In accordance with the definitions made in section 3.2.1 quotas are on the other hand used for the national emission limitations specified in a protocol.

8.1 Experience from international trade with quotas

There is so far limited experience with international trade in pollution quotas. One important reason for this is that the geographical emission patterns usually matters for the degree and distribution of environmental damage. This implies that increased emission of transnational pollutants in one country can not be offset by a similar amount of decrease in emission from another country without influencing the distribution of damage across countries. Montgomery (1972) developed a cost-effective design of a quota system in the case where the location of emissions does matter.

However, as discussed in Tietenberg (1995), Montgomery’s *ambient tradeable permit* system is complicated to implement because an emitter would have to acquire separate permits for each affected sector.[29] Contrary too most transboundary pollutants, greenhouse gases are well mixed in the atmosphere. Hence, the location of emissions does not effect the impact on the climate. One precondition for international trade with quotas is therefore in place.

CFCs are greenhouse gases that also have a depleting effect on the ozone layer. CFCs are controlled by the Montreal Protocol (UNEP (1987)). An interesting feature about this protocol is that it allows Parties to transfer production quotas for CFCs to other Parties for the purpose of industrial rationalizations. [30] In the following section we have a further look at this protocol.

8.1.1 The Montreal Protocol

The Montreal Protocol (MP) sets a timetable for gradual elimination of production and consumption of certain Ozone Depleting Substances (ODS), among them CFCs. [31] Limits for production and consumption was “grandfathered “ to Parties on the basis of their 1986 levels of production and consumption. Consumption is defined as production plus imports minus export. The Montreal Protocol does not accept trade in *consumption quotas* between Parties in general. However, EU-member countries are allowed to jointly fulfill their obligations with respect to consumption.

[29] The problem of differing spatial impacts of emissions is for instance faced by the European “Second Sulphur Protocol” aimed at reducing SO_2 emissions below “critical loads”. The location of SO_2 emissions can greatly effect levels of acid rain and some areas may have less tolerance for acid rain than others. No trading rule under the “Second Sulphur Protocol” has yet been approved.

[30] The Montreal Protocol defines industrial rationalization as “transfer of all or a portion of the calculated level of production of one Party to another, for the purpose of achieving economic efficiencies or responding to anticipated shortfalls in supply as a result of plant closure”.

[31] The original protocol was signed in 1987. The protocol was later amended in London 1990 and Copenhagen 1992.

The Montreal Protocol's rules for international transfer of *production quotas* have been developed gradually. Initially the transfers were not allowed to increase the individual production by more than 10% to 15% of the 1986, except for Parties with very low productions. The London Amendments of 1990 removed this restriction and the remaining rules for transfer of quotas between parties are:

- The total combined levels of production of the parties concerned are not allowed to exceed the production limit agreed on
- The UNEP Ozone secretariat must be notified of transfers, their term, and the periods for which they apply
- The protocol does not accept transfer of quotas to non-participating countries.

National/regional implementation of the Montreal Protocol

The Montreal Protocol does not set restrictions on the use of national policies to meet the targets as long as their production and consumption are in compliance with the limits set by the Montreal Protocol and that international trade of production quotas follows the rules set out in the protocol.

Approximately 70 per cent of world production of ODS in 1986 were produced in EU and USA (Klaassen (1996)). EU has translated the national limits of production and consumption into individual limits for ODS producers and consumers. EU rules allow for international transfers of consumption and production quotas within the region and trade in production quotas with non-EU countries. The United States' government has allocated their national ODS production quotas to ODS producers and their national consumption quotas to ODS producers and importers. USA rules allow for national trade in production and consumption quotas and international trade in production quotas.

Trade under the Montreal Protocol

Klaassen (1996) and Mullins (1997) have studied the transfers of quotas under the Montreal Protocol. They point out that it is difficult to get access to information about international trade, because, according to Mullins (1997), the information is commercially sensitive. As of January 1994, the ozone secretariat had not received any notification of transfers of production levels, but international trade had taken place.

According to Klaassen (1996), EU-companies had a traded volume of 20 000 –30 000 tonnes per year of ODS in 1992 and 1993 (which correspond to 11-15 percent of EU's 1991 production). Much of the trade was among European member states. United States companies traded 35 000 tonnes of ODS per year internationally in the same period (which corresponds to 27 per cent of their 1991 production). Klaassen (1996) did not find that trade by companies outside EU and USA had occurred in 1992/93.

Quota-trade and cost-effectiveness:

According to Klaassen (1996) the market for CFC production seems to have been active. Approximately 10 per cent of actual production have been transferred internationally. The cost savings from international quota trade is however unknown. There are nevertheless several factors that reduce the cost effectiveness of the tradeable quota system under the Montreal Protocol.

The Montreal Protocol does not set restrictions on national laws regarding quota trade. According to the amendment of the Clean Air Act in USA in 1990, domestic transfer of quotas is permitted provided the amount of remaining quotas held by the seller is reduced by the amount transferred plus 1 percent. This insures that trade result in greater total reduction in production than would otherwise occur, but limits the cost reducing potential from domestic quota trade. Rules regulating the international transfer of allowable production levels are stricter than rules for domestic trade.

The production allowed to the transferor is reduced not only by the amount transferred, but also by the difference between allowable and actual production in USA. This creates a bias in favor of domestic rather than international trade. According to Mullins (1997) the domestic trade for certain ODS was approximately nine times larger than the international trade in the period 1989 to 1995. Both the domestic and international restrictions on trade reduce the cost-effectiveness of a tradeable quota scheme.

Market power
Production of ODS has been concentrated in a few companies. Klaassen (1996) reports that Du Pont de Nemours serves 25 per cent of the world market and ICI's market share is 15 –20 per cent. This implies that market power in the quota market can reduce the cost-effectiveness of quota trade, as discussed in section 3.2. However, there is not available sufficient information to analyze whether companies have exercised market power in the quota market.

Limited trade in consumption quotas
With the exception of EU countries, consumption quotas can not be traded internationally. This implies that the Montreal Protocol does not ensure a cost–effective distribution of global abatement of CFC consumption. This restriction may however not be very significant for the cost-effectiveness of tradeable quota scheme. According to Klaassen (1996), in order to keep contacts with their customers, EU companies did not make use of their right to trade consumption quotas internationally.

Uncertainty regarding credits from trade with developing countries.
According to the MP, developing country parties are allowed to increase their production limits by 10 to 15 per cent to meet basic domestic needs and they are allowed to delay meeting compliance deadlines for 10 years. This implies that these countries currently have no binding production quotas. As argued by Klaassen (1996), this could lead to a situation where developing countries increase their "baseline" production level and transfer this to other countries. This would effectively increase worldwide production. He claims, however, that transfer with developing parties appear to bear the risk of being rejected instead of leading to an increase in production.

8.1.2 Relevant experience for the design of a tradeable CO_2 quota scheme
The Kyoto Protocol does not set restrictions on each Parties choice of policy instrument domestically to ensure that national emissions are in compliance with the amount of national quotas. This may imply that countries are less reluctant to accept a tradeable quota system. However, national laws regarding quota trade (as implemented in USA) may reduce the cost effectiveness of a tradeable quota scheme.

The rules for international transfer of quotas under the Montreal Protocol developed gradually. A stepwise approach to emission trading is also what we suggest for trade in GHGs included in the Kyoto Protocol. If countries initially only were allowed to trade a portion of their quotas, one could limit the possible adverse affects of a trading regime, namely that countries sold quotas well in excess of what was met by increase in their national abatement. Countries that proved to be in compliance with their obligations over a certain time period could be allowed to trade a larger portion of their quotas in the future. The cost of this gradual development of the trading regime is that restrictions on trade would not lead to a cost-effective distribution of abatement.

In the USA consumption quotas were allocated to producers and importers, and not to consumers. According to a reference in Klaassen (1996) the reason for this is that the large numbers of consumers (5,000-10,000) would have increased the administrative costs. [32] In the case of a national trading regime of CO_2 quotas the administrative and monitoring cost of distributing CO_2 quotas to all consumers would probably be very high. Distributing quotas to the national energy suppliers could solve this problem.

8.2 Experience from national trade of quotas

Although there is limited experience with international quota trade, quota trade is a widely used policy instrument nationally, especially in the USA. In the previous section we discussed national trade under the Montreal protocol within USA. Another example of emission trade in USA is the trade in SO_2 permits, which will be discussed below. [33]

SO_2 is an example of a pollutant where the damage caused by emissions is not independent of where the emissions occur. Emission trading allows for flexible emission patterns and there are therefore a common concern that tradeable SO_2 permits may lead to so called “hot spots” of emissions. “Hot spots” means that emissions are accumulated in certain geographical areas. However, all utilities participating in the US SO_2 trading program must comply with all other requirements of the Clean Air Act (CAA). The CAA already regulates SO_2 emissions at local and regional levels to ensure that health and environment quality standards are maintained. Beyond these regulations, the fact that the geographical source of emissions is of significance for the damage is ignored in the design of the trading system.

8.2.1 The US SO_2 Allowance program

The United States 1990 Clean Air Act Amendments include provisions for SO_2 allowance trading among electric utilities. The objective of the acid rain program was among other things, to reduce emissions of SO_2 of approximately 10 million tonnes per year from 1980 emissions levels. The program is being implemented in two phases. Phase I, which began in 1995, is designed to achieve 4.5 million tonnes emission reductions. The second phase begins in 2000 and will complete the goal of 10 million tonnes emission reductions.

In the first phase of the program the highest emitting electric utility plants (Phase I utilities) are required to meet an interim ceiling for emissions (5.7 million tonnes). In phase II, the limits for emissions will not apply only to the phase I utilities, but also to smaller, cleaner plants. With phase II, a national cap of 8.95 million tonnes of SO_2 is placed on the number of allowances. The initial allocation of quotas was based on historical production levels (“grandfathering”) and the SO_2 emission rates. Each allowance is dated and entitles the holder to emit one tonnes SO_2 in the year of issue. Each boiler receives individual annual emission limits for 30 years from the time they enter the program.

[32] Hahn and McGartland (1989)

[33] In relation to the US SO_2 trading regime, the word “allowances” is used instead of “permits”.

Allowances may be sold, bought and banked, but not borrowed. There are no restrictions on the portion of allowances that the participants can sell. A special reserve of the annual total allowances is being sold on an auction held by US Environmental Protection Agency (EPA) every year. Furthermore EPA sell allowances directly to newcomers. The auctions and direct sale reduce the existing utilities' possibility to withhold allowances in order to prevent entry of new producers.

In addition to the auctions, quotas are traded between the participants either directly or through brokers. There is both a market for emission allowances for phase I and a market for trade of emission allowances for phase II. The sulfur-trading program is expected to lead to considerable savings in the overall abatement costs compared to a policy where the allowances where non-tradeable. The cost reduction is estimated to be 40 to 45 per cent over the lifetime of the program (Klaassen (1996) table 6.3)). This estimate takes into account the administrative implementation costs and the utilities' transaction costs.

Trade under the US SO_2 Allowance program

Although allowance trading began in 1992, it is too early to make an analyses of how the trading program succeeded to reduce the costs, since Phase I started as late as in 1995. The achievement of the potential cost savings depends on how well the market works. According to Mullins (1997), trade among utilities has steadily increased from 1994 to 1996. The cumulative total transfer was 1,902 transactions, which represent 34.2 million allowances. However, most of these transfers occurred between boiler units within companies.

Phase I-utilities, that have been able to reduce their SO_2-emissions, have tended to bank them rather to sell them. According to Adams (1997) there has been less trading of allowances than was expected. Initially there was a large discrepancy between the auction price and the secondary market (trade between utilities) price. However, both prices have fallen and gradually converged (Klaassen (1996)). The price on allowances for phase I has fallen from between 180-270 US$ in 1993 to around US$137 in 1995. The forward prices for emission allowances for phase II are much lower than was expected. This indicates that the cost of SO_2 reductions had been overestimated.

8.2.2 Relevant experience for the design of a tradeable CO_2 quota scheme

An interesting feature about the SO_2 trading program is the annual auctions of emission allowances held by EPA. The auctions are organized partly to address the issue of new utilities, and for the early auctions, to provide a price signal for allowance prices. A small per cent of the distributed annual allowances are taken from the allocations made to utilities and sold at the auctions. Furthermore, private holders of allowances can offer their allowances for sale at the auction and set a minimum price. The auction revenues are returned to the utilities from which the EPA withheld allowances. Such a system could possibly be applied in an international trading regime for GHGs. In the case of tradeable GHG quotas it can be valuable that auctions are organized initially by an international authority designated by COP to help create a price signal. In that case countries can offer some of their quotas for sale and receive their share of the auction revenue in return.

It is important to note that the SO_2 trading regime has high, automatic, and well-enforced penalties of non-compliance. Strict enforcement provisions have facilitated political acceptance of SO_2 trading in USA. An equally high level of punishment and enforcement will probably be difficult to achieve under an international GHGs trading regime. However, in the design of a tradeable quota regime it should be considered different measures for increasing the countries' cost of non-compliance. This may increase some countries' willingness to accept emission trading as some countries' main mean to fulfill their commitment under the Kyoto Protocol.

In the SO_2 trading program the emitters have complete information about their future emissions limits. Each boiler receives individual annual emission limits for 30 years from the time they enter the program. At the end of each year the government allocates the 31st year of allowances. This system implies that all participants are well informed about the total emission allowances in the future. The certainty about future emission limits together with the "forward market" for emission allowances for phase II reduces the participants' uncertainty regarding future prices on allowances.

This information, together with the possibility to freely bank emission allowances, facilitates the participants optimal planning of emission reductions over time. The Kyoto Protocol allows for banking of quotas, which increases the flexibility. But it is also important that the participants agree on emissions budgets for future commitment periods well in advance. If countries are uncertain about future emission limitations when trade is initiated, the future quota prices will be very difficult to predict. This may imply that countries are reluctant to sell quotas because they fear high prices in the future. In that case the cost-effectiveness of the tradeable quota system can be reduced.

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Appendix A:

A simple numerical illustration of the gains from emission trading

The motivation for emission trading is the potential for reduced total abatement costs. The purpose of this subsection is to illustrate in a non-technical way why there are such cost-saving potentials connected to emission trading. The gains from emission trading are illustrated with a simple numerical example.

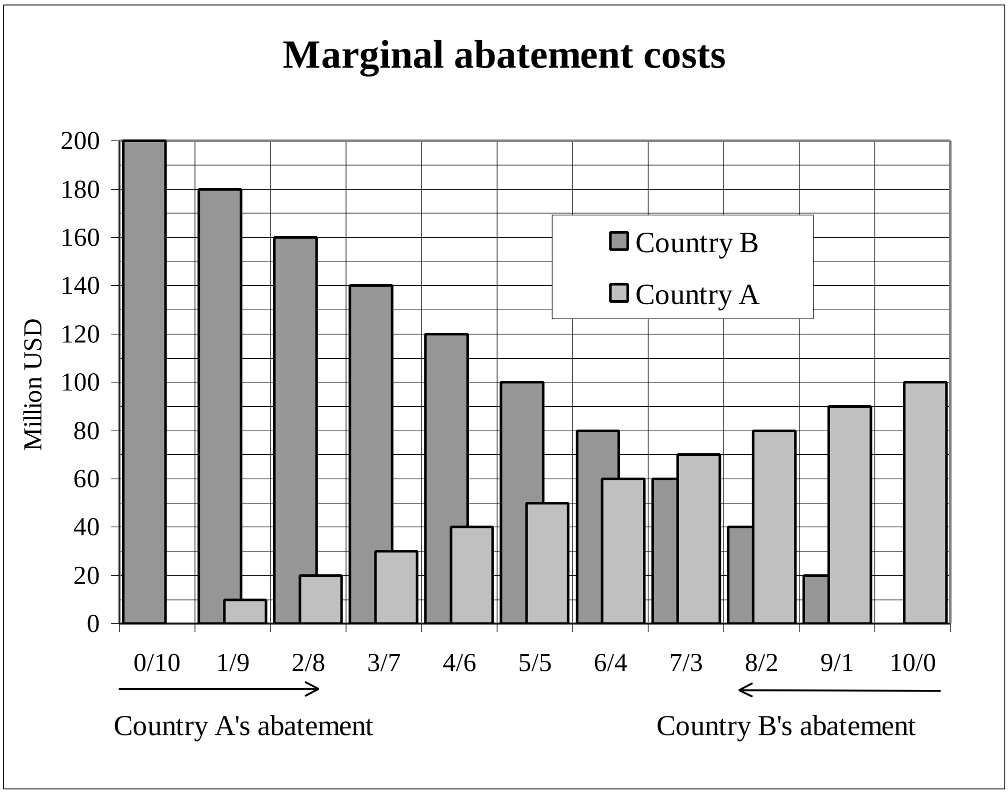

Figure A.1: A simple numerical illustration of the gains from emission trading between two countries. The columns in the front describe the marginal abatement costs of country A. The columns in the background illustrate the marginal abatement costs of country B, but for illustrative purposes these columns are ordered from right to left.

We assume that two countries are both committed to reduce their emissions of greenhouse gases by five million tonnes of CO_2. We furthermore assume for illustrative purposes that the abatement could only be done step by step, each step reducing the emission by one million tonnes of CO_2. Each step should be considered as concrete projects or measures, like fuel switching in an industry or introduction of a new energy-efficient technology in a company.

The two countries' abatement costs, as described in Figure A.1, are different. The columns in the front of Figure A.1 describe the marginal abatement costs of country A.[34] The first of these columns from the left side shows that the cost of reducing the emission in country A by

[34] More precisely, the *additional* abatement costs, related to reducing the emissions by one million tonnes of CO_2.

one million tonnes of CO_2 is USD 10 million. Further emission reduction of one million tonnes costs USD 20 million (cf. the height of the second column from the left), and so forth. The cost connected to the last million tonnes this country has to curb is USD 50 million. If country A should reduce the emission by for example 10 million tonnes the marginal abatement costs would reach a level of USD 100 millions.

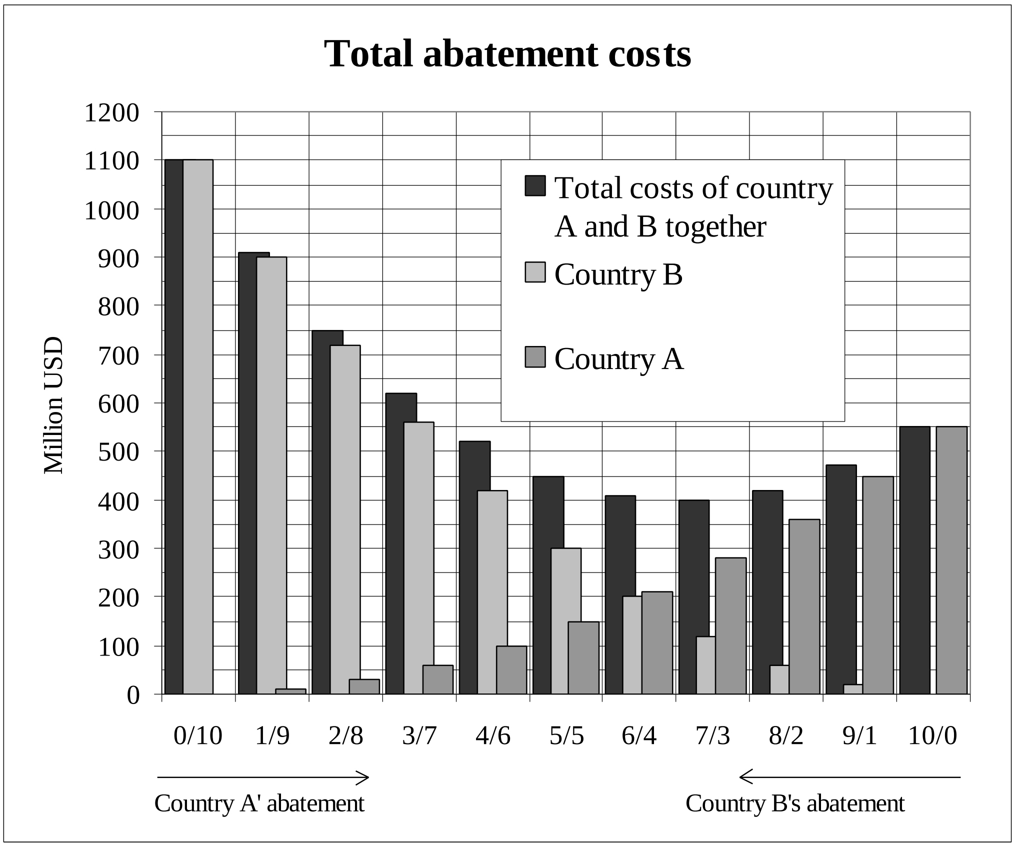

Figure A.2: Total abatement costs. The columns in the front describe the total abatement costs of country A. The columns in the background illustrate the total abatement costs of country B, but for illustrative purposes these columns are ordered from right to left.

The columns in the background illustrate the marginal abatement costs of country B, but for illustrative purposes, the columns are ordered from the right to the left. This means that the first of these column from the right shows that the costs of reducing the emissions in country B by one million tonnes are USD 20 million. The second column from the right shows that reducing the emissions with another million tonnes of CO_2 will cost USD 40 million and so forth. The costs connected to the last, fifth, million tonnes country B according to the commitments has to curb, is USD 100 million.

The cumulative height of the columns reflects the total abatement costs of the countries. Country A has for example to cover a total cost of USD 150 millions in order fulfil its emission reduction commitments on its own, while the corresponding cost of country B is assumed to be USD 300 millions.

The two countries are committed to reduce their total emissions by 10 million tonnes. It is evident from the diagram that the quotas of two times 5 million tonnes will not bring about a cost-effective solution. A somewhat larger emission reduction in country A and a

More participants in the numerical example

In the numerical illustration, there were only two participants in the trading system. Increased number of participants will have several implications. Let us only mention some important implications.

Let us assume that there is a third country, which has an emission limit and wants to take part in the emission trading market. If this country experiences marginal abatement costs even lower than country A, country A could go from being a seller of emission quotas, to being a buyer. That depends on several circumstances, among other things the exact form of the third country's abatement cost curve.

If for example the third country has a huge potential for low cost emission reductions, it is likely that country A will be interested in buying quotas. If on the other hand the third country has only slightly lower abatement costs compared to country A, it is more likely that country A still will be a seller in the quota market, but the sold number of quotas might be lower. The entrance of the third country could in that case weaken the strategic position of country A in the quota market, with lower quota price as the result. Hence, it could be in the interests of country A not to let the third country into the emission trading market.

We will see an example of such strategic interests in the empirically based numeric examples presented in chapter 7. There we present a case where the emission trading is restricted to the Nordic countries. In other cases, the emission trading market is larger. The extension of the market is clearly in the interests of the quota buyers who are Denmark, Norway and Sweden, cf. Figure 7.4.

correspondingly smaller emission reduction in country B will reduce the total abatement costs. The crucial point is that, when both countries reduce their emissions by five million tonnes, the marginal abatement costs are higher in country B than in country A. If country A for example curbs its emissions with another million tonnes of CO_2, the costs will increase by USD 60 million. Then the emissions from country B could be increased by one million tonnes of CO_2. That would release USD 100 million in reduced abatement costs. Hence, there will be a net gain of USD 40 millions.

Let us now calculate the total potential gains from emission trading in this case. The cost-effective solution is found by picking out the set of 10 columns in Figure A.1 with the lowest, added height. This means that country A should reduce its emission by 7 million tonnes, while country B should reduce its emission by three million tonnes. [35] The total abatement cost of country A is increased by USD 130 millions, to a total abatement cost of USD 280 millions. The total abatement cost of country B is reduced by USD 180 millions to a total abatement cost of USD 120 millions. The total abatement cost of the to countries together is consequently USD 400 millions. Hence, the total abatement costs of the two countries will be reduced by USD 50 million compared to the situation with no emission trading, which represent 12.5 percent of total abatement cost. The total costs are illustrated in Figure A.2.

This simple numerical example illustrates that different marginal abatement costs is the key to gains from emission trading. When the marginal abatement costs are equalized, the distribution of abatement is cost-effective. There is no longer possible to reduce the total cost through trade in quotas.

The size of the costs saved in this numerical example is however relatively small compared to what could be the case in real world emission trading. In the empirically based numerical

[35] Further emission reductions in country A at the expense of reduced emission reductions in country B is not cost-effective, because the reductions would pass the limit where marginal emission reductions are lower in country A than in country B.

examples presented in chapter 7 the case with free emission trading among all the Annex B countries reduces total abatement costs by approximately 95%. Similar results from other studies are discussed in chapter 6.

Some further aspects of the numerical example are discussed in the two attached text boxes.

Appendix B:

Parties listed in the Annex B to the Kyoto Protocol and their emission limitations

Party	**Quantified emission limitation or reduction commitment** (percentage of base year or period)
Australia	108
Austria	92
Belgium	92
Bulgaria*	92
Canada	94
Croatia*	95
Czech Republic*	92
Denmark	92
Estonia*	92
European Community	92
Finland	92
France	92
Germany	92
Greece	92
Hungary*	94
Iceland	110
Ireland	92
Italy	92
Japan	94
Latvia*	92
Liechtenstein	92
Lithuania*	92
Luxembourg	92
Monaco	92
Netherlands	92
New Zealand	100
Norway	101
Poland*	94
Portugal	92
Romania*	92
Russian Federation*	100
Slovakia*	92
Slovenia*	92
Spain	92
Sweden	92
Switzerland	92
Ukraine*	100
United Kingdom of Great Britain and Northern Ireland	92
United states of America	93

* Countries that are undergoing the process of transition to a market economy.

Appendix C:

Fossil fuel taxes in 1990 and fossil fuels production and consumption patterns in the 2010 BAU-scenario*

	Production (Mill. tonnes CO_2)			Consumption (Mill. tonnes CO_2)			Taxes (USD/tonnes CO_2) *		
	Oil	Coal	Gas	Oil	Coal	Gas	Oil	Coal	Gas
USA	1655	2695	1131	3102	2311	1338	15.8	0.0	0.0
Canada	354	177	223	298	113	148	31.4	0.0	0.0
EU12	298	828	287	1745	1107	453	66.5	0.1	13.0
Denmark	2	0	0	34	27	5	82.1	25.9	0.0
Finland	0	0	0	42	15	6	41.8	2.2	2.2
Sweden	0	0	0	61	10	2	87.6	38.4	25.8
Norway	427	0	154	39	3	6	47.0	23.9	0.0
Other OECD	0	0	0	43	2	3	49.2	1.0	0.6
Russia	1548	639	1027	749	655	787	0.0	-1.0	-0.9
Other EIT	53	1030	182	455	954	400	0.0	-1.0	-0.9
Australia and New Zealand	117	540	53	150	203	58	50.1	0.0	0.0
Japan	0	25	5	917	340	118	26.9	0.0	0.1

* The estimated average tax rates are taken from ECON (1995), which presents average fossil fuel taxes in the OECD countries from 1980 to 1994. The tax rates presented there are based on weighting energy taxes by product and sector. The information on taxes is based on IEA Energy Prices and Taxes. The information on taxes has been supplemented with EU's oil price statistics, 'Oil Bulletin' and with direct contact with national administrations. The weights are based on 'Basic Energy Statistics'. The Basic Energy Statistics have been supplemented with oil industry information and EU statistics on the use of leaded and unleaded gasoline and on the breakdown of heavy fuel oil according to sulphur content (relevant for countries differentiating heavy fuel oil taxes according to sulphur content). The calculation of the average taxation by sector takes into account the exempted use of energy within the sector. Concerning gasoline the taxes are for premium gasoline. Taxes for leaded and unleaded gasoline (where relevant) have been weighted with the consumption of the two qualities. For countries differentiating the tax between high and low sulphur, taxes are represented by the tax on the typical quality in industry and power generation.

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