13 Emission Trading Schemes in Europe: Linking the EU Emissions Trading with National Programs

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INTRODUCTION

Emission trading was first introduced in the US during the mid 1970s. It was applied in several ways (e.g. lead-free petrol, ozone depleting chemicals) among which the acid rain programme may have the closest similarity with potential national CO_2 trading schemes (UN 1995 pp. 19-23). In the context of the UN Framework Convention on Climate Change it first looked as if taxes could be the instruments of choice for countries to control the GHG emissions (NRP 1995 p.1). However, emission trading on state level was finally formally introduced with the Kyoto-Protocol agreed on in 1997. As Parties to the Protocol lack information on abatement options and costs, the theoretical efficiency gains may never be realised by nation to nation trading. This may be one reason why the discussion on national trading schemes, i.e. involving sub-national entities, has remarkably intensified since then: Numerous reports by "industry/governmental" working groups have been published throughout the industrialised world. With national schemes emerging, the question of linkage evolves. We analyse this aspect in general.

On the other hand there are, by now, two existing schemes in Europe. We describe these two systems and see how they can be linked with regard to technical feasibility, environmental integrity and economic impacts. The latter aspect will be investigated with a focus on the interaction of linking national schemes in the context of the Kyoto-provisions only, as it is generally understood that linking of different schemes itself increases overall cost-efficiency.

EMISSION TRADING

The concept of emission trading

Compared to other economic instruments as for example taxes, emission trading has the advantage that the total quantity of emissions can be determined prior to the introduction of the instrument by the quantity of emission rights/permits issued by authorities. (In the following the terms *emission right* and *permit* are used equivalently). Furthermore, emissions trading allows for a cost efficient meeting of emission targets as long as the market functions well. Initially, each participant has to be assigned a certain number of emission rights. At the

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end of the period, every participant has to hold at least the same quantity of emission rights as he released emissions into the atmosphere. Any surplus permits can be sold on the market (or possibly be banked). Buyers are those emitters whose marginal abatement costs are higher than the permit price on the market. In the long run abatement cost are to be equal.

However, before national schemes can start operation in real economies, several design features have to be decided on.

Design of national ET-schemes

Below, an overview on important features to be decided on when implementing emission trading schemes is given. The concrete design affects economic efficiency, environmental integrity and acceptability[1]. As the focus of this paper is on linking of trading schemes, we only discuss them in short.

Absolute vs. specific targets

An absolute target for participants of a trading scheme helps to ensure the meeting of a national target. Meeting the target may require huge investments, especially when output is increased. With specific targets[2], the output can be increased as much as desired without the restrictions by an absolute one. This is why they are favoured by industry. As permits are generated compared to business-as-usual scenarios (see Fig. 1), increasing numbers of permits are generated with increasing output - suggesting additional environmental benefits.[3]

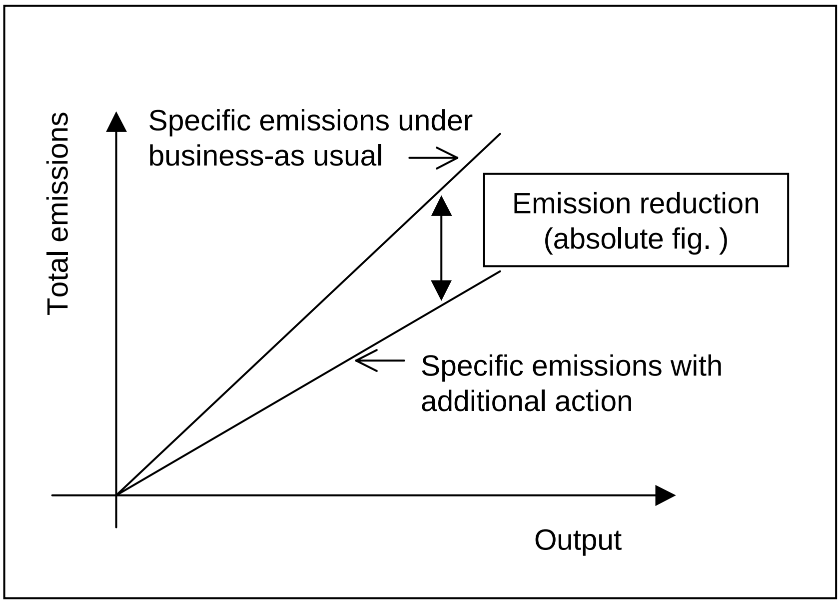

Figure 1. Absolute emission reductions with specific emission targets (AGE 2002b p. 34)

1. Including compatibility with existing regulation, equity and competitiveness issues.
2. I.e. emissions per reference figure (e.g. CO_2 / kWh)
3. What is indeed true but only compared to the business-as-usual scenarios. Absolute emissions may, however, increase.

Stringency of the target

The more stringent the overall target, the higher the environmental effectiveness.[4] On the other hand, with increasing marginal abatement costs, the more stringent the target, the higher total abatement costs.

Mandatory vs. voluntary participation

Depending on the concrete design, a mandatory scheme is likely to be more environmentally effective as a greater number of participants than in a voluntary scheme can be expected. A voluntary system is likely to face a mismatch between offer and demand as only entities that expect themselves in seller position may want to joint the scheme. Thus, it might need some incentives to make more entities participate and accept an absolute cap (AGO 1999a, p. 22). A mandatory scheme is likely to be more cost-efficient due to greater variance of abatement costs - depending on who has to participate.

Participants

As for the mandatory scheme a wide scope of categories of participating emitters will reduce total costs.[5] On the other hand, transaction costs may increase if small and/or mobile sources are to be part of the scheme. Obliging up-stream sources[6] is one way to solve this problem. (For a detailed discussion see CCAP (1999)). Furthermore, producers of indirect emissions (e.g. emissions resulting from electricity consumption) can be obliged to surrender certificates.

Coverage of gases

As abatement costs differ for different gases, the inclusion of as many gases as possible increases efficiency. On the other hand, transaction costs can increase when sources cannot be administered adequately (NZME 1998, p. 22). For example, it might be impossible to calculate emissions by means of standardised emission factors and input (as it is possible for fossil fuels for example), so that continuous measurement would be necessary.

Mode of allocation

Permits may either be allocated for free or can be charged. If we neglect transaction costs and assume competitive markets, the efficiency of the system does not depend on the initial allocation. It has "only" distributional effects (AGO 1999a, p.26-50).

Monitoring, Verification and Reporting (MVP)

MVP-provisions have to be set against the background of the trade-off between completeness and costs (WBCSD 2001, p. 8).

Banking and borrowing

Banking and borrowing between different commitment periods enable an intertemporal optimisation and thus can reduce costs. Borrowing is, however, generally badly regarded by environmental NGOs as it is perceived to violate environmental integrity.

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4. Keeping in mind the Kyoto-targets for Annex B countries these targets are already fixed. Governments now have to allocate targets to the participating and non-participating emitters.
5. Participating in this paper is understood as being obliged to surrender permits at the end of a compliance period. The question of who is allocated the permits at the beginning is – at least from a theoretical point – another issue.
6. For example fuel producers/imports or fuel wholesalers.

Non-compliance provisions

Law enforcement is an important aspect of every environmental legislation. There are no special requirements for emission trading.

Market access

The question whether only entities with targets or every legal/natural person has to the right purchase emission rights has to be answered. The latter option may result in higher prices when for example environmental NGOs buy rights in order to redeem them.[7]

Compatibility with existing instruments

Compatibility with existing regulation is important with regard to both, accordance with a constitution and the acceptance of emission trading in a political economy.[8]

Register

A register is necessary to administer the permits and to allow check of authenticity. As long as it is assured that each permit only exists once and that it is cancelled after being surrendered by an obliged participant, there are no specific requirements for a national register (AGE 2002b, p. 107-112)

Use of project based credits

The use of credits from emission reduction projects either in the non-participating sector in the home country as well as abroad can be an appropriate tool for increasing cost-efficiency even though higher order of problems may occur. Environmental integrity strongly depends on the rules for calculating the project based emission reductions.

Treatment of new sources / plant shut down

New sources could simply be obliged to buy permits on the secondary market, just as existing growing participants have to do. Equity considerations may on the other hand call for an initial allocation equal to the one for the early participants Plant shut down should also be considered in order to avoid incentives for shut downs by “eternal rents seekers”. (For similar discussion see Pedersen (2000))

Compliance period

The length of the compliance periods can be set as desired. Following the Kyoto provisions, it might be five years from 2008 onwards. However, annual compliance seems reasonable as (Haites, E, Aslam, M. E. 2000, p. 31)

- it is the standard form many reporting requirements (e.g. other emissions reporting, taxes)
- it would help governments with the annual reporting obligation under the UNFCCC
- it may help to facilitate the treatment of plant shut down.

Liability

7. However, even if the purchase of non-participants is not allowed, they may find participating entities that redeem permit for them.
8. For example, major parts of German industry opposes emissions trading as proposed by the EU-Commission while pointing out the successful voluntary agreement (BDI, VDEW, BGW, VIK (2002).

Basically, two kinds of liability can be distinguished: Seller and buyer liability.[9] Seller liability puts the responsibility in case of non-compliance on the participant who has sold parts of its permits. Buyer liability, one the other hand, would result in a cancellation of trades in case the seller is non-compliant. There are different criteria for assessing liability rules as for example: environmental effectiveness, cost to participants or markets confidence (IEA 1999, p. 17). Kerr (1998, p. 9) believes that seller liability is the better option as long as serious sanctions in case of non-compliance are imposed. This should not cause any problems within national legislation.

EXISTING GHG EMISSION TRADING SCHEMES IN EUROPE

Even though there is an intensive discussion on the implementation of GHG emission trading schemes on entity level in several Annex B countries (see for example AGE 2002a, AGO 1999b, Council 2002, Hauf 2000,MIES 2000, Commission 1999) there are at the moment only two existing public[10] systems in Europe: in Denmark and the United Kingdom.[11]

The Danish System

In 1999 the Danish Parliament approved a bill on CO_2 quotas for electricity production as part of a legislative reform of the electricity sector (DEA 1999). Absolute emission targets for emissions from electricity generation are set to 23 Mio. t of CO_2 in 2000 being reduced by 1 Mio. per year until 2003.[12] The 2003 target is only about 66% of historical emissions from 1994 to 1998 and can thus be considered as a stringent one.[13] Emission rights are not allocated to companies with historical emissions smaller than 100.000 t of CO_2 per year that result from combined heat and power production.[14] As a consequence of this rule, only eight companies actually have to participate in the trading scheme, 2 of which hold about 93% of the permits allocated. Thus, it cannot really be considered as a competitive market. Nevertheless, more than 90 % of CO_2 emissions from power generation are covered.

The permits were allocated free of charge based on historical emission in 1994-1998. Emissions are calculated on the basis of fuel input and standardised emission factors. Companies have to report all relevant data once a year to the Minister of Environment and Energy who will decide on compliance. Detailed rules for punishment in case of suppressing or submitting wrongful or misleading information are given. In case of non-compliance a penalty of 40 DKK has to be paid for each t of CO_2 emitted and uncovered by a permit. Any income will be spent for additional energy savings. Banking is possible with certain restrictions. A “saving limit” has been introduced according to which banking is only possible if emissions are lower than the saving limit[15].

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9. Combinations of these two basic options are also possible. For detailed discussion see IEA (1999)
10. Private systems exist for example within the companies BP and Shell.
11. The Dutch Erupt/Cerupt programme (see: www.carboncredits.nl) cannot be considered as a trading scheme on entity level even though they have been successfully implemented with business being involved.
12. The system became operational only in 2001 as the European Commission raised a number of questions before approving the system in April 2000.
13. Total emissions from electricity production in Denmark strongly depend on export to other Scandinavian countries that regularly face energy shortage in dry summers when the yield from hydro power stations is low.
14. I.e. small producers (< 100.000 t CO_2 / y) that only produce electricity are allocated permits.
15. The saving limit was set to 20 Mio. t CO_2 for each year until 2003.

Transfer of permits has to be reported to the Minister of Environment and Energy within four weeks after an agreement was reached. So far the use of emission certificates from project-based mechanism is not foreseen. However, the Minister is authorised by the bill to specify such rules. Last but not least, the minister can withhold parts of the total permits in order to allocate them to new sources. The allocation shall be relative to the new producer's estimated CO_2 emissions. In case there are no new producers, what can indeed be expected for the period until 2003, the permits withheld are redistributed to the existing electricity producers. (Information in the section see: Pedersen (2000), Queen (1999).)

The UK System

The UK system was developed by the *Emissions Trading Group*, which was led by industry and included the UK government. A scheme with voluntary participation was developed where different ways for entry are offered:

- Through a target set through a Climate Change Levy Agreement. Companies in such an agreement have to meet specific or absolute targets to get an 80% discount of the Climate Change Levy. By participating in emissions trading they can increase flexibility on the way to compliance. In order not to inflate the overall market with "virtual" reductions (remember Fig. 1) and thus undermining stringency, permits from the "specific sector" can only be sold to the absolute sector as long as the former one is altogether a net buyer.[16] Otherwise, the so-called "gateway" will close. Companies that opt in only have to carry out additional reporting and verification measures compared to the agreement requirements in case they want to sell permits. The compliance period is on a biennial basis after an introductory period from January 1, 2002 to December 31, 2002. Permits are only generated at the end of these years (so-called *milestone years*). Companies failing to meet the target lose at least the 80 % discount for the following two year period.
- Any company with direct or indirect[17] greenhouse gas emissions within the UK can also ask to participate in the scheme with sources not covered by an existing agreement.[18] Companies bid in an auction for absolute emission reductions calculated against a baseline that describes what would have happened without the reductions induced by the auction. The baseline is the average emissions for the three years from 1998 to 2000. The auction is designed as an *descending clock auction* and a total amount of £ M 215 is spent.[19] Each participant who wins in the auction has set itself an linear emission reduction path with 5 annual targets until 2006. For these so-called *direct participants* guidelines for measurement and reporting of emissions are provided. Non-compliance results in non-payment of the incentive for the year the target has not been met as well as a reduction of permits allocated in the next year amounting to the shortfall multiplied by a penalty factor. Finally, detailed rules for divestments and investments are given.

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16. This will be the case as long the abatement costs are lower in the absolute sector.
17. Indirect emissions result from energy consumption (e.g electricity) during the production of which GHG emissions were released. An emission factor of 0.43 g CO_2 / kWh was laid down. Power generators are to restrict their involvement as direct participant to self-consumption or by taking on responsibility for other parties' emissions.
18. Government will decide on a case by case basis on the entry into the scheme.
19. 34 participants won the auction in March 2002. Emission reductions totalled about 4 M t $CO_{2\text{-eq}}$.

- UK-based projects can earn credits in case the lead to quantified emissions reductions. Rules are still under discussions, but it is sure that projects have to be approved by government.

In contrast to the Danish scheme not only CO_2 but rather all greenhouse gases are generally considered.[20] Unlimited banking is allowed until 2007. Banking into the first Kyoto-commitment period is possible for participants with absolute targets only. The quantity is restricted to the extent that they have over-complied their targets.

Generally, anyone who wants to enter the scheme is free to do so. However, it goes without saying that anyone who wants to hold, buy or sell permits has to have an account[21] in the registry. The UK government intends to allow the use of credits from the project based mechanisms under the Kyoto-Protocol but point out that a decision will only be taken after the rules have been decided on. (All information in this section comes from DEFRA)

LINKING SCHEMES

As long as the abatement costs in separated trading schemes are different, the linkage of two schemes can result in increased overall cost-efficiency. However, given that on the balance one country is either a net importer or a net exporter the permit price will go down in the former and go up in the latter. Consequently, selling entities in the importing countries will lose whereas buyers will win. The contrary goes for the exporting country. This in turn may raise resistance by the losing participants in advance of linking to schemes (Haites & Mullins 2001 p. viii).

Above, the impacts of a certain choice for different features have been discussed. These impacts of different approaches are a general concern in the design of a national system. Differences may, however, prevent linkage for technical reasons or effect environmental integrity when schemes are linked. Table 1 shows in which way these two points are affected.

20. There are some exemptions as for example the CH_4 emissions from landfill activities that are already covered by the landfill directive.
21. There are four kinds of accounts: A compliance, a trading, a retirement and a cancellation account.

Table 1. *Linking national trading schemes: Technical feasibility and environmental integrity*

Design feature	Effect of differences in design features
Absolute vs. Specific Target	Linkage technically feasible as long as some units are defined (e.g. t CO2) but risk weakening the env. integrity in case permits are sold on the balance from the specific to the absolute system by increasing output (see also Fig 1)
Stringency of target	Linkage technically feasible; overall stringency remains unaffected from linking (for different incentives to manipulate stringency prior to the linkage see discussions in section on economic compatibility).
Mandatory vs. Voluntary participation	Linkage technically feasible; as permit price will go up in one system and go down in the other one, incentives to join may also be increased. In case that allocation of permits is generous ("hot air") in the system where prices go up, a greater number may volunteer due to linkage and thus env. Integrity can be weakened.
Participants	Linkage technically feasible; env. integrity may be endangered especially if systems with direct and indirect emissions from the same product are linked
Coverage of gases	Technical feasibility and environmental integrity are unproblematic with regard to linking schemes with different coverage of gases as long as reasonable conversion factors are applied in both systems.*)
Mode of allocation	The method of allocation is not affecting technical feasibility of linkage nor env. Integrity
Monitoring, Verification and Reporting (MVR)	Technical feasibility unaffected from MVR; higher prices due to linking and lax MVR provisions may give incentives to cheat and thus affect env. integrity
Banking and borrowing	No impact on technical feasibility or env. integrity for banking. For borrowing difference do not cause technical problems but can undermine env. intergrity
Non-compliance provisions	Linkage technically feasible; but difference in penalties and enforcement can weaken env. effectiveness as the lowest penalty determines the place of non-compliance.
Market access	Unproblematic from both technical and environmental point of view.
Register	Can *a priori* prevent linkage as well as negatively affect env. integrity. However, structures can be adopted causing higher costs.
Use of project based credits	Linkage technical feasible; env. integrity might be affected if quality of standards is different.
Treatment of new sources / plant shut down	Technically unproblematic; env. integrity may be affected in case perverse incentives to create new source due to generous allocation are given.
Compliance period	Unproblematic from both technical and environmental point of view.
Liability	With different liability provisions, trading would have to be limited to surplus permits on the sellers account after compliance has be established.

*) Global Warming Potentials (GWP) adopted in the Kyoto-Protocol have been adopted by a political decision. Other conversion factors for different gases are also conceivable (see for example IPCC (2001) pp. 388-390)
Basic argumentation following Haites & Mullins (2001 pp. 38-64)

On the compatibility of the UK and the Danish scheme

After the general analysis presented in Table 2 the UK and the Danish scheme are focused on below.

Table 2. *Linking national trading schemes: Technical feasibility and environmental integrity: the case of Denmark and the UK*

Design feature	Effect of differences in design features
Absolute vs. Specific Target	The specific targets in the UK scheme do not cause any problems in case of linking the two schemes as this aspect is already satisfactorily considered by the gateway in the British scheme.
Stringency of target	Stringency remains unaffected from linking; incentive to inflate total quantity of permits by net-selling country not realised as both have a clear reduction target given their Kyoto obligation
Mandatory vs. Voluntary participation	Marginal costs are yet unknown for the two systems. With the price valve of 40 DKK / t CO_2 it is, however, unlikely that many (if any at all) companies in the UK opt in due to higher prices. Furthermore, the British allocation mode cannot be judged to be generous ("hot air")
Participants	As the UK is a net-importer and Denmark a net-exporter of electricity (UCTE 2000), problems with double counting in env. integrity due to different approaches (indirect vs. direct) are not expected to occur.
Coverage of gases	No problems due to consideration of different gases.
Mode of allocation	The method of allocation is not affecting technical feasibility of linkage nor env. Integrity
Monitoring, Verification and Reporting (MVR)	Unclear if MVR are more lax in net-selling country; thus uncertain if undesirable incentives are given.
Banking and borrowing	Only banking is allowed in the two schemes; thus no problems with technical feasibility or env. integrity for banking.
Non-compliance provisions	Fixed penalty in Denmark whereas company-specific penalty in the UK (e.g. depending on payment received in the auction). However, the Danish penalty can be judged to be very soft and thus the Danish safety valve could be expected to be used by participants in British scheme.
Market access	Unproblematic from both, technical and environmental point of view.
Register	Unclear if structures are similar or if additional efforts are necessary.
Use of project based credits	Detailed rules have not been specified yet in either of countries.
Treatment of new sources / plant shut down	Perverse incentives cannot be seen.
Compliance period	Unproblematic from both, technical and environmental point of view.
Liability	Unproblematic as same liability provisions in both systems.

To sum it up, the two schemes could be linked with probably little technical efforts (depending on the registries), but could at the same time affect environmental integrity due to the different non-compliance provisions.

In this context it the first permit swap between the two systems might be worth being mentioned. In summer 2002 Royal Dutch Shell and Elsam have swapped carbon allowances (Buchan 2002). However, the mere international trade in permits is different from linking schemes as discussed in this paper. The use of foreign permits for compliance needs approval by national authorities. Insofar, the acquisition of UK permits by Elsam – which has no operation in the UK – has to be considered as a simple investment as in any share.

LINKING NATIONAL SCHEMES IN THE CONTEXT OF THE KYOTO-PROTOCOL

After discussing the linkage of national schemes from a technical and an environmental point of view, we analyse the economic impact in the context of the Kyoto-provisions in this section.

The Kyoto-Provisions

The Kyoto-Protocol – agreed on during the 3rd Conference of Parties to the UNFCCC in Kyoto in 1997 - defines absolute emission targets (so-called Assigned Amount) for countries listed in Annex B for the first commitment period from 2008-2012. The targets are defined as a percentage figure compared to 1990's GHG emissions. In order to enable a cost-efficient meeting of these targets, some so-called flexible mechanisms have been introduced, among which is emission trading: Parties listed in Annex B to the Protocol are (under certain conditions) allowed to trade the underlying emission rights, the so-called Assigned Amount Units (AAUs). Emissions without any flexible mechanisms would have to decline sooner or later in all countries according to the national targets. With trading the emission path will change – maybe even before 2008[22] (see Fig. 2).

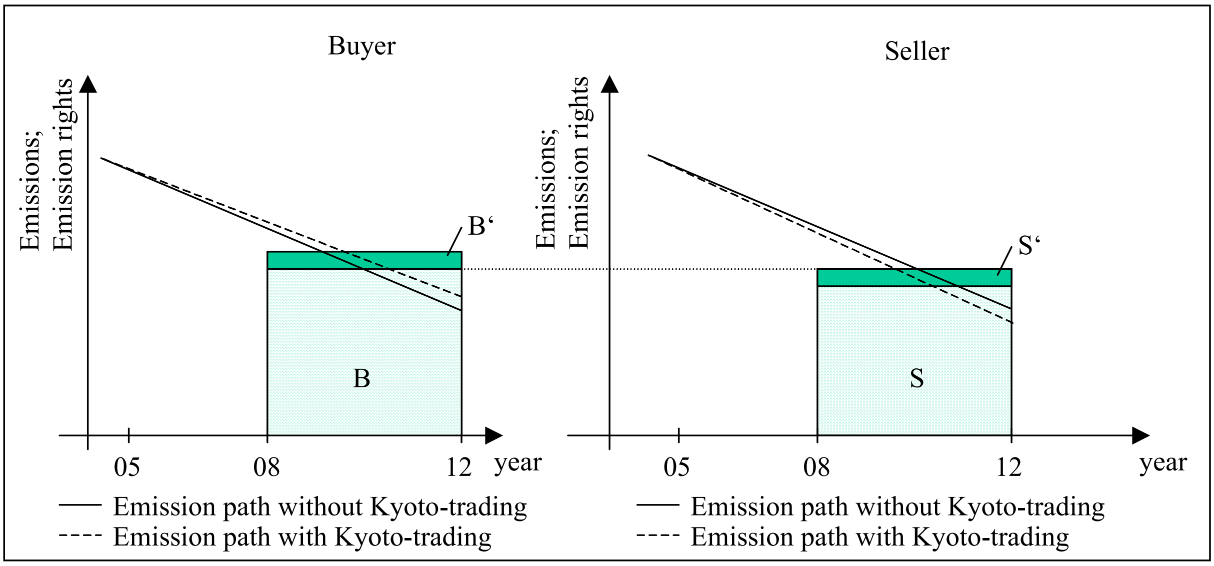

Figure 2. Change of emission path considering emissions trading under the Kyoto provisions for a simple 2 country case.

However, as the system starts in 2008 only, one has to ask how international pre-2008 trading interacts with the Kyoto provisions.

It is interesting to note that there are no concrete mandatory emissions paths for reaching the Kyoto-targets. Article 3 (2) of the Kyoto-Protocol says that "Each Party included in Annex I shall, by 2005, have made demonstrable progress in achieving its commitments under this Protocol" but it will be interesting to see how the term *demonstrable progress* will

22. As an example The Netherlands can be given. Since they realised that meeting the Kyoto target at home would be quite expensive, they prepared the purchase of emission rights under the Kyoto-provisions. This allows for increased emissions according to the no-Kyoto-trading case even before 2008. (see www.carbencredits.nl for further information)

be interpreted in 2005. As there is furthermore no penalty mentioned in case a Party does not show any demonstrable progress, the emission path can be assumed to be completely undetermined.

International trading prior to the first commitment period

As mentioned above, linking trading schemes can result in increased overall cost-efficiency on the global scale. However, apart from efficiency on a global scale the incidence of costs has to be discussed.

International emissions trading prior 2008 may either be based on the exchange of AAUs or not. For analysing this interaction let us consider a two country, two period model and analyse first the situation without any international trading prior to the first commitment period.

Kyoto-trading only

We assume that – with regard to the Kyoto target – one country will be a net buyer whereas the other will be a net seller. (Note that the model discussed below has been rigidly simplified for illustrative purposes. A general version is presented in Annex 1.) Both countries have the same reduction obligation in each period (that changes, however, over time). Banking is not allowed. The cost functions of the countries are quadratic[23]. The lifetime of an investment in emission reductions is one period.

Without loss of generality, let *a* denote the buying and *b* the selling country. Indices 1 and 2 denote the two periods. The two countries face the optimisation problem[24]:

(1)

$$\min_{R_{a1},R_{a2},P_2} C_a = \alpha_a R_{a1}^2 + \alpha_a R_{a2}^2 + \pi_2 P_2 \; ; \quad \min_{R_{b1},R_{b2},P_2} C_b = \alpha_b R_{b1}^2 + \alpha_b R_{b2}^2 - \pi_2 P_2$$

s.t.

$$R_{a1} \geq T_1 \; ; \; R_{b1} \geq T_1 \; ; \; R_{a2} + P_2 \geq T_2 \; ; \; R_{b2} - P_2 \geq T_2$$

where, C = Costs, α = parameter, R = emissions reduced internally, π = permit price (assuming a perfect market where each participants faces the same price), P = quantity of permits bought or sold, T = reduction obligation

Whereas T_2 should be based on the Kyoto-target there is more freedom when defining T_1 (see next chapter for a more detailed discussion).

First order conditions are given in Annex 2. (1) solves as:

(2)

$$R_{a1} = T_1 \; ; \; R_{b1} = T_1 \; ; \; \lambda_{a1} = 2a_a T_1 \; ; \; \lambda_{b1} = 2a_b T_1$$

$$R_{a2} = \frac{2\alpha_b}{\alpha_a + \alpha_b} T_2 \; ; \; R_{b2} = \frac{2\alpha_a}{\alpha_a + \alpha_b} T_2 \; ; \; \pi_2 = \lambda_{a2} = \lambda_{b2} = \frac{4\alpha_a \alpha_b}{\alpha_a + \alpha_b} T_2 \; ; \; P_2 = \frac{(\alpha_a - \alpha_b)}{\alpha_a + \alpha_b} T_2$$

where λ = Lagrange multiplier

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23. They represent the aggregated abatements cost functions of the participants of the national trading schemes.

[24] The underlying model is taken from Rehdanz and Tol (2002) who analyse a one-period problem.

We can see, that by introducing trading in the second period marginal abatement costs (λ_{i2}) become the same for both countries.

Non AAU-based international emission trading before 2008

In case that no AAUs are used in the linked schemes another "commodity"[25] has to be transferred. Let us denote the commodity as *Pre-Kyoto-Unit (PKU).* Generally, a government can issue as much as PKUs as desired. The selling country actually has an incentive to increase the number of permits as it is beneficial to its industry. As this is at the expense of the environment, a pro-environmental buying country may look for instruments to reduce import of "worthless" permits. Rehdanz and Tol (2002) analyse the different impacts of a discount factor, a tariff and a quantity limit. In the following analysis we assume, however, that the PKU allocation prior to the first commitment period is based on the Assigned Amount and that arbitrarily flooding of the market does not occur. For a linear compliance path the situation can be as depicted in Figure 3:

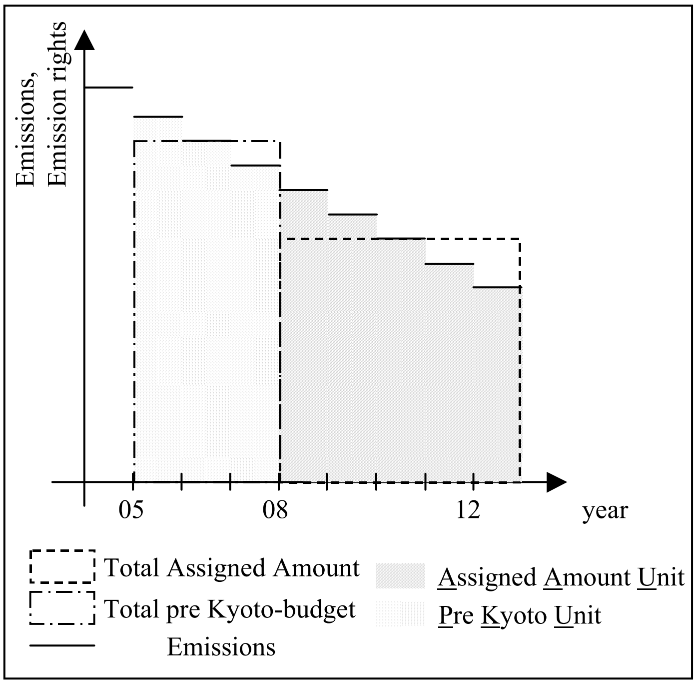

Figure 3. Permit budget prior and during the first commitment period.

Extending (1) with trading in both periods gives:

$$(3)\quad \min_{R_{a1},R_{a2},P_1,P_2} C_a = \alpha_a R_{a1}^2 + \pi_1 P_1 + \alpha_a R_{a2}^2 + \pi_2 P_2 \; ; \; \min_{R_{b1},R_{b2},P_1,P_2} C_b = \alpha_b R_{b1}^2 - \pi_1 P_1 + \alpha_b R_{b2}^2 - \pi_2 P_2$$

s.t.

$$R_{a1} + P_1 \geq T_1 \; ; \; R_{b1} - P_1 \geq T_1 \; ; \; R_{a2} + P_2 \geq T_2 \; ; \; R_{b2} - P_2 \geq T_2$$

First order conditions are given in annex 3. (3) solves as:

25. It is still not clear what legal status the permits will have (commodity, commercial paper etc.).

(4)

$$R_{a1} = \frac{2\alpha_b}{\alpha_a+\alpha_b}T_1 \;;\; R_{b1} = \frac{2\alpha_a}{\alpha_a+\alpha_b}T_1 \;;\; \pi_1 = \lambda_{a1} = \lambda_{b1} = \frac{4\alpha_a\alpha_b}{\alpha_a+\alpha_b}T_1 \;;\; P_1 = \frac{(\alpha_a-\alpha_b)}{\alpha_a+\alpha_b}T_1$$

$$R_{a2} = \frac{2\alpha_b}{\alpha_a+\alpha_b}T_2 \;;\; R_{b2} = \frac{2\alpha_a}{\alpha_a+\alpha_b}T_2 \;;\; \pi_2 = \lambda_{a2} = \lambda_{b2} = \frac{4\alpha_a\alpha_b}{\alpha_a+\alpha_b}T_2 \;;\; P_2 = \frac{(\alpha_a-\alpha_b)}{\alpha_a+\alpha_b}T_2$$

where λ = Lagrange multiplier

As we can see the quantity of PKU purchased by country *a* depends on the reduction obligation and the abatements costs in the two countries. Even though being in compliance with the pre Kyoto-target, emissions are less reduced in the buying country in the pre-Kyoto period than without any linkage of the trading schemes. As permits are bought, country *a* ultimately finances the emission reductions in country *b* without getting anything in return. It could not even state that it has made *demonstrable progress in emission reductions.* Consequently, government *a* may argue for weak reduction obligations in pre-Kyoto period or insist on a transfer of AAU in order to benefit in some way. This point is analysed in the next section. Note, however, that this system would be cost-efficient from a global climate policy perspective.

AAU-based international emission trading before 2008

We still assume that the national total budgets are consistent with the Kyoto target.

As a consequence of the aforementioned "subsidy effect" we now assume that the buying country demands a transfer of an equal quantity of AAUs with each PKU bought from the other country. As emissions must only be "backed-up" by AAUs from 2008 on, they can be used for any trading scheme prior to the start of the Kyoto scheme. They do not have to be redeemed at the end of 2007 for instance. Thus, the total quantity of AAUs will not change due to their use in early trading schemes. However, ownership will change.

We consider the aforementioned by changing the budget constraint in (2). Any permit bought (sold) in period 1 is added (subtracted) in the second period. (Note that this is no banking in the traditional sense):

(5) $R_{a1} + P_1 \geq T_1 \;;\; R_{b1} - P_1 \geq T_1 \;;\; R_{a2} + P_2 + P_1 \geq T_2 \;;\; R_{b2} - P_2 - P_1 \geq T_2$

See annex 4 for first order conditions. (5) solves as:

(6)

$$R_{a1} = \frac{2\alpha_b}{\alpha_a+\alpha_b}T_1 \;;\; R_{b1} = \frac{2\alpha_a}{\alpha_a+\alpha_b}T_1 \;;\; \pi_1 = \lambda_{a1} = \lambda_{b1} = \frac{4\alpha_a\alpha_b}{\alpha_a+\alpha_b}T_1 \;;\; P_1 = \frac{(\alpha_a-\alpha_b)}{\alpha_a+\alpha_b}T_1$$

$$R_{a2} = \frac{2\alpha_b}{\alpha_a+\alpha_b}T_2 \;;\; R_{b2} = \frac{2\alpha_a}{\alpha_a+\alpha_b}T_2 \;;\; \pi_2 = \lambda_{a2} = \lambda_{b2} = \frac{4\alpha_a\alpha_b}{\alpha_a+\alpha_b}T_2 \;;$$

$$P_2 = \frac{(\alpha_a - \alpha_b)}{\alpha_a + \alpha_b} T_2 + \frac{(\alpha_b - \alpha_a)}{\alpha_a + \alpha_b} T_1$$

Comparing (6) with (4) we can see that the quantity traded in period 2 (P_2) changes. As $\alpha_b - \alpha_a < 0$ by definition (abatement costs in country *a* are higher) the second addend becomes negative and thus less permits are traded. Thus, with all other unknowns being unchanged the transfer of AAUs along with PKUs reduces the total costs in the buying country (see next chapter for detailed discussion). The latter should argue for strong reduction obligations in the pre-Kyoto period (second addend in P_2) . On the other hand, total costs are increasing for the selling country which in turn should prefer the approach presented first (no-AAU-transfer).

Discussion and Conclusion

If we take the results in (2), (4) and (6) and substitute them in the cost functions, we get the compliance costs for both countries (see annex 5 and 7).

We find that the buying country prefers the AAU-transfer to the no-AAU-transfer scenario. It prefers, however, both approaches to the Kyoto-trading only scheme as long as we assume that the government is interested in cost-efficient international climate policy instruments prior to the start of the first commitment period. It may, however, be reluctant to "subsidise" reductions in the other country without getting anything (but the *Pre-Kyoto-Units*) in return.

The situation is, however, different for the selling country: It prefers the no-AAU-transfer scenario to all other options. Furthermore, it favours the Kyoto-only approach over the AAU-transfer approach as additional costs from foregoing benefits from trading in the first period are overcompensated by reduced costs in the second period (see Annex 5).

Apart from this, both countries do have different interests with regard to the stringency of the reduction obligation in period 1 (see Table 3).

Table 3. *Preferences for different approaches and stringency of reduction obligation under different design options for international emissions trading.*

	Lifetime of investment: 1 period	
	Net-buyer	net-seller
Support of different approaches		
Kyoto-only-trading	Low*)	Medium
No-AAU-transfer	Medium*)	High
AAU-transfer	High	Low
Preferred stringency of reduction obligation in period 1 for different approaches		
Kyoto-only-trading	Indifferent	Indifferent
No-AAU-transfer	Indifferent	Indifferent
AAU-transfer	Strong	Weak

*) Only if country is interested in cost-efficient international climate policy prior to 2008

One can see that there is an inherent conflict of interests between seller and buyer with regard to the transfer of AAUs in international emissions trading prior to 2008. Against this background, one may question whether governments will voluntarily decide to link their trading schemes prior to 2008.

Unfortunately, there are no information available on the marginal abatements cost for the target sets in Denmark or the UK. Thus, no recommendation for the two governments concerning the approach to be to preferred is possible.

In October 2001 the European Commission presented a proposal for a mandatory emissions trading scheme within the EC (EU COM 2001)[26]. Keeping the results given in Tab. 3 in mind, an obligation to participate will inevitably entail winners and losers among member states with regard to compliance costs of Kyoto commitments and might even provoke resistance in case governments are aware of their of their situation.

SUMMARY

Before greenhouse gas emission trading can start on the entity level, several design features have to be decided on. Linking of these national schemes can result in increased cost-efficiency. But as in sovereign nation states these decisions may differ the linkage may be prevented for technical reasons or effect environmental integrity.

The analysis reveals that potential technical obstacles can likely be overcome inducing additional costs. This goes for example for differences in registry structures. Environmental integrity may be affected easily. If this is to be avoided, systems would have to be adapted or linkage has to be abstained from.

For the only two existing schemes in Europe (Denmark and UK) linkage would likely be possible without causing any problems with regard to the two aforementioned aspects. The situation is, however, different from the economic point of view. Even though the overall cost-efficiency can be increased, the incidence of costs in the context of the Kyoto-regime, which may start in 2008, suggests that governments could refrain from linking their schemes voluntarily prior to 2008: Net-buyer and net-seller do have contrary interests with respect to the transfer of AAUs. This also means that a mandatory linkage as proposed by the European Commission is likely to produce winners and losers among member states.

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26. As it is not an existing system yet, we did not want to discuss the different design features.

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ANNEX

Annex 1:

General version of (2)

$$\min_{R_{i1},R_{i2},P_{i1},P_{i2}} C_i = \alpha_{i1}R_{i1}^2 + \pi_1 P_{i1} + \frac{\alpha_{i2}R_{i2}^2}{1+\delta} + \frac{\pi_2 P_{i2}}{1+\delta}$$

s.t.

$R_{i1} + P_{i1} \geq E_{i0} + A_{i1}$; $R_{i2} + P_{i2} \geq E_{i0} + A_{i2}$

where δ = discount rate; E = Emissions; A = Permits allocated

Annex 2:

First order conditions for (1): Kyoto trading only

$$2\alpha_a R_{a1} - \lambda_{a1} = 0$$
$$2\alpha_a R_{a2} - \lambda_{a2} = 0$$
$$\pi_2 - \lambda_{a2} = 0$$
$$R_{a1} - T_1 = 0$$
$$R_{a2} + P_2 - T_2 = 0$$

$$2\alpha_b R_{b1} - \lambda_{b1} = 0$$
$$2\alpha_b R_{b2} - \lambda_{b2} = 0$$
$$-\pi_2 + \lambda_{b2} = 0$$
$$R_{b1} - T_1 = 0$$
$$R_{b2} - P_2 - T_2 = 0$$

Annex 3:

First order conditions for (2): Non AAUs-based PKU-tradings

$$2\alpha_a R_{a1} - \lambda_{a1} = 0$$
$$\pi_1 - \lambda_{a1} = 0$$
$$2\alpha_a R_{a2} - \lambda_{a2} = 0$$
$$\pi_2 - \lambda_{a2} = 0$$
$$R_{a1} + P_1 - T_1 = 0$$
$$R_{a2} + P_2 - T_2 = 0$$

$$2\alpha_b R_{b1} - \lambda_{b1} = 0$$
$$-\pi_1 + \lambda_{b1} = 0$$
$$2\alpha_b R_{b2} - \lambda_{b2} = 0$$
$$-\pi_2 + \lambda_{b2} = 0$$
$$R_{b1} - P_1 - T_1 = 0$$
$$R_{b2} - P_2 - T_2 = 0$$

Annex 4:

First order conditions for (4): AAUs-based PKU-tradings

$$2\alpha_a R_{a1} - \lambda_{a1} = 0$$
$$\pi_1 - \lambda_{a1} = 0$$
$$2\alpha_a R_{a2} - \lambda_{a2} = 0$$
$$\pi_2 - \lambda_{a2} = 0$$
$$R_{a1} + P_1 - T_1 = 0$$
$$R_{a2} + P_2 + P_1 - T_2 = 0$$

$$2\alpha_b R_{b1} - \lambda_{b1} = 0$$
$$-\pi_1 + \lambda_{b1} = 0$$
$$2\alpha_b R_{b2} - \lambda_{b2} = 0$$
$$-\pi_2 + \lambda_{b2} = 0$$
$$R_{b1} - P_1 - T_1 = 0$$
$$R_{b2} - P_2 - P_1 - T_2 = 0$$

Annex 5:

Country a (net buyer):

Kyoto trading only:

$$C_a^{(1)} = \alpha_a T_1^2 + \alpha_a\left(\frac{2\alpha_b}{\alpha_a+\alpha_b}T_2\right)^2 + \frac{4\alpha_a\alpha_b}{\alpha_a+\alpha_b}T_2\ \frac{(\alpha_a-\alpha_b)}{\alpha_a+\alpha_b}T_2$$

No AAU-transfer:

$$C_a^{(2)} = \alpha_a\left(\frac{2\alpha_b}{\alpha_a+\alpha_b}T_1\right)^2 + \frac{4\alpha_a\alpha_b}{\alpha_a+\alpha_b}T_1\ \frac{(\alpha_a-\alpha_b)}{\alpha_a+\alpha_b}T_1 + \alpha_a\left(\frac{2\alpha_b}{\alpha_a+\alpha_b}T_2\right)^2 + \frac{4\alpha_a\alpha_b}{\alpha_a+\alpha_b}T_2\ \frac{(\alpha_a-\alpha_b)}{\alpha_a+\alpha_b}T_2$$

AAU-transfer:

$$C_a^{(3)} = \alpha_a\left(\frac{2\alpha_b}{\alpha_a+\alpha_b}T_1\right)^2 + \frac{4\alpha_a\alpha_b}{\alpha_a+\alpha_b}T_1\ \frac{(\alpha_a-\alpha_b)}{\alpha_a+\alpha_b}T_1 + \alpha_a\left(\frac{2\alpha_b}{\alpha_a+\alpha_b}T_2\right)^2 + \frac{4\alpha_a\alpha_b}{\alpha_a+\alpha_b}T_2\left[\frac{(\alpha_a-\alpha_b)}{\alpha_a+\alpha_b}T_2 + \frac{(\alpha_b-\alpha_a)}{\alpha_a+\alpha_b}T_1\right]$$

$$C_a^{(1)} > C_a^{(2)} > C_a^{(3)}$$

Country b (net seller):

Kyoto-trading-only:

$$C_b^{(1)} = \alpha_b T_1^2 + \alpha_b\left(\frac{2\alpha_a}{\alpha_a+\alpha_b}T_2\right)^2 - \frac{4\alpha_a\alpha_b}{\alpha_a+\alpha_b}T_2\ \frac{(\alpha_a-\alpha_b)}{\alpha_a+\alpha_b}T_2$$

No-AAU-transfer:

$$C_b^{(2)} = \alpha_b\left(\frac{2\alpha_a}{\alpha_a+\alpha_b}T_1\right)^2 - \frac{4\alpha_a\alpha_b}{\alpha_a+\alpha_b}T_1\ \frac{(\alpha_a-\alpha_b)}{\alpha_a+\alpha_b}T_1 + \alpha_b\left(\frac{2\alpha_a}{\alpha_a+\alpha_b}T_2\right)^2 - \frac{4\alpha_a\alpha_b}{\alpha_a+\alpha_b}T_2\ \frac{(\alpha_a-\alpha_b)}{\alpha_a+\alpha_b}T_2$$

AAU-transfer:

$$C_b^{(3)} = \alpha_b\left(\frac{2\alpha_a}{\alpha_a+\alpha_b}T_1\right)^2 - \frac{4\alpha_a\alpha_b}{\alpha_a+\alpha_b}T_1\ \frac{(\alpha_a-\alpha_b)}{\alpha_a+\alpha_b}T_1 + \alpha_b\left(\frac{2\alpha_a}{\alpha_a+\alpha_b}T_2\right)^2 - \frac{4\alpha_a\alpha_b}{\alpha_a+\alpha_b}T_2\left[\frac{(\alpha_a-\alpha_b)}{\alpha_a+\alpha_b}T_2 + \frac{(\alpha_b-\alpha_a)}{\alpha_a+\alpha_b}T_1\right]$$

$$C_b^{(3)} > C_b^{(1)} > C_b^{(2)}$$