The economic effects of the European ceilings proposal

Jesper Jensen, *Copenhagen Economics,*
Claus Kastberg Nielsen, *Copenhagen Economics* and
Thomas F. Rutherford, University *of Colorado, Boulder*

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Abstract:
Current and prospective EU members have recently proposed a set of guidelines for trade with emissions reductions within the Kyoto Protocol. The European proposal effectively eliminates exports of hot air and limits imports of emission reductions by Annex B countries to 50% of the total abatement requirement. We analyze the economic effects of the European proposal in the EDGE-model, a dynamic multi-region general equilibrium model. In the short run, the proposal drives up global prices for emission reductions, because the elimination of hot air reduces the supply of emission reductions. In the longer run, the proposal drives down global prices for emission reductions, because binding import ceilings on emission reductions, reduce the demand for emission reductions. Whether compared to free Annex B or global trade, the European proposal increases global welfare costs by approximately 15 bn € (or 0.1 percent) per year. But the source of the welfare costs differ. Relative to free Annex B trading, global costs are driven by the elimination of hot air, but relative to free global trading, they are driven by binding import ceilings on a market swamped by low-cost reduction possibilities from non-Annex B countries. Neither, EU, nor the US experience significant welfare losses as dead weight losses are moderated by lower global prices on emission reductions due to binding import ceilings. Russia and other Annex B hot air exporters loose unambiguously from the European proposal, but the losses are dwarfed by their losses if trade in emission reductions become truly global.

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Table of Contents

List of Tables

List of Figures

The Kyoto Protocol requires Annex B countries[1] to cut down annual emissions of green house gases in 2008-12 to a specific percentage of their emissions in 1990 (UNFCCC, 1997). To achieve this goal, the Protocol opened up for international trade in emission reductions as long as it was "supplementary" to domestic action. But the Protocol itself stopped short of defining the precise meaning of "supplementary".

In June 1999 current and prospective EU member states proposed a set of guidelines for trade in emission reductions (Submission, 1999). The proposal defines a set of concrete ceilings for selling and buying emission reductions for all Annex B countries. The European countries argue that their proposal (1) increases domestic abatement ratios, stimulating additional technological improvements in green house gas efficiency that in turn may lower the costs of future abatement and (2) limits the role of hot air. Most countries expect to have higher annual emissions in 2008-12 than in 1990 and need to cut down emissions. However, some countries, notably the Former Soviet Union and some Easter European countries, expect to have *lower* emissions than in 1990 and can realize a windfall gain if they are allowed to sell the residual emissions, called hot air, on the international market. The European countries oppose the presence of hot air on the market, presumably on ethical grounds, because buyers of hot air avoid cutting down emissions at home, while sellers of these same emissions do not reduce emissions more than they would have done anyway.

The European proposal is complex and has different levels and types of restrictions on the sale and purchase of emission reductions. The complexity of the proposal makes it difficult to evaluate the economic consequences of the proposal without relying on formal analysis in an economic simulation model. We use the EDGE-model, which is a dynamic multi-regional applied general equilibrium model for quantitative environmental analysis currently being constructed by Copenhagen Economics. We stress that the model is under construction and that all results are preliminary.

Clearly, the European proposal implies a reduction in global welfare. This is so because binding ceilings imply that you have to abate more at home at high marginal abatement cost even though you would have preferred to import emission reductions from countries with lower marginal abatement costs.

But the European proposal is motivated by a stated preference for higher domestic abatement ratios and lower volumes of hot air on the market. We are not able to judge whether the supposed benefits of higher domestic abatement ratios and less hot air more than outweigh the higher efficiency costs, but the least we can do is to make the implied trade off visible by stating the costs at which a specified domestic abatement ratio (alternatively, a specified reduction in hot air) is achieved. This

[1] Annex B countries include the industrialised countries and the transition economies.

allows any observer of the proposal to judge by its own preferences which side of the costs is to be preferred.

Our analysis builds on some of the analyses presented in the 1999 special issue of the Energy Journal (Weyant, 1999), especially Bernstein et al. (1999), MacCracken et al. (1999) and Tol (1999). See also Kemfert (1999). All of these papers focus on the consequences of generic ceilings *either* on the purchase *or* on the sale of emission reductions. We extend their analysis by modelling the details of the European proposal allowing for the various ceilings to be active in any time period both on the demand and supply side. This allows, among others, for the possibility that a ceiling may be binding on the sale of emission reductions in some time periods, but on the purchase of emission reductions in other time periods.

We present three main results. We first argue, that the European proposal has different consequences in the short and long run. In the short run, the proposal eliminates the supply of hot air, *driving up* market prices and stimulating domestic abatement such that ceilings on the purchase of emission reductions rarely become binding. In the longer run, when there is no hot air left, restrictions on the purchase of emission reductions (in most cases) become binding, raising domestic abatement ratios and *driving down* market prices.

Secondly, the annual global welfare costs of the European proposal are estimated at approximately 15 billion 1995€. The level of costs is independent of whether trading takes place between Annex B countries or is truly global. But the primary source of the welfare costs differs significantly. In an Annex B trade regime, costs are primarily driven by the elimination of hot air from the market. In a global trade regime, costs are, in contrast, driven by the binding ceilings on the import of emission reductions in Annex B countries, that raises domestic abatement ratios by 25-30 percent point.

Thirdly, the welfare costs for EU and the US are quite modest. Relative to unrestricted trade, the welfare costs of the Kyoto Protocol increase by less than 10 percent for any of the two regions. The main reason is that the dead weight loss in the two regions is moderated by the lower global prices on emission reductions induced by the binding ceilings on the import of emission reductions. Russia and other Annex B hot air exporters bear a large proportion of the costs of the European proposal either because hot air is eliminated or because export prices of emission reductions are driven down. But the losses from the European proposal are peanuts compared to the losses that Russia will experience if trade in emission reductions really turns global.

To our knowledge Baron et al. (1999) is the earliest analysis of the European proposal. They report qualitative results similar to the our results, but - due to their analytical approach - abstain from making any quantitative conclusions. Our analysis has much in common with the analysis presented by Criqui and Viguier (1999), Ellerman and Wing (2000) and Holtsmark (20000), who also take some care to model the complexities of the European proposal within a consistent modelling framework. Criqui and Viguier (1999) interpret the European proposal as more restrictive than we do[2] and using the POLES energy model they achieve domestic abatement ratios in most Annex B countries very close to 100. In our model it would translate into welfare costs of the European proposal very similar to the welfare costs of autarchy. Our interpretation of the European proposal seems to have much more in common with Ellerman and Wing (2000) and we achieve similar types of results. However, their preferred baseline in the EPPA model assumes higher emission growth, implying that the ceilings on the import of emission reductions can never bind with Annex B trade. Holtsmark (2000) analyse the European proposal in the ACT-model and conclude that the import ceilings never become binding because tight export ceilings drive up market prices and domestic abatement. In their simulation (but not in their text) they seem to use the same interpretation of European proposal as Criqui and Viguier (1999), at least on the export side.

In our future work we plan to extend the analysis by evaluating the European proposal with different baseline assumptions, by incorporating the remaining green house gases and sinks and by introducing the possibility of banking of unused hot air for future domestic use.

The paper is organized as follows. The first section briefly presents the main properties of the European proposal. The second section introduces the main features of the EDGE model, and in the third section we set up a number of versions of the European proposal and simulate their effects in the model. we then report and discuss results, before we turn to the concluding remarks in the last section four.

1. The European proposal

The European proposal was presented by Germany on behalf of current and prospective EU member states at the June 1999 meeting of the Subsidiary Body in Bonn (Submission, 1999). The proposal defines concrete ceilings for the net purchase and net sale of emission reductions for all Annex B countries and is one example on how to define "supplementarity".[3] The proposal is complex and here we just summarize the main properties needed for our analysis. A detailed presentation and analysis of each of the elements of the proposal can be found in Appendix 1.

The proposal defines a number of ceilings on the *net purchase* of emission

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[2]They assume that the however clauses cannot be used. It implies much stricter ceilings on the import and, especially, export of emission reductions. See section 1.

[3]All three types of trade in emission reductions are covered by the proposal: permit trade (article 17 in the Kyoto Protocol), joint implementation (article 6) and clean development mechanism (article 12).

reductions from abroad[4] and allows each Annex B country to choose its own ceiling. The most important ceiling is the ceiling described in the however clause. It allows Annex B countries to purchase emission reductions from abroad up to half the abatement requirement in 2010 (that is the difference between the Kyoto target and the emissions in 1990) provided the country can verify a similar volume of domestic abatement undertaken after 1993. For most countries this ceiling corresponds to 10-15 percent of the targeted emissions in 2010. For now we will assume that verification is possible without significant transaction costs, although the exact verification procedure yet has to be defined. We will briefly discuss the verification requirement in the end of this section.

The proposal has a number of additional ceilings on the purchase of emission reductions. These ceilings are less restrictive than the however ceiling[5], such that in the model no region would be better off choosing one of those ceilings instead of the however ceiling. For this reason, the additional ceilings are only relevant if the verification procedure in the however clause cannot be agreed upon or implemented.

The proposal also defines a number of restrictions on the *net sale* of emission reductions by Annex B countries. The most important restriction is again the ceiling described in the however clause. It allows an Annex B country to sell as much emission reductions as they please provided they can verify that a similar volume of domestic abatement has been undertaken after 1993.[6] We understand the clause as an attempt to link any sale of emission reductions to well defined domestic abatement activities and thus to eliminate the sale of emission reductions that are made possible by the presence of hot air. In Russia the volume of hot air corresponds to about 23 percent of the targeted emissions in 2010. We implement this feature in the model as a ban on the sale of hot air in any time period, but otherwise an Annex B country is allowed to sell any volume of emission reductions in the market. This is same interpretation as used by, among others, MacCracken et al. (1999) and Bernstein et al. (1999). In principle the Kyoto Protocol allows an Annex B country to bank unused emission reduction for use in future periods. For now we abstract from this possibility, but we plan to include this extension in the next version of the paper.

Th proposal has yet another ceiling on the net sales of emission reductions corresponding to about 5 percent of the target emissions in 2010. In our model this

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[4]The ceiling if both for emission reductions purchased from other Annex B countries and from non-Annex B countries.

[5]The ceilings correspond to 5-15 percent of the targeted emissions in 2010.

[6]Notice that this restriction can never be a ceiling. It is more like a minimum reduction requirement. A country is allowed to sell as much permits as it please less the volume of domestic abatement that cannot be verified.

much more restrictive ceiling will not become binding given our assumption that the verification procedure can be agreed upon and implemented.

A key question in our analysis will be whether the market, if at all, will be rationed from the supply side or the demand side (Benassy, 19xx). Supply side rationing creates an excess demand that drives up the market price of emission permits. The higher market price raises the incentive to engage in domestic abatement, raises domestic abatement ratios, but also gives rise to an income transfer from buyers of emission reductions to sellers. In contrast, demand side rationing creates an excess supply, that drives down the market price of emission permits. The lower market price reduces the incentive to engage in domestic abatement, drives down domestic abatement ratios, and gives rise to an income transfer from sellers of emission reductions to buyers. Ellerman and Wing (2000) has named demand side rationing as "the monopsonistic case".

The European proposal relies heavily on a verification procedure, that yet has to be defined. Both net sellers and net buyers of emission reductions must document that they abate domestically more than they trade emission reductions. The problem is that we can physically observe total emissions and the volume of trades in the market. But we can only determine the volume of domestic abatement if we are willing to make some assumption about what the level of emissions would have been in the absence of any Kyoto activity.

Basically, there are two approaches. First, the participating countries can simply define official baselines for each country and make it part of the Kyoto agreement. Without doubt this approach gives rise to a very difficult political process, especially if the baselines also should be defined in such a way to eliminate hot air. But once baselines have been defined, the verification procedure will be simple and without significant costs. Secondly, it is possible to define a project-by-project verification procedure similar to the verification procedure required by Joint Implementation and the Clean Development mechanism. In each and every act of trading between economic agents in two Annex B countries, the seller must document that a similar amount of domestic abatement has been undertaken by himself or by another agent in the country, and the buyer must document that a similar amount of domestic abatement has been undertaken in *his* country. This second approach can probably be implemented with limited political costs. On the other hand, the specific transactions costs may be significant. Given that a Joint Implementation procedure already is under development, one interpretation of the verification requirement in the however clause could be that the only valid method for exchanging emission reductions under the however clause is by Joint Implementation.

2. The EDGE-model

This section provides a nontechnical overview of the EDGE model and discusses issues related to the calibration of the model.

The EDGE model[7] is a dynamic, Ramsey-type, multi-sectoral global general equilibrium model designed for climate policy analysis. Conceptually, the EDGE model consists of eight regional general equilibrium models linked by consistent interregional flows of goods and services. There is one model for each region, and as all markets clear simultaneously, all agents in the model correctly anticipate changes in all relative prices. See Table 1.

Table 1: Regions and sectors in the EDGE model

Regions	Sectors
European Union (EU)	Coal
United States (US)	Petroleum
New Zealand, Australia and Canada	Crude oil
Japan	Natural gas
Eastern Europe and Former Soviet Union (FSU)	Electricity
China	
Major oil exporters	Energy intensive sectors
Rest of the world	Other sectors

We furthermore assume that each regional model consists of seven production sectors and a representative agent, and that similar agents solve similar problems. This assumption greatly facilitate development and presentation of the model, but it does not eliminate the most important regional differences, as all the regional models differ with respect to behavioural parameters, government policies, and endowments.

Within a region, all goods are produced using intermediate inputs and primary factors capital and labour. All markets for goods and factors are perfectly competitive. The primary energy supply sectors crude oil, natural gas and coal furthermore use inputs of natural resources calibrated to represent positive supply elasticities. We represent the production processes with nested constant elasticity of substitution (CES) functions, and we assume that all firms behave competitively and select output levels such that marginal costs equals the given market price.

Only one good, crude oil, is perfectly homogenous across all regions. We assume that all other goods are differentiated products according to the region in which they have been produced. Specifically, we adopt the Armington assumption for both imports and exports of the differentiated goods, and we use nested CES

[7] See Jensen et al. (2000a) for an algebraic description of the model.

functions to characterize the choices between, first, the region-specific imports and, second, between the composite import good and the domestically produced good. On the export side, we employ constant elasticity of transformation functions to characterize the allocation of domestic production, first between domestic consumption and exports, and, second, between the different export markets. Finally, there are no restrictions on period-by-period trade balances, but we assume that each region cannot change its net indebtedness over the model horizon. This implies, among others, that there are no restrictions on capital flows and that the present value of total capital inflows and outflows over the model horizon equals zero.

The capital stock evolves via a constant depreciation rate and via new investments. We assume that it takes two years before new investments begin to provide capital services. New investments are allocated to equalize the rate of return in all sectors and regions but once installed, the new investments become sector-specific capital stock.

The labour supply is inelastic. The labour force grows at an exogenous rate and the entire labour force is always fully employed. Labour is perfectly mobile across sectors within a given region, but immobile between regions.

A representative agent in each region describes aggregate final demand, and the agent is endowed with an initial capital stock and a fixed amount of labour and natural resources in each period. The agent's lifetime income consists of labour income, rents from natural resources, and revenues from VAT, excise taxes, and border taxes and tariffs, and he allocates lifetime income across consumption in different time periods to maximize welfare. The agent is forward-looking and always anticipates the future effects of announced policies.

Finally, we approximate the infinite horizon of the infinitely-lived representative agent by imposing balanced growth in investment in the terminal period of the model horizon. This provides for post-terminal capital as the agent would otherwise choose to reduce investments towards the end of the model horizon.

The only green house gas in the current version of the EDGE model is carbon dioxide, but we include both energetic and industrial uses. We plan to incorporate the remaining green house gases and sinks in the next version of the model.

We begin the calibration of the model by reproducing a benchmark steady-state data set. This baseline is based on 1995 data from the GTAP database and an assumption about uniform economic growth across all regions. Among others, we use this part of the calibration to determine the behavioural parameters of the production, trade, consumption, and utility functions. All value flows in the benchmark database are in US$1995, and, as part of the reporting of the results we convert all values to EU€1995 using a one-to-one exchange rate.

We then calibrate the model such that it reproduces a set of baseline paths for emissions growth, GDP growth, energy production, and energy prices. The baseline path consists of assumptions and output from the two energy models POLES and PRIMES (European Commission, 1999). We assign autonomous energy efficiency improvements to match growth in GDP and emissions, and we calibrate the quantity of natural resources to match the supply elasticities in energy production and the baseline paths for energy production and prices[8].

This baseline is characterized by aggregate emission growth rates that are comparable with other widely used baselines, for example the baselines from International Energy Outlook. It differs by having lower growth in emissions in the European Union reflecting higher growth rates for autonomous improvements in energy efficiency and rather abrupt changes in emissions from the FSU and Eastern European countries after 1990. The latter implies that there are more hot air in 2010 than in other baselines, but also that hot air disappears faster being completely eliminated between 2015 and 2020.

Finally, the calibration procedure employ a set of elasticities based on survey of similar models presented in Weyant (1999). A more extensive literature review will be part of the next round of model development.

3. The effects of the European proposal

We now set up the EDGE model described in section 2 to analyse the effects of the proposal described in section 1.

We let the representative agent in each region choose the combination of domestic abatement and trade in emission reductions that maximizes the discounted welfare over the model horizon conditional on the restrictions that we impose. In all scenarios we assume that there are no transaction costs when emission reductions are traded.

We set up scenarios in two different trade regimes. In the first trade regime, we estimate the effects of the European proposal in a situation with free trade between Annex B countries only. In the second trade regime we estimate the effects in a situation with free global trade, also allowing Annex B countries to import emission reduction from non-Annex B countries using CDM. See table 2. In all scenarios the European proposal is implemented in 2010 and remains in force in the entire model horizon. This is common knowledge to all agents in the model in the initial period.

We keep Annex B emissions (in the Annex B trade regime) and global emissions (in

[8]See Jensen et al. (2000b) for more information about the calibration procedure and the characteristics of the baseline path.

the global trade regime) constant from 2010 and onwards. It allows us in principle to evaluate each scenario by looking on the costs of the scenario alone and ignore the benefits.[9] In both regimes all Annex B countries reach their Kyoto target in 2010 and keep emissions fixed in all future periods. In addition in the global trade regime, all non-Annex B countries follow their baseline emissions such that any sale of emission reductions must be accompanied by a similar amount of domestic abatement. In the Annex B trade regime, there will be some leakage to non-Annex N countries, such that a part of the emission reductions in Annex B countries will be offset by increases in emissions in non-Annex B countries.

Table 2: Definition of scenarios

Regime	Scenario name	Scenario description
Annex B trade	*NoTrade*	No trade. Only domestic abatement
	ProposalB	The European proposal excluding trade with non-Annex B countries
	Hot Air	The European proposal excluding trade with non-Annex B countries and no restrictions on hot air
	AnnexB	Free trade between Annex B countries only
Global trade	*NoTrade*	No trade. Only domestic abatement
	ProposalG	The European proposal including trade with non-Annex B countries
	Global	Free global trade

In the Annex B trade regime, the *NoTrade* and *AnnexB* scenarios are the two standard reference scenarios. The *ProposalB* and *HotAir* scenarios reflect different interpretations of the European ceilings proposal. In the *ProposalB* scenario, the European proposal excludes hot air completely and imposes a domestic abatement ratio not less than 50 percent of the abatement requirement. But in the end, the volume of hot air that is excluded from the market depends on sensitive political negotiations and we therefore define an alternative extreme scenario, *HotAir*, that maintains the requirement of domestic abatement but stops short of excluding hot air from the market.

[9]Two qualifications are required. In scenarios where the sale of hot air is banned global emissions are lower than it would be otherwise. For example, banning hot air reduces global emissions in 2010 by 6 percent relative to a situation where hot air is on the market. There may also be path dependent ancillary environmental benefits not included in this analysis. For example, if higher domestic abatement ratios implies a substitution of coal for gas, emissions of green house gases go down, but so do emissions of sulphur oxides reducing acid rain. But it is not evident that regulating green house gases is the optimal way to regulate acid rain.

In the longer run, the import of emission reductions from non-Annex B countries via the Clean Development Mechanism may be an important source of low cost emission reductions in Annex B countries. This is the global trade regime, where the *NoTrade* and *Global* scenarios are the two standard reference scenarios. The *ProposalG* scenario imposes the same European proposal as in *ProposalB*, but allows Annex B countries to import emission reductions from non-Annex B countries as long as it does not conflict with the import ceilings.

We now solve the model for the period 2000-2030 in five-year intervals and compare the resulting time paths in the different scenarios with the corresponding values in the baseline path.

Our first conclusion is that market prices for emission reductions are higher than free trade prices in the beginning of the period, but lower than free trade prices in the end of the period.

This is so, because the equilibrium is rationed from the supply side in the early years, but rationed from the demand side in the later years. The conclusion holds for both trade regimes, but the short run price increase is most clearly visible with Annex B trade, while the long run price decrease is most clearly visible with global trade. See figure 1 and 2.

Figure 1: Market price on emission reductions with free Annex B trade, 2010-30

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Figure 2: Market price on emission reductions with free global trade, 2010-30

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In the Annex B trade regime, the exclusion of hot air from the market in the period between 2010 and 2015-20, reduces the supply of emission reductions and drives up the corresponding market price. The high market price improves the profitability of domestic abatement and drives up already high domestic abatement ratios well above 50 percent in most regions. The high domestic abatement ratios make void any ceilings on the purchase of emission reductions, except in Japan where domestic abatement is very costly relative to other industrialized countries.

When hot air disappears between 2015 and 2020, there are no restrictions left on the supply of emission reductions. However, the ever increasing abatement requirement has driven up the need for domestic abatement and domestic abatement ratios stay well above 50 percent for most regions, except in Japan. The binding ceiling on the import of emission reductions in Japan lowers the equilibrium price in the *ProposalB* scenario slightly below the price in the *AnnexB* scenario.

When all hot air is allowed on the market in the *HotAir* scenario, prices in *all* periods are predictively lower than the *AnnexB* price, because the ceilings on the purchase of emission reductions become binding for all major regions in 2010. The larger number of binding ceilings reinforce the price-reducing impact of demand side rationing. This is especially clear in 2010.

In the global trade regime, the availability of emission reductions via CDM completely swamps the market for emission reductions and significantly reduces the impact of the hot air elimination. Prices are driven slightly upwards in 2010, but not sufficient to increase domestic abatement ratios above 50 percent. The ceilings on import of emission reductions become binding for all regions in all periods and significantly drives down the *ProposalG* market price below the *Global* market price after 2010. This is again due to the price-reducing effect of demand side rationing.

Our second conclusion is that apart from eliminating hot air the European proposal increases domestic abatement ratios by 25-30 percent point, but only in a global trade regime. These effects raises the global welfare costs of the Kyoto Protocol by about 14 billion 1995-€ per year independent of the trade regime.

In the Annex B trade regime, the import ceilings of the European proposal has little impact on domestic abatement ratios. Almost none of the import ceilings ever become binding, because the elimination of hot air (initially) and the increased abatement requirement over time keep domestic abatement ratios well above the 50 percent requirement. See as an example domestic abatement ratios in the EU in figure 1.

Figure 3: Domestic abatement ratios for EU with free Annex B trade, 2010-2030

[Insert figure here]

In the global trade regime, the European proposal has a clear impact on domestic abatement in all regions. The availability of low cost abatement possibilities in non-Annex B countries has reduced domestic abatement ratios in EU and the US below 25 percent in free trade. When the European proposal is implemented, the import immediately becomes binding and forces abatement ratios up by 25-20 percent point in all regions and for all periods. See as an example domestic abatement ratios for EU in figure 4.

Figure 4: Domestic abatement ratios for EU with free global trade, 2010-30

In the EDGE model we estimate that the European proposal increases the annual costs of the Kyoto Protocol by about 14 billion 1995-€[10] . See table 3. The increase in costs is independent of the trade regime even though the source of the extra costs differs significantly. In the Annex B trade regime, the elimination of hot air drives most of the cost increase, because the import ceilings never really become binding. In contrast, in the global trade regime, the import ceilings drive most of the cost increase, because the ample supply of low cost abatement possibilities from non-Annex B countries reduces the role of hot air on the market and makes import ceilings binding in all periods and in all regions.

Table 3: Welfare costs of the European proposal, 2010-30

	Equivalent variation as an infinite annuity, billion 1995€ *Change in lifetime equivalent variation, percent*					
	Global	EU	USA	FSU	Other AnnexB	Non AnnexB
NoTrade	-93 *-0.26*	-20 *-0.18*	–30 *-0.31*	-0 *-0.04*	-33	-10
ProposalB	-50 *-0.14*	-11 *-0.09*	-26 *-0.28*	+15 *+1.50*	-18	-10
HotAir	-41 *-0.12*	-9 *-0.08*	-22 *-0.24*	+15 *+1.56*	-16	-9
AnnexB	-36 *-0.10*	-10 *-0.09*	-24 *-0.25*	+18 *+1.85*	-12	-9
ProposalG	-35 *-0.10*	-1 *-0.01*	-11 *-0.11*	-1 *-0.07*	-12	-11
Global	-20 *-0.06*	+2 *+0.01*	-11 *-0.12*	+2 *+0.24*	-4	-8

Our third conclusion is that the costs of the Kyoto Protocol only increases

[10]Measured as the annuity of the discounted change in equivalent variation over the model horizon using a six percent discount rate.

moderately for EU and the US. Russia and other Annex B countries bear most of the costs of the European proposal. However, for Russia the European proposal is a much lesser evil than the possibility that trade in emission reductions one day becomes truly global.

In the EDGE model the costs of the European proposal increases moderately for EU and the US. See table 3. European costs increase by 1-3 billion 1995-€ depending on the trade regime, while US costs increase by 2 billion 1995-€ with Annex B trade and turns into a small gain with global trade. The increase in welfare costs for the two largest importers of emission reductions is small because deadweight losses of the restrictions on emissions trade are moderated by an implicit income transfer from sellers to buyers of emission reductions. The income transfer arises because rationing on the demand side drives down the market price of emission reductions lowering the cost of acquiring emission reductions aborad. For the US the income transfer even dominates the deadweight loss in the global trade regime such that US gains (marginally) from the European proposal relative to free global trade. This is a result also reported by Ellerman and Wing (2000) and Bernstein et al. (1999).

Russia loses from the European proposal because hot air is excluded from the market, but the losses are small relative to the losses of going from Annex B trade to free global trade. Notice that Russia is indifferent between the *ProposalB* scenario and the *HotAir* scenario. In the former scenario hot air is excluded, but the reduced supply pushes up prices on emission reductions sufficiently to compensate Russia for the lost revenue on the sale of hot air. For Russia free global trade is almost as bad as autarchy, as the abundant supply of low cost emission reductions dramatically reduces the export value of Russian export reduction. One could argue that the best strategy for Russia could be to support the European proposal in exchange for tight regulation of CDM.

The costs of the Kyoto Protocol is generally much larger in the US than in EU. In no cases EU welfare costs exceed 0.1 percent of baseline welfare, while it reaches almost 0.3 percent in the US. This is a particularity of our baseline. The difference in costs arises because growth rates of exogenous energy efficiency in our baseline increases faster in EU than in the US. If growth rates are assumed more equal as in other baselines, EU costs would approach the same level as US costs.

4. Concluding remarks

The European proposal is complex and is clearly open for interpretation. To make a meaningful economic analysis it has been necessary to make specific choices in a number of cases, where the text of the proposal has not been particularly helpful. Some of these choices are for example: Will the European proposal be in place for 1o years or for 30 years? We have assumed that it is in place forever! Will Russia be allowed to bank hot air excluded from the market and use it for domestic abatement one day when there is no hot air left. We have decided that this is not possible! Can Annex B countries agree on and implement the verification procedure that is required to use the however clauses. We have said yes! And will export of emission reductions from non-Annex B countries via CDM be able to make a difference on the world market for emission reductions? We have said maybe and reported two extremes! Our choices could have been different, and later versions of this paper is going to explore the sensitivity of our results to some of the choices we have made.

We also plan to incorporate the remaining green house gasses and sinks in the EDGE model and repeat the analysis. We expect that this extension will lower the aggregate costs of reaching the Kyoto target, because of the availability of a larger array of low cost abatement possibilities as reported among others by Reilly et al. (1999). Whether it is going change the effects of the European proposal is less clear. But if emissions of the high potential green house gasses (HFCs and PFCs) increase faster than emissions of carbon dioxide in countries exporting hot air, the inclusion of these gases in the analysis may limit the amount of hot air and lower the costs of excluding hot air from the market.

Even more important may be the choice of baseline. The choice of baseline may have significant effects on the analytical results. Baselines with high emission rates report larger aggregate costs of the Kyoto Protocol than baselines with lower emission rates. And two baselines with different emission rates for particular countries have different demand and supply schedules of emission reductions and may change the effects of the European proposal. A large number of different baselines exist and each of these baseline reflects a specific perception of the world and its future development. But comparing the results from simulations using two different baselines - and maybe two different views of the world - can also provide deep insight into the game-theoretic aspects of the climate policy negotiations. This is next on our agenda.

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Appendix: The European ceilings proposal

The European proposal was presented by Germany on behalf of current and prospective EU member states at the June 1999 meeting of the Subsidiary Body in Bonn (Submission, 1999). The proposal defines concrete ceilings for the net purchase and net sale of emission permits for any Annex B-country. As the proposal is rather complex, it is instructive to see the text in its entirety and we cite below the wording of paragraph 2, where the concrete ceilings are defined:

> ***Para 2 Supplementarity***
>
> *Net acquisitions by an Annex B Party for all three Kyoto mechanisms together must not exceed the higher of the following alternatives:*
>
> *5% of:* $\dfrac{\textit{its base year emissions multiplied by five plus its assigned amount}}{2}$*,*
>
> *or*
>
> *50% of: the difference between its annual actual emissions in any year of the period from 1994 to 2002, multiplied by five, and its assigned amount.*
>
> *Net transfers by an Annex B Party for all three Kyoto mechanisms together must not exceed:*
>
> *5% of:* $\dfrac{\textit{its base year emissions multiplied by five plus its assigned amount}}{2}$*.*
>
> *However, the ceiling on net acquisitions and on net transfers can be increased to the extent that an Annex B party achieves emission reductions larger than the relevant ceiling in the commitment period through domestic action undertaken after 1993, if demonstrated by the Party in a verifiable manner and subject to the expert review process to be developed under Article 8 of the Kyoto Protocol."*

The demand side

On the demand side (net acquisitions) the proposal first defines two ceilings, which we call **D5** (5% of:...) and **D50** (5o% of:...). Each of the two ceilings determines a maximum number of permits to be acquired in order to meet the Kyoto commitment. They are easily computed as their calculation either relies on historical data that are already known (baseline emissions and assigned amounts) or on near future data that will be known well before the beginning of the commitment period (actual emissions in any year between 1994 and 2002).

An Annex B-country can freely choose the most favourable of the two ceilings, but is allowed to acquire further permits if the country can verify that domestic action after 1993 has been undertaken at least at the same level. This is the however clause, called **DH**. In short, the however clause allows any Annex B country to meet its abatement requirement **equally** by domestic abatement and import of emission permits. There is one important caveat, however. The Annex B-country must document the volume of domestic abatement in a verification procedure, that is still undefined. In this analysis, we simply assume that verified domestic abatement is any domestic abatement that reduces emission below the baseline emissions. How this assumption can be implemented in real life is a matter of future technical and political dispute.

In table 1 we present the demand side ceilings for four major regions in percentage of their assigned amount. Both the D50 and the DH ceiling are calculated on the basis of two different baselines: the default model baseline (EU 1999) and the 1998-version of the baseline from International Energy Outlook (IEO 1998). The default baseline of the EDGE model is the EU 1999 baseline assuming rather modest growth in European emissions. In contrast, the IEO 1998 baseline assumes European growth rates on par with the US growth rates. It is clear that especially the DH ceiling is heavily dependent on the choice of baseline.

Table 4: Demand side ceilings 2010, percent of assigned amount

	EU		USA		JPN		FSU	
	EU1999	IEO1998	EU1999	IEO1998	EU1999	IEO1998	EU1999	IEO1998
D5	5.2		5.2		5.2		5.0	
D50	6.3	8.4	14.2	14.8	7.2	9.8	Na	Na
DH	8.8	14.6	20.1	22.2	14.2	16.1	11.5	7.5

Note: EU2000 is the default baseline of the EDGE model. IEO1999 is the most recent baseline from International Energy Outlook 1999. For further presentation of the two baselines refer to appendix 2

We now turn to a brief exposition of the economic consequences of restrictions on the net purchases of permits. Obviously, the DH ceiling is the least restrictive ceiling and no country will be worse off by choosing the DH-ceiling as the relevant ceiling provided their level of domestic abatement can be verified. Consequently, in scenarios where domestic abatement exceeds 5o percent, there will be no binding restrictions on the demand for permits. This situation is more likely to occur, the faster emissions grow in the baseline scenario. If, however, domestic abatement is lower than 50 percent, demand side restrictions will be binding.

The economic consequences of a constrained equilibrium are illustrated in figure 5 for the world market (a), an importing country (b) and an exporting country with hot air (c).

Figure 5: The economic consequences of a demand side ceiling

[Insert figure here)

Figure 5a shows standard demand and supply schedules, where the world market permit price is P_F in the free trade equilibrium. When demand is restricted, the demand schedule moves from D_0 to, say, D_1. At the going price there is excess supply, and the price decreases to P_D to clear the market. As ususal the restriction gives rise to a dead weight loss (the grey triangle) being split between the buyer and seller and an income transfer from seller to buyer (the hatched rectangle) due to the lower price on all permits sold.

Figure 5b shows the marginal abatement cost curve (MAC) for a net permit importer with assigned amount K and baseline emissions in the commitment period corresponding to BAU. Initially, the country chooses to abate DA_F units domestically and import permits up to BAU. When import is restricted, permit import must decrease and domestic abatement increases to, say, $DA_{D.}$ The country experiences a welfare gain equal to the rectangular hatched area due to the lower world market price on all imported permits, but also a welfare loss due to the extra costs of abating domestically equal to the grey triangle. For limited restrictions on demand the latter may outweigh the former and, paradoxically, give rise to a net welfare gain for the restricted permit importer. For mere severe restrictions, the opposite conclusion holds. Ellerman and Wing (2000) as well as Criqui and Viguier (1999) give excellent account of these trade-offs.

Figure 5c shows that the permit exporter always loses, partly due to the lower price of permits and partly due to a lower volume of trade. The lower price of permits decreases domestic abatement as it is now less profitable to abate domestically and sell the released permits. Notice, that demand side restrictions have no impact on the sale of hot air unless total demand is reduced below the volume of available hot air.

The supply side

Now, turn to the supply side (net transfers). Essentially, we interpret the proposal as saying to any prospective exporter: Sell 5 percent of your assigned amount without any further complications OR sell whatever you desire provided you agree not to let any hot air come to the market.

The ceiling, S5, is completely analogous to the D5 ceiling on the demand side. But the however clause, SH, is *not* a ceiling, but rather a deduction requirement. SH allows for further export of permits provided verifiable domestic action after 1993 has been undertaken at least at the same level. But the pairing of export to domestic action is on the margin a trivial requirement as domestic abatement and permit export are natural complements. One extra unit of domestic abatement releases by definition one extra unit of permits for export, no more and no less. The key to understanding the SH clause is rather the verification requirement. Our interpretation is that the requirement excludes hot air from being put on the market as it may be hard to argue that hot air has been generated by verifiable domestic action after 1993. In this analysis, we simply define hot air as the difference between the assigned amount and the baseline emissions. How this assumption can be implemented in real life is again a matter of future technical and political dispute.

In table 5 we summarize the two restrictions on the supply side for the four major regions in percentage of their assigned amount, keeping in mind that only S5 is a ceiling, while the SH clause is better characterized as a deduction.

Table 5: Supply side restrictions 2010, percent of assigned amount

	EU		USA		JPN		FSU	
	EU1999	IEO1998	EU1999	IEO1998	EU1999	IEO1998	EU1999	IEO1998
S5	5.2		5.2		5.2		5.0	
SH	0	0	0	0	0	0	22.9	14.9

Note: S5-figures are ceilings on permit export. In contrast, SH-figures are deductions on otherwise unlimited export.EU1999 is the default baseline of the EDGE model. IEO1998 is the 1998 version of the baseline from International Energy Outlook. For further presentation of the two baselines refer to appendix 1.

It is clear, that exporting countries are faced with a real dilemma. Either they are allowed to export 5 percent of their assigned amount or about one fifth of their available hot air or they are allowed to export whatever they want, apart from the volume of hot air. For FSU this is estimated to about 23 percent of the assigned amount. In this account we assume that hot air permits cannot be banked.

The economic consequences of a binding ceiling on the supply side like the S5 clause is illustrated in figure 6 for the world market (a), an importing country (b) and an exporting country with hot air (c).

Figures 6a-c illustrates the economic consequences of a supply side ceiling. A binding ceiling creates an excess demand, driving up the world market price from P_F to P_S to clear the market as seen in figure 6a. There is still a dead weight loss to be split between sellers and buyers, but now the income transfer goes from buyer to seller.

Figure 6: The economic consequences of a supply side ceiling

[Insert figure here)

The higher price on permits induces the importing country in figure 6b to increase domestic abatement from DA_F to DA_S. The import country loses unambiguously from the higher price on permits acquired in the market and on the higher costs of domestic abatement. Domestic abatement increases induced by the higher opportunity costs of acquiring permits on the market. On the other hand, the exporting country realises a gain when the income transfer from higher prices outweighs the loss of revenue from the lover level of permits sold, and an economic loss when the opposite holds. The former is likely to hold when restrictions on supply are mild. Domestic abatement unambiguously goes down and hot air is only excluded from the market to the extent that the ceiling is lower than the amount of hot air.

The economic consequences of a restriction on the supply side like the SH clause is illustrated in figure 7 for the world market (a), an importing country (b) and an exporting country with hot air (c).

Figures 7a-c illustrates the economic consequences of a supply side deduction. The exclusion of hot air from the market, reduces at any price the supply of permits and drives up the market price from P_f to P_s as illustrated in figure 7a. There is still a dead weight loss to be split between sellers and buyers (the grey area) and an income transfer from buyer to seller (the hatched area).

Figure 7: The economic consequences of a supply side deduction

[Insert figure here)

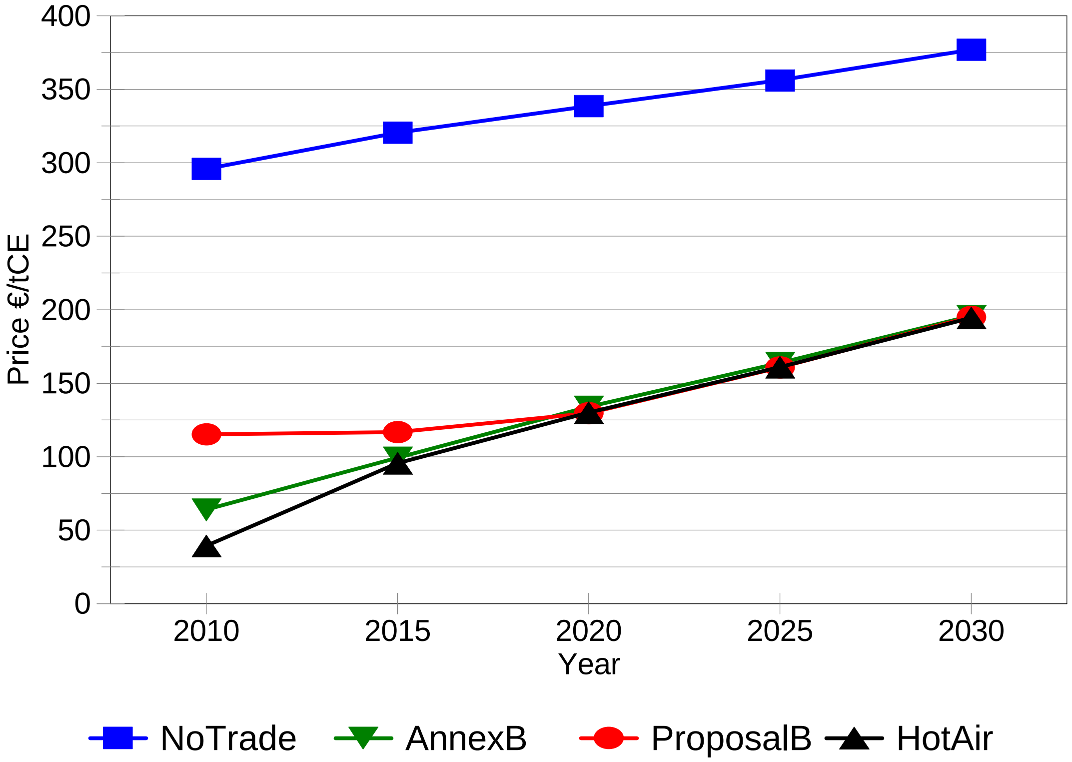
The higher price on permits induces the importing country in figure 7b to increase domestic abatement from DA_F to DA_S. The import country loses unambiguously from the higher price on permits acquired in the market and on the higher costs of domestic abatement. On the other hand, the exporting country realises a gain when the income transfer from higher prices outweighs the loss of revenue from the lover level of permits sold, and an economic loss when the opposite holds. The former is likely to hold when restrictions on supply are mild. However, in contrast to the supply side ceiling domestic abatement increases, because there is no upper limit on the export of permits provided hot air has been taken out of the market.

Table 6 summarizes the economic consequences of demand and supply side ceilings and supply side deductions.

Table 6: Summary of effects of demand and supply side restrictions on permit trade

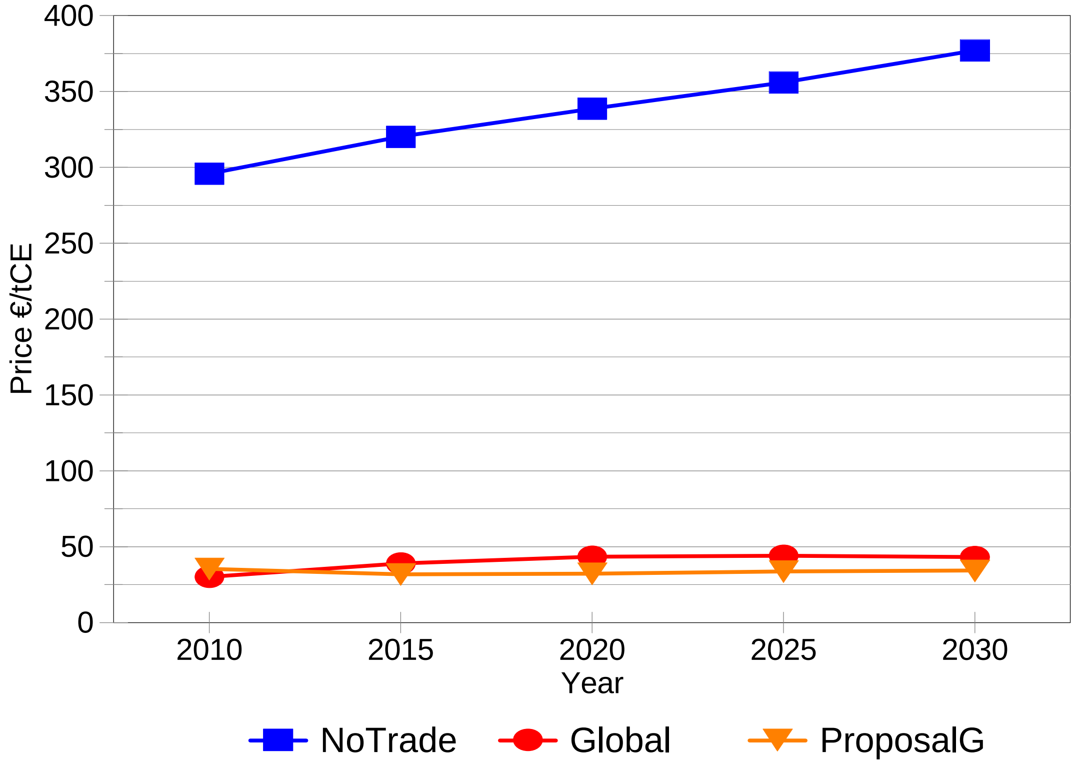
	World		Importer		Exporter		
	Price	Welfare	Abatement	Welfare	Abatement	Welfare	Hot air
Demand ceiling	-	-	+	+ / -	-	-	0
Supply ceiling	+	-	+	-	-	+ / -	0
Supply deduction	+	-	+	-	+	+ / -	-

Figure 1



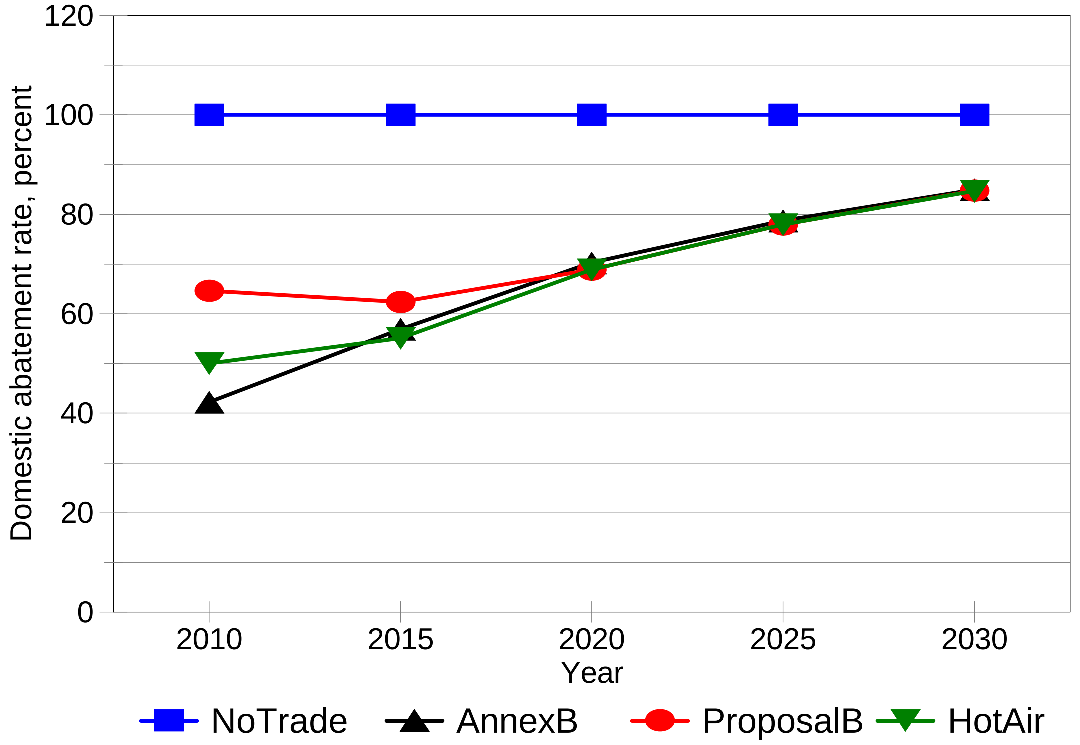
400
350
300
250
200
150
100
50
0
Price €/tCE
2010
2015
2020
2025
2030
Year
NoTrade
AnnexB
ProposalB
HotAir

Figure 2



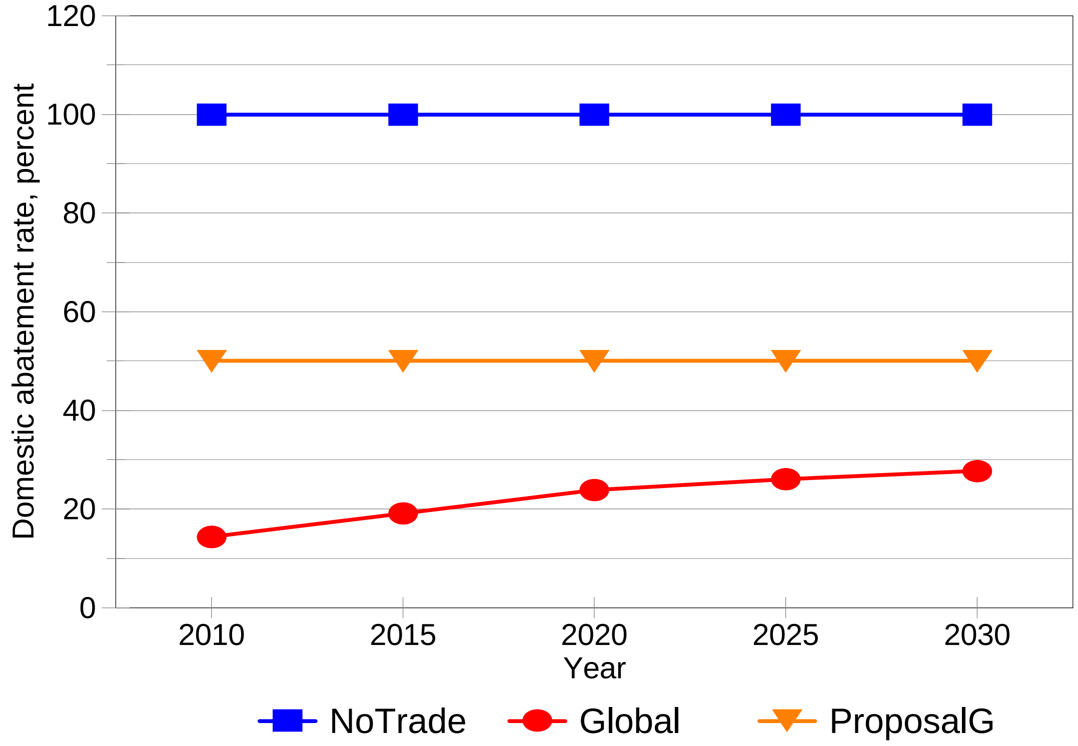
400
350
300
250
200
150
100
50
0
Price €/tCE
2010
2015
2020
2025
2030
Year
NoTrade
Global
ProposalG

Figure 3

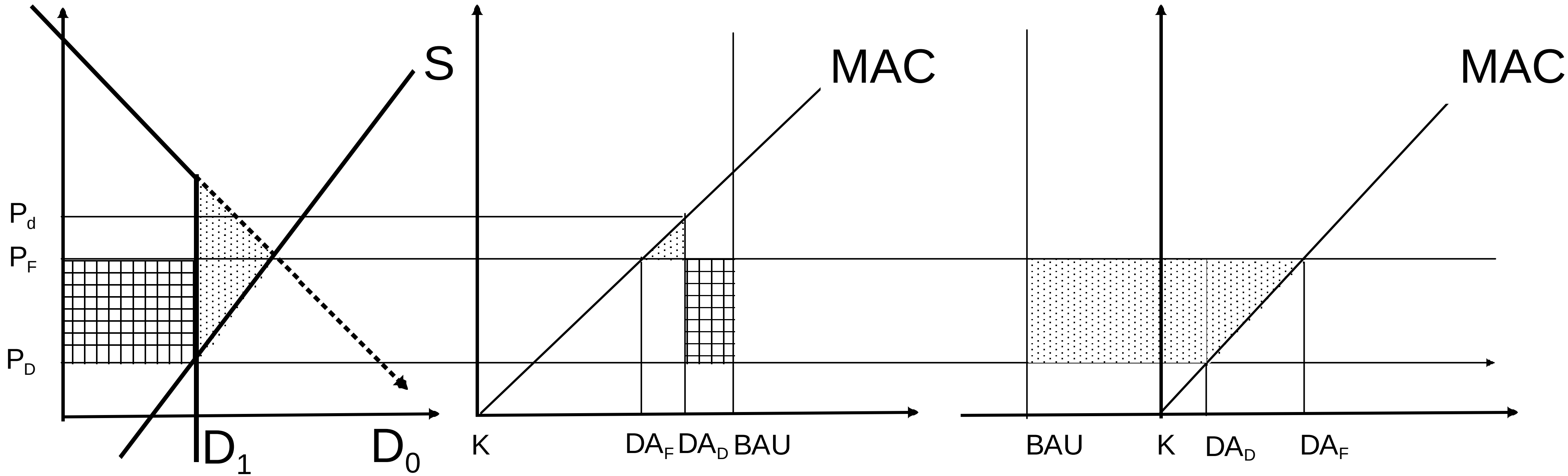


120
100
80
60
40
20
0
Domestic abatement rate, percent
2010
2015
2020
2025
2030
Year
NoTrade
AnnexB
ProposalB
HotAir

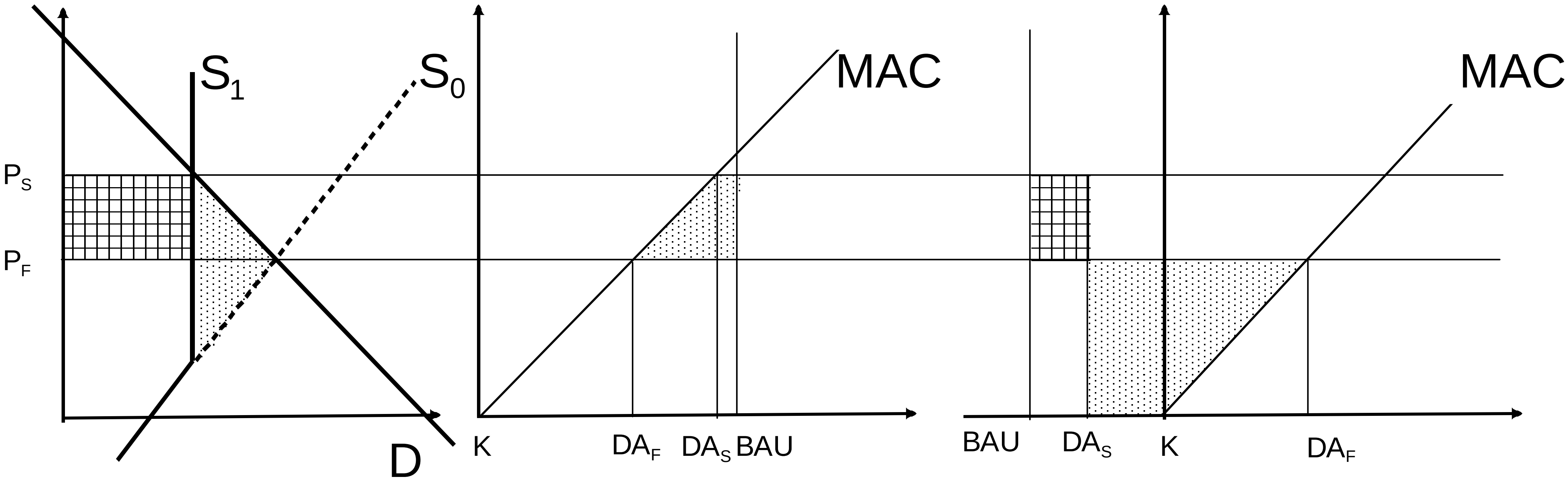
Figure 4



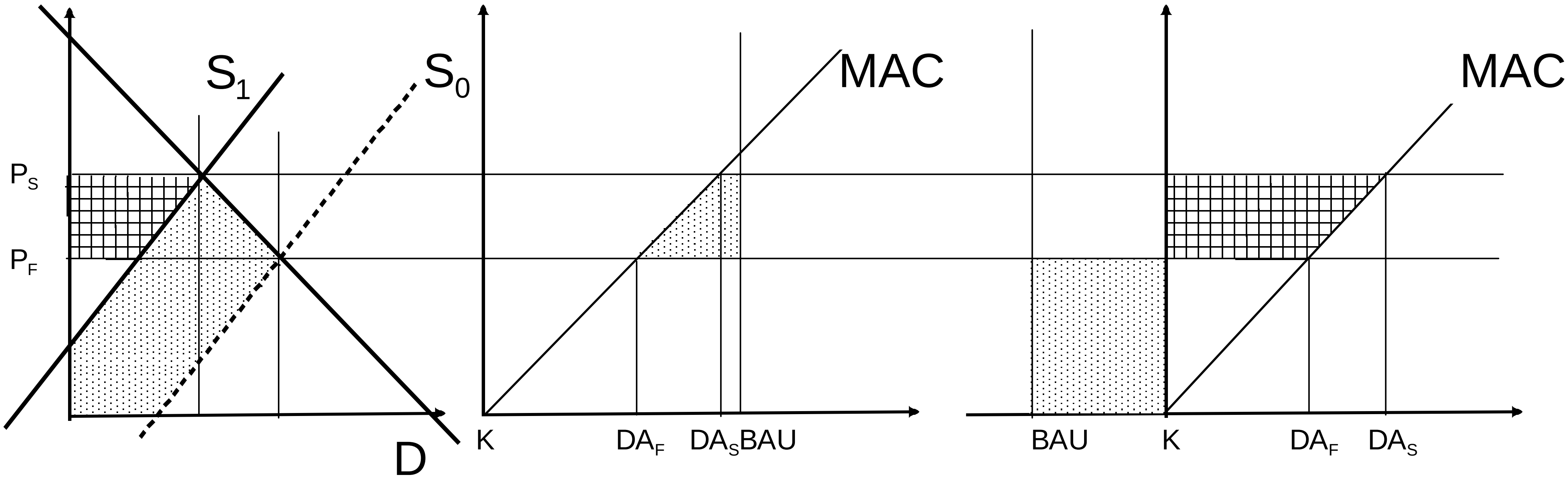
120
100
80
60
40
20
0
Domestic abatement rate, percent
2010
2015
2020
2025
2030
Year
NoTrade
Global
ProposalG



(a) World market (b) Permit importer (c) Hot air exporter



(a) World market (b) Permit importer (c) Hot air exporter



(a) World market (b) Permit importer (c) Hot air exporter