Curbing climate change

An outline of a framework leading to a low carbon emitting society

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Executive summary

The overriding environmental challenge of our time is climate change. In relation to Kyoto and beyond, humanity is facing some really tough choices. There is no such thing as a handful of simple short-term solutions. Economy, energy and environment are closely interlinked, so we have to realize that we are implementing a major shift in the world economy that will ultimately influence everything and everybody and that a long-term perspective must be applied stretching up to 100 years. Combating climate change must and will be a part of everyday life all over the globe.

In the article an outline of an adaptive burden-sharing model is presented. The model is based on the assumption than an overwhelming majority of all countries commit to participate in the system given that they will only face restrictions once the country is wealthy enough in relative terms. The long-term predictability and the flexibility needed for economic growth can

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thereby be sustained. Most important is that we start now by forming a burden-sharing model built on commitments to long-term reductions.

Up to now, business leaders in general have made a strategic mistake by letting politicians and NGOs handle the challenge mainly on their own. Looking forward, business and industry have to show leadership. Instead of being pulled by society, business leaders should be pushing and in a positive way integrate climate issues into the world of markets and trade on a global scale.

The article mainly covers three aspects of climate change policy:

- global burden-sharing
- the need for a global price on carbon dioxide emissions and how markets can contribute
- implementation issues

1. The challenge

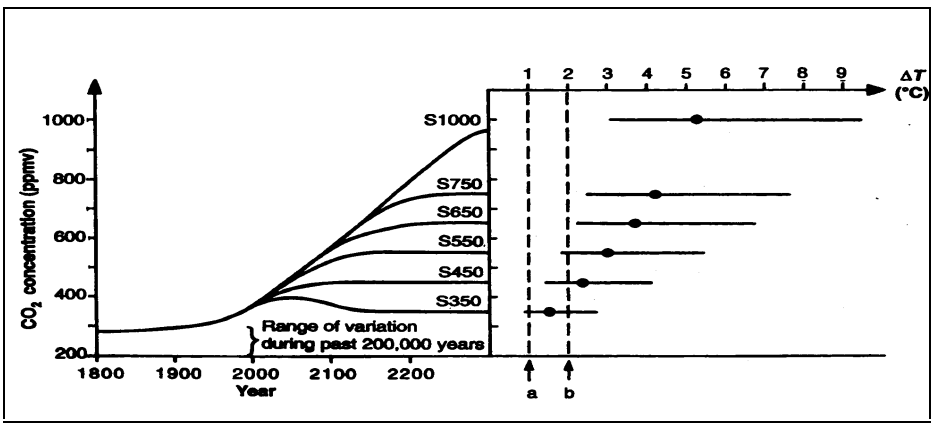
The overriding environmental challenge of our time is climate change. The problem originates from the emission of greenhouse gases, primarily carbon dioxide, mainly from the transport and energy sectors. If humanity fails to come to terms with this problem, we will be forced to make dramatic changes in the way we live our lives, but above all it will radically affect the lives of our children and grandchildren. The climate change issue is by its very nature global and long-term. This is something new. Previously, environmental problems have been short-term and local.

Total global emissions of greenhouse gases in 2000 amounted to 37 billion tonnes[2] of carbon dioxide equivalents, of which more than 23 billion tonnes carbon dioxide.[3] The trend is towards a dramatic increase, especially in countries that are experiencing rapid growth such as China and India. Carbon dioxide from combustion dominates. Studies show that an acceptable temperature increase and long-term temperature stability could be achieved at a concentration of 550 ppm of carbon dioxide equivalents in the atmosphere. But, we have to respect that this is the current wisdom, it

[2] Personal communication with Professor Christian Azar of the Institute for Physical Resource Theory at the Chalmers University of Technology, Spring 2005.
[3] Assessment made by Vattenfall. Based on IEA data regarding emissions 1990 and 1995.

may very well be necessary to revise this target downwards.[4]

Figure 1 Carbon dioxide scenarios and effects on the global average temperature



Source: science – vol. 276 – 20 June 1997 – www.sciencemag.org – Azar & Rodhe

Whatever the level, it is very clear that we must drastically reduce the current level of total emissions. If, in a hundred years time, the per capita emissions, including those of the developing countries, should be equalized at the same time as temperature stability is achieved, then a dramatic reduction in emissions from fossil fuels is required. Global emissions must be reduced by probably more than 50 per cent. During this period, the developing countries will increase their economic activity tremendously, so the presently industrialised countries will have to reduce their emissions by something in the range of 80 to 90 per cent. It is obvious, therefore, that we have a huge long-term problem on our hands.

The challenge is, however, not only long-term, it is urgent that we start acting now. At the same time, we must also ensure that the measures taken do not lead to unnecessary costs. The most pressing need is to create a credible, stable and predictable long-term framework defining how reductions will be achieved. Given efficient incentives, most parties in society can and will act in a rational and accountable way.

[4] In the latest material, even lower levels, 450 or less, are indicated as more realistic stability levels.

With the Kyoto Protocol, an agreement was reached to decrease the global emissions of greenhouse gases in the period 2008-2012 by at least 5 per cent below the 1990 levels. What will happen after this Kyoto period is still unclear, which makes long-term planning and investment decisions extremely difficult. Furthermore, the commitments under the Kyoto Protocol only apply to the industrialised countries (the so-called Annex I countries) that have ratified the Protocol. A number of countries with large emissions, most notably the USA, and fast growing economies such as China, do not face these restrictions. This is not a sustainable situation. When countries with commitments have to take measures their cost level, primarily for energy, will increase. If so, in the short term, energy-intensive industry will most certainly stop investing in these countries and, in the long term, companies affected will probably completely move out. The economic effect on the commitment countries will be substantial, while the environmental benefits will be very limited or even negative due to carbon-leakage.

Against this background, three issues are of outstanding importance. First of all, it is necessary to continue reducing emissions after the Kyoto period ends. Secondly, we must establish a long-term global framework that will provide governments, citizens and corporations with a stable and predictable environment. A framework is crucial to ensure that correct and relevant decisions are taken and that a sufficient reduction of greenhouse gases is achieved at the lowest possible cost to society. Thirdly, since greenhouse gas emissions are a global problem, all countries in the world must, in due course, accept emission limits and contribute to the solution.

The climate change issue is global and long-term. Drastic reductions must be made and in the long term global total emissions must be capped to a sustainable level, i.e. we must switch over to a low carbon emitting society. Emissions are closely coupled to economic activities. Real long-term global governance is needed. Is a common effort really possible? In this article we will discuss three important aspects of this challenging need:

- An outline of an adaptive global burden-sharing model
- The need for a global price on carbon dioxide emissions and how markets can contribute
- What is needed to implement a global market-based regime regarding carbon dioxide?

2. An outline of an adaptive global burden-sharing model

In this chapter an outline of a model for the global allocation of emissions is presented. The attitude is humble, the model including the calculations, has been developed with the intention of providing an illustration, and of inspiring further discussion by providing some food for thought. The results presented here rest on a number of high-level assumptions, based on other material. It should be underlined that these assumptions should not be seen as a prognosis of future development.

The allocation to each country in the outline primarily depends on the country's share of global GDP. In addition, developing countries will be phased in to the system and face emission restrictions once they have reached a certain pre-determined GDP threshold.

2.1. Overriding principles of the proposed emission allocation model

- All countries should participate – participation is a part of being a member of the global community
- No poor country shall be denied its right to economic development – no extra cost burden on the poorest
- No rich country shall have to go through disruptive change
- Richer countries pull a larger weight (emission caps do not embrace countries until they have reached a certain economic level; poorer countries with caps get higher allocations compared to richer countries)
- There shall be a level playing field. The proposed framework shall not change relative competitiveness
- The system shall be robust. As new knowledge is accumulated parameters may change, but not the principles underlying the system
- Emission caps should be binding
- Emission allowances are allocated to each country in relation to its share of global GDP (Gross Global Product)
- The final allocation to individual companies or facilities will be made at the national level
- The mechanism should be able to achieve wide acceptance as being fair and balanced

While the focus is on a long-term solution, the path as such is also important. Without disregarding the fact that some measures need to be taken also in the near future, it should be realised that enormous investments have already been made in carbon-emitting technologies. These investments often have a life span of several decades. Furthermore, technological development will probably mean that low-carbon technologies will gradually become available at a lower cost. This justifies not setting too severe requirements regarding early actions.

The allocation model allocates emission permits to each country in three steps:

First a global target cap is set to reach a specific carbon dioxide concentration level year 2100. The calculations presented are based on a 550 ppm CO_2-equivalent target. Whether this target is too lax, or too harsh, is beyond the scope of this work, but the same principles can be used for other target levels.

Secondly, the (assumed) emissions of developing countries that do not face any emission restrictions are deducted from this cap. Developing countries should not face restrictions on their emissions until they have reached a certain level of economic development. This is measured in terms of their GDP/capita quota. However, all countries should commit themselves from the start. Thus, individuals and companies in developing countries will, from the start, know that once a certain level has been reached activities in their country will also face restrictions.

Thirdly, the remaining scope for emissions is divided between all countries facing restrictions in a particular year in line with their share of total global GDP.[5] Countries poorer than average receive a higher allocation per unit of GDP, while richer countries receive a lower allocation per unit of GDP. The allocations have been calculated for every fifth year between 2015 and 2100.

In the model, all Annex I countries face emission restrictions from the first year (2015), while the non-Annex I countries do not face any restrictions until the country reaches 50 per cent of the average GDP/capita in the

[5] GDP is throughout this paper converted to US$ using purchasing power parity (PPP) and not market rates. PPP will generally better reflect actual physical production than if market rates were used. This choice has a clear effect. The GDP of China in 2002 was 1208.9 billion US$ (1995) using exchange rates, while it was 5197.4 billion US$ (1995) using PPP (US GDP would in both cases be 9196.4 billion US$).

Annex I countries in 2002. When the GDP/capita exceeds this threshold, the country begins facing emission restrictions and the allowances are calculated based on its share of global GDP. The poorest countries among the Annex I countries had a GDP/capita quota in 2002 that was about 25 per cent of the average in the Annex I countries, and it seems reasonable that also non-Annex I countries should be able to take on commitments at least when they have reached a GDP/capita level that is twice as high.[6]

For the non-Annex I countries, an assumed business-as-usual emission scenario has been used. This has been allocated to each country relative to its assumed growth in GDP. Eventually, all countries will face restrictions as their GDP/capita exceeds the determined threshold.

2.2. Adjustments

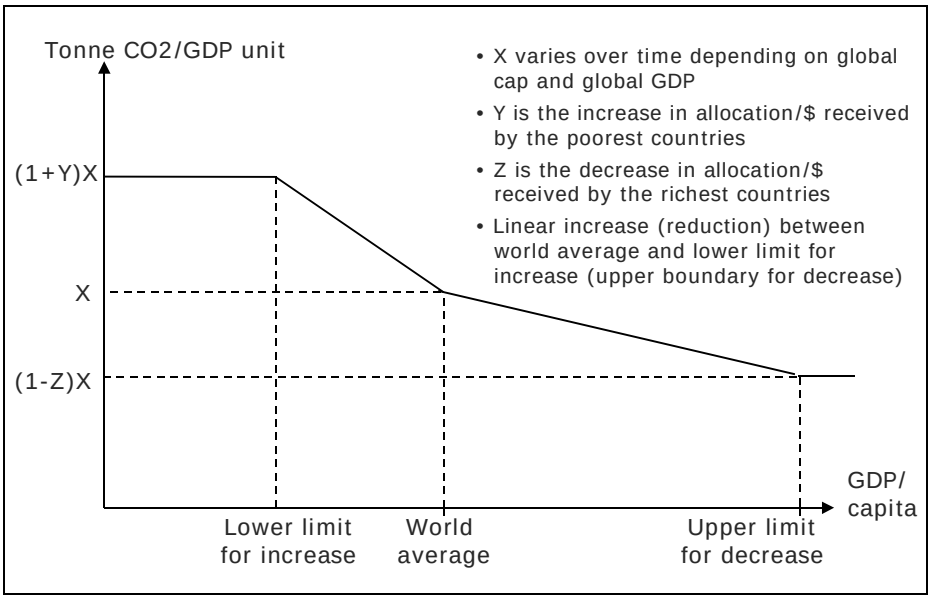
Countries facing restrictions but with a GDP/capita quota less than the world average are allocated up to 1.25 times extra emission allowances compared to a country at the average level.[7] The extra allocation increases linearly below the average GDP/capita and the maximum extra allocation is reached if the country has a GDP/capita that is equal or less than 0.5 times world average GDP/capita. In a similar manner countries that are richer than the world average receives less allocation/GDP unit. For countries with a quota twice, or higher, than the world average, the allocation/GDP unit is 0.9 times the allocation for a country at the average level. The declining energy intensiveness at higher GDP/capita levels is handled by means of this adjustment. Figure 2, below, illustrates those adjustments.

For the Annex I countries, two additional adjustment mechanisms have been applied. The first one sets a minimum level of reductions relative to the emissions in 2002, and the second one sets a maximum level of reductions relative to the emissions in 2002. In 2015, the minimum reduction level is 5 per cent, increasing to 15 per cent in 2035, independent of what the base model allocation is. After 2035, the restriction is kept at 15 per cent, although this restriction will not be binding in the long run as the total global cap is decreased, forcing all Annex I countries to make at least

[6] The poorest Annex I countries are countries such as Belarus and Ukraine that faced an enormous economic downturn following the collapse of the Soviet system. There are non-Annex I countries that have a clearly higher level of GDP/capita then these countries.
[7] Note that this first applies when a country has a GDP/capita above the set threshold, otherwise the country face no restriction on its emissions.

these reductions. The maximum reduction level means that no country has to reduce its emissions by more than 15 per cent in 2015, relative to 2002 levels, and this gradually increases to 55 per cent in 2045. Then the maximum speed restriction is lifted and the allocation is fully determined by the base model. The actual allocation to each country will be in the area between these two levels. As already stated, these two rules only apply for the current Annex I countries. The maximum reduction level is imposed primarily to allow existing capital to serve its lifetime. If this rule was applied to the developing countries that gradually qualify into the system, it would lead to perverse incentives to invest in particularly high-emitting technologies.

Figure 2. Description of the GDP based allocation adjustment mechanism



Note to (1+Y) X: The poorest countries do not face any restriction, see section 2.1

2.3. GDP over 100 years and population growth

In the model, GDP in Annex I countries is assumed to increase by a factor of six between 2002 and 2100. This is broadly in line with the average of the GDP projections in the scenarios presented by IPCC[8]. For the remaining countries, growth depends on an assumed convergence in GDP/capita towards the Annex I average. All countries are assumed to converge towards the average GDP/capita level in 2100. Full convergence has, however, not been assumed until 2100, but the relative differences are reduced to a considerable extent.[9]

There are no strong arguments for assuming that it is impossible for any part of the world to experience similar economic development to that seen in parts of Asia in recent decades and in Europe and North America in the centuries before that. Thus a rather high degree of convergence has been chosen as an assumption for the calculations made. Clearly, however, the projections used in the calculations should not be seen as a prognosis of the actual future development.

The population growth is based on the (unweighted) population assumption in the different IPCC scenarios, which were reported for four regions.[10] It has been assumed that the population growth is equal within each region.

2.4. Two scenarios

The mechanism is outlined with two different reduction path scenarios, labelled the early-peak and the late-peak scenario. Both these scenarios imply approximately the same accumulated emissions seen over the entire period in question (2015-2100). In both scenarios, the path towards the long-term target means a gradual decrease in emissions for the industrialised countries, while developing countries are allowed to initially increase their emission levels. This will mean that total global emissions will increase at first, and then decrease towards the long-term target. The early-peak scenario implies that the increase in total global emissions will be halted

[8] Data for the scenarios are available from the IPCC Data Distribution Centre.
[9] The poorest regions (countries) are assumed to have a GDP/capita that is 80% of the richest regions in year 2100. Currently, Africa has a GDP/capita that is below 8% of the GDP/capita in OECD North America.
[10] OECD90 covering the OCED member states in 1990, ASIA covering Asia, REF covering eastern European and former USSR and ALM covering Africa, Latin America and Middle East.

rather early in the future, around 2025, while the late-peak scenario implies that emissions are allowed to increase for an additional 15 years. Since the accumulated emissions are set to be approximately equal, this means that the emissions will have to be lower in the latter half of the period in the late-peak scenario compared with the early-peak scenario.[11] Both the target and the path in the late-peak scenario have been adjusted to reach the same accumulated emissions, about 1 600 gigatonnes CO_2 in the period 2015-2100.

2.4.1. The early-peak scenario

The long-term target is set to 12 000 megatonnes CO_2 in the year 2100, compared with approximately 24 000 megatonnes in 2002. This long-term target, together with the reduction path, is intended to approximate to the emission path of a 550 ppm CO2 equivalent target.[12]

The areas in Figure 3 represent the allocation between different regions[13], while the line is the global target cap.[14]

Figure 3 shows that China would be allowed to increase its emissions substantially until 2015. By 2020, the GDP of China is assumed to have grown sufficiently so that the country will face emission restrictions. After 2025, China would have to start reducing its emissions towards its long-term target. Since the developing countries do not face any restrictions before their GDP/capita exceeds the threshold, they are in practice allowed to increase their emissions to begin with. There is obviously a risk that they will invest in high-emitting technologies, creating the same adjustment problems that we are facing in the industrialised world.

[11] No attempt is made to judge whether the chosen target concentration level is sufficient or not in terms of acceptable climate consequences. The reason for choosing this target level is that it is viewed by many sources as reasonably ambitious. A 550 ppm carbon dioxide equivalent level is expected to result in a temperature increase excessing the EU target of 2 degrees Celsius.

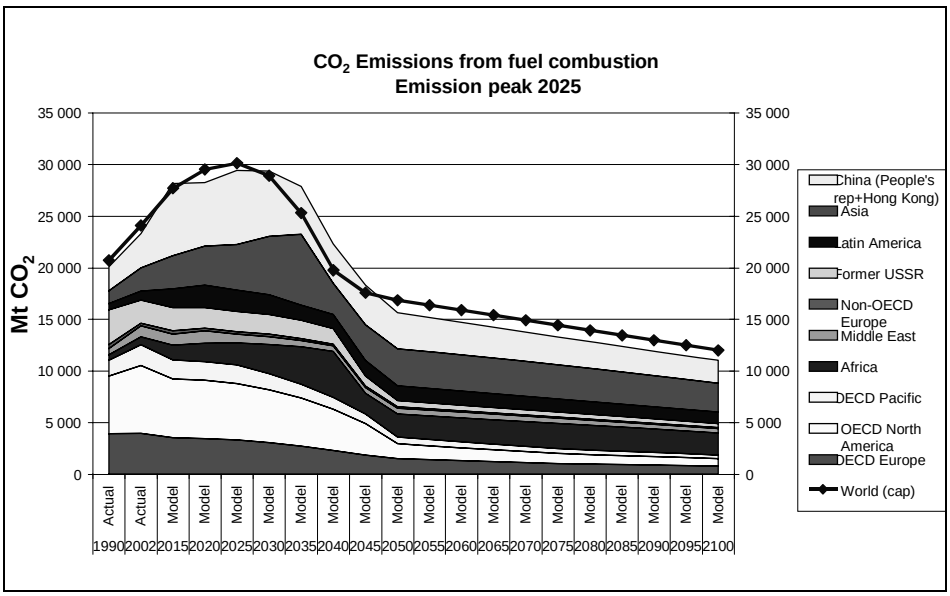
[12] Only CO_2 from fuel combustion has been included in the calculations made. The emission levels presented here is thus lower than if all greenhouse gases were included. The CO_2 emissions from fuel combustion represent about 80% of total greenhouse gas emissions in Annex I countries (in 2002) and about 60 per cent of global greenhouse gas emissions. Source: IEA, CO_2 Emissions from fuel combustion, 2004 edition.

[13] The regions follow the division used in IEA (2004).

[14] Due to the different adjustment mechanisms described above, the actual allocated emission permits will not exactly add up to the target cap. It would of course be possible to make the model more complex in order to solve this problem, but since the purpose of these calculations is to provide an illustration for a discussion on principles and the degree of precision is not that high, it is not meaningful to conduct such an exercise. The total allocated emission permits and the sum of the emissions according to the target cap over the period 2015-2100 are also almost identical.

A development in that direction must be avoided. For this reason it is of vital importance that all countries enter into the agreement at the start, even though some will not face any restrictions to begin with. A pre-commitment will send a clear and strong signal to investors, and presumably also affect policy choices at an early stage. This is likely to affect investments from the start, and reduce the risk that developing countries invest in high emitting technologies. It is quite possible that it will result in less CO_2-intensive investments and thus lower emissions in the period up to 2015 compared with a normal business-as-usual scenario. For the USA, the imposed restriction on the maximum speed of emission reductions allows the country to continue with its relatively high level of emissions for a period. Germany and Japan will be affected neither by the maximum nor the minimum restriction. Their allocations will be determined by the basic mechanism.

Figure 3 Allocation of emissions - early peak



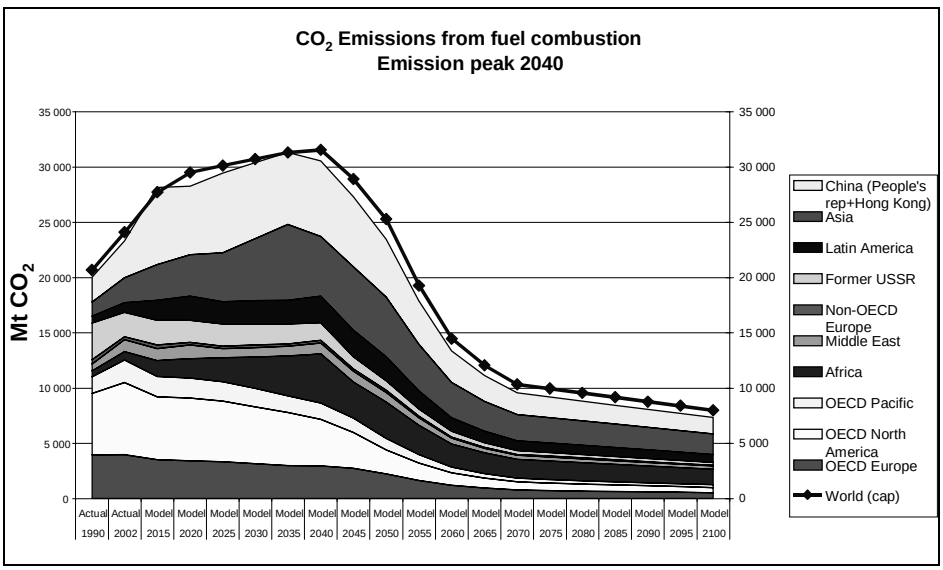
In the long run, the emissions per GDP unit converge for all countries. Furthermore, as GDP/capita is assumed to converge the emissions per capita will also converge in the long run. This will result in a more equal distribution of the emissions between different regions. Today, non-OECD Asia (incl. China and Middle East), Africa and Latin America only account for about 35 per cent of the global emissions of CO_2 (from fuel

combustion) while about 75 per cent of the world population live in these areas. At the same time, North America and OECD Europe are responsible for over 40 per cent of the emissions, while only about 15 per cent of the world population live there. According to the proposed model, this division will gradually become more equal towards the end of the period (2100). North America and (current) OECD Europe will only be allocated about 12 per cent of the global cap, while the above-mentioned developing regions will be allocated about 72 per cent of the global cap.

2.4.2. Late-peak scenario

The late peak scenario implies that all countries that face restrictions will be awarded a (non-strictly) higher allocation up until 2060 and a lower allocation thereafter, compared with the early-peak scenario. The long-term target is consequently reduced to 8 000 megatonnes in 2100. The fact that the reduction in the level of emissions comes later in the late-peak scenario, i.e. that a larger share of the total emissions comes early, has some effect on the climate, although the difference is likely to be fairly limited since it is only a matter of a few decades. Guesswork based on IPCC material indicates that the effect will be minor and it has been judged negligible in comparison to the overall uncertainties in the calculations made. Consequently, no compensation is made for this effect.

Figure 4. Allocation of emissions - late peak



A late peak will primarily benefit the countries that have relatively high emissions in the first half of the century, i.e. industrialised economies and fast growing economies (newly industrialised countries and some developing countries). Some poor countries, which first start facing restrictions on their emissions in the latter part of the century, will, however, not directly reap the advantages of higher allocations in the first half of the century, but will receive lower allocations in the latter half.

2.4.3. A comparison between the early-peak and the late-peak scenario

The differences between the two scenarios hardly affect the USA at all. This is due to the fact that the restriction on the speed of adjustment protects the USA from too drastic reductions in the first half of the period. This restriction is not completely lifted until 2045, and determines the allocations for the USA up until then in both scenarios. The late-peak scenario gives the USA slightly higher allocations in the period 2050-60 and a slightly lower allocation thereafter. The maximum reduction speed for high-emitting countries will primarily be set by the adjustment mechanism rather than the timing of the global peak.

The late-peak scenario will, however, shift the reduction requirements quite substantially for a few developing countries. From the figure it is quite clear that China, India and Brazil will be allowed to continue with relatively high emissions for a longer period of time, but will have to make larger reductions in the future. A similar pattern will be the case for all countries facing restrictions fairly early in the century (i.e. Annex I countries, newly industrialised countries, and fast growing developing countries).

The speed of reductions does not only affect the timing, but also the total accumulated emissions over the entire period for individual countries. As shown in Table **1**, fast growing developing countries and newly industrialised countries seems to gain most from the late peak, while these selected industrialised countries (Annex I) lose in the sense that their accumulated emissions over the period will be lower[15]. The explanation is that the fast growing developing countries and newly industrialised countries are allowed to increase their emissions for a longer period of time in the late peak scenario. As mentioned above, the industrialised Annex I

[15] The countries presented in the table are chosen to indicate the effect for different types of countries, with different levels of emissions, GDP level and growth, etc.

countries are protected in the early-peak scenario from too drastic reductions, and the main effect of the late-peak scenario for these countries is that the emissions in the latter half of the period will have to be reduced even further.

Table 1. Accumulated emissions for selected countries

Countries	Accumulated emissions in early-peak scenario	Accumulated emissions in late-peak scenario	"Gain" from late peak	% "Gain"
China	348 056	363 552	15 495	4.5 %
Tanzania	3 432	2 963	- 469	- 13.7 %
Iran	25 104	26 295	1 191	4.7 %
Brazil	67 657	70 855	3 198	4.7 %
South Africa	17 747	18 577	830	4.7 %
India	194 612	203 753	9 142	4.7 %
Poland	10 526	10 449	- 77	- 0.7 %
USA	170 582	166 271	- 4 311	- 2.5 %
Sweden	2 590	2 489	- 101	- 3.9 %
Korea	15 673	16 862	1 189	7.6 %
Mexico	25 386	26 879	1 493	5.9 %
Germany	31 459	32 086	627	2.0%
Japan	30 524	31 437	913	3.0%
Total above	**943 348**	**972 469**	**29 121**	**3.1 %**

2.4.4. Concluding remarks on the burden-sharing outline

We have tried to outline a burden-sharing model that both results in a practical and acceptable way of reducing global emissions and at the same time creates a stable and predictable environment for governments, individuals and corporations. It is based on the belief that this can be achieved by setting long-term rules that all parties are prepared to accept, and that these rules should include commitments to reduce emissions. Different methods can be used to achieve these reductions.

It is our belief that a GDP-based mechanism has the best chance of being accepted by different countries. For a given level of global emissions, it will not force the industrialised countries to commit to unreasonably large reduction, but at the same time it will give all countries similar opportunities to grow – especially since poor countries do not face restrictions at the start. This also means that if the GDP/capita quotas converge then the allocation of emission permits per capita will also converge, thus giving equal entitlements to everyone.

In the ongoing discussion on allocation, several different approaches have been identified.[16] To what extent is our outline in line with these approaches? To begin with, our proposal clearly follows the multi-stage approach, since we suggest that countries should "qualify" into the system when they reach a certain pre-determined threshold. All countries should, however, commit *ex-ante* of doing so. To some extent the proposal also follows the contraction and convergence approach, although the convergence towards equal per capita allowances depends on the assumption of convergence in GDP per capita. This means that our proposal provides a possibility of meeting the equal entitlements principle in the long run. The outline also has the potential to lead to equal mitigation costs, although not necessarily as a share of GDP. Given that the right instruments are used to reach the targets, we can however achieve equal marginal mitigation costs, and thus cost efficiency. This also means that the actual emission reductions will take place where the opportunities are best. High emitting economies also have to make larger reductions and thus take on a larger share of the total burden, which in practice means that wealthier countries will take on a larger burden.

[16] In our report (see note 30) we discuss six different approaches for burden sharing schemes. These are the multistage approach, contraction and convergence, the Brazilian proposal, ability to pay, the triptych approach and the equal mitigation cost approach. These issues are also discussed extensively in Wrang and Busk (2005).

The proposal outlined here can clearly not satisfy all the, partly conflicting, views on fairness.[17] But no other proposal can do that either. What is important is that this proposal has the potential of allocating the burdens in a way that is acceptable to most, or hopefully, all parties. For a given level of global emissions, it will not force the industrialised countries to commit to unreasonably fast reductions, but at the same time it will give all countries similar opportunities to grow – especially since poor countries do not face restrictions at the start. In the long run, it is also necessary that it will be more attractive to be a part of the system then to stay outside. Given the establishment of an international system, each single country's relation to this system will be a new and important part of that country's role in the international community.

It should be noted that the adaptive nature of the model in combination with a long time span and uncertainty about the future development of GDP (both regarding the total amount and its distribution) and the global population will lead to special demands on how the emission allowances must be constructed. The total emissions allowed for a specific year will be set by the global cap, but how this total amount is allocated among countries depends on how their economies and populations develop in relation to each other. This is of course a complication but, on the other hand, it is not more complicated than the present state regarding already ongoing international trade in currencies. The implementation of our model will to a great extent have to be built on forecasts regarding GDP development and population growth on country level. Employing an envelope curve as well as opening for checkpoints (i.e. international re-negotiations) say year 2025, 2050, 2075, can level out short-term variations.

The most important issue is the robustness of the method, not the calculations as such. Two conditions must be fulfilled; the climate change effects must be acceptable (and that is in the end due to global policy commitment achieved) and the short-term economic consequences must be acceptable to all countries. The calculations made indicate that an adaptive model built on a long-term target is an interesting clear-cut alternative to the present short sighted Kyoto accord.

[17] Different views on fairness are further discussed in our report (see note 30). See also Wrang and Busk (2005) for a discussion of fairness with regard to climate change policies.

3. How can the need for a global price on carbon dioxide be met?

Given an international burden-sharing agreement, with allocation based on each country's share of global GDP, policy measures must be taken to fulfil the national commitment. It is likely that these measures, at least to some extent, will be a matter of national policy. At the same time, as countries are mutually dependent, too large differences may lead to an undesired outcome. As already said, commitments made only by some countries are likely to result in unacceptable long-term effects. Similar problems, although probably to a lesser extent, may arise due to differences in national policy.

The implementation of a policy to reduce emissions of greenhouse gases, and as well as any other policy, includes two fundamental questions. The first relates to ways and means of achieving the goal of the policy in the most efficient way, i.e. an efficiency issue. The second is a distributional issue – how should the costs and the benefits of the policy be divided?

Economic instruments generally provide the best means of achieving emission abatement at the lowest possible cost, i.e. of achieving a cost-efficient solution. Such instruments put a price on the emissions and create the same incentives for all parties to reduce emissions, in practice the burden will also be shared among different parties in society.

The possibilities for abatement differ between countries so international trade aspects are important. Virtually all traded goods will consist of a carbon dioxide component. There is thus an obvious risk that countries implement different measures that will seriously distort trading patterns. The result will be an increase in the total cost of achieving the necessary emission reductions. Therefore, it would clearly be beneficial if the instruments implemented facilitated cooperation, exchange and global cost efficiency.

The choice between a system with tradable emission allowances or taxes may from a formal perspective not be of crucial importance. In principle, these two instruments represent a choice between using the price (taxes) or the quantity (emissions trading) as the primary target. If taxes are used, the "price" is essentially fixed, while the market determines the actual quantity. If an emissions trading system is used, the quantity will be fixed and the market determines the price. In a deterministic world, regulation based on either prices (e.g. taxes) or quantities (e.g. tradable permits) can yield the economically efficient outcome. The theoretical properties of tradable

permits and environmental taxes are to a large extent similar. But in the non-deterministic real world, the differences may be striking. With a quantity limit, the primarily responsibility for finding the right price is handled by the market, not the government. With a tax system, the government must find the appropriate tax rate and also adjust the taxes for inflation and other changes.

From a theoretical point of view, the optimal choice generally depends on the degree of uncertainty and the correlation between the marginal damage and the marginal abatement costs (MAC).[18] With uncertainty about costs, the different policies may lead to different outcomes. Taxes are preferable if the environmental damage is flat relative to the marginal abatement cost curve[19] and the lack of a clear, short-term threshold for severe climate changes also favours the use of taxes.[20] However, a steep marginal damage curve instead favours the quantity approach, since this implies a threshold that should be avoided. Many claim that the marginal benefit curve for emission reductions is relatively flat,[21] which then would favour the use of taxes. This may very well be true looking at the problem from a national perspective.

Taking a global perspective there are, however, thresholds that should not be exceeded. The possibility of a catastrophic development, which cannot be ruled out in this case, speaks clearly in favour of using a quantity-based instrument.[22] The possibility of banking also strengthens the arguments for quantity policies, since banking across a period make these more flexible and efficient. With full banking and borrowing across all periods, quantity control will behave much like a price control mechanism and quantities rather than marginal costs will fluctuate between years.

One possibility that has been discussed is using a safety valve, i.e. a mixed regime.[23] By putting a cap on permit prices, risk-averse firms and

[18] Weitzman (1974). Climate change is related to the stock of greenhouse gases and the flow (yearly emissions). Weitzman (1974) looked at the problem from a static point of view, but costs and benefits are not only a function of current output. Newell and Pizer (2003) study the optimal regulation of stock externalities under uncertainty. Like Weitzman (1974), they find that flatter marginal damage and steeper marginal costs curves favour price instruments and applied to the problem of green house gases policy they find that the use of price instruments dominates the use of quantity instruments.
[19] Weitzman (1974), Hoel and Karp (1998).
[20] Hoel (1998) and Pizer (1997).
[21] Nordhaus (1994), Kolstad (1996), and Pizer (2002).
[22] Pizer (2003) studied the effect on the optimal policy choice with the possibility of such a catastrophic development. As expected, the results suggest that quantity instruments may be preferable.
[23] Smith (1999).

households can more easily be convinced and the potential welfare losses from over- or under-estimates of marginal abatement costs can be reduced.[24] In practice, the possibility of banking seems to be more important than a safety valve, especially since, on a global basis, we need to make the necessary long-term reductions.

3.1. Climate change – an international problem demanding international solutions

There are strong arguments from the perspective of political feasibility, global cost-efficiency and the certainty of reaching the necessary reductions for using emissions trading on a global basis. Some arguments are in favour of using taxes as an economic instrument to create incentives for emission reductions. These arguments are however most valid in a national context. Climate change is not a national problem, and the solution cannot be national. Both the efficiency and the political feasibility of different systems in a global perspective must be taken into account.

For instance, within the European Union tax policy is primarily a national issue. Discussions about common (minimum) tax levels have been going on for a long time and these have, for better or worse, not had much result. Implementing a common carbon tax would in this perspective probably have been much more problematic than implementing a common emissions trading scheme. In a global context, it seems even more unlikely that a global carbon tax scheme can be implemented. The use of emissions trading provides a possibility to achieve cost-effective emission reductions at an international level. Even if the formal reduction requirements differ between countries, trading can ensure that these reductions are made at the lowest possible cost.

Curbing greenhouse gas emissions seems to be particularly well suited for emissions trading.[25] The locations of the emissions are unimportant and an international trading system is therefore possible from an environmental point of view. The opportunities for cost savings are furthermore greater when the abatement costs differ more. There are strong reasons for believing that the costs of reducing greenhouse gas emissions vary widely among sources (and countries) and the cost savings will thus be larger the

[24] Roberts and Spence (1976).
[25] This is, for instance, suggested by Ellerman, Joskow and Harrison (2003).

wider the trading scheme is. International trade can thus provide the flexibility needed to achieve the lowest-cost abatement options. This is a very important argument in favour of forming a common system.

3.2. Experience from the European Emissions Trading Scheme

The emissions trading system that the EU introduced on 1 January 2005 utilises market forces. The price prognosis for the emission allowances, before the system was introduced in January 2005, varied substantially from levels of €5/tonne carbon dioxide up to €20/tonne or more. Pre-trade, although very thin at the beginning, has been going on since early 2003. In the second half of 2004, prices seemed to have stabilised around a level of €8/tonne. In mid-January 2005, prices dropped below €7 for a short while, before starting to rise again. During the spring, prices rose fast and in July trades at prices above €30 were recorded, By the beginning of August prices fell below €20 before starting to rise a little again to levels around €23-24. At the time of writing this article (January 2006), prices have fallen slightly again. One clear conclusion can be drawn from this. There are huge uncertainties about the price level for emission allowances. This was the case before the system was launched and is still the case.

There are many reasons for the price uncertainty. It is very difficult to assess how large the emission reduction needs to be. The number of allocated emissions is of course well known, but the real business-as-usual emission level is very uncertain. It is affected by factors such as economic development and the weather. Small errors (in relative terms) in the predictions of the business-as-usual levels can result in very large changes (still in relative terms) in the requirement for emission reductions. Better information will first become available when the official statistics on actual emissions during 2005 are published, which is expected in the second quarter of 2006. Better transparency and faster reporting and publication of emissions are likely to improve the functioning of the market.

The costs of emission reductions are not very well known either, which creates uncertainties about the supply. Furthermore, fuel price developments are important. Rising gas prices mean that fuel switching from coal to gas in the power sector needs much higher prices of emission allowances to be profitable. During 2005, gas prices have risen much more than coal prices, which is primarily caused by the fact that gas prices are often linked to oil prices through contractual arrangements. The effect that

this has had on the possibilities for fuel switching, and thus on the prices of allowances, during 2005 is substantial.

The prices for emission allowances have been much higher than expected in beforehand. As a consequence the price effects on electricity are also greater than expected. This obviously has an effect on the competitiveness of the industries in Europe that use electricity as a vital input.

One additional important issue is that the allocations for future periods are not yet determined. Uncertainties about whether emission reductions will now decrease future allocations may limit the willingness to reduce the emissions now and sell allowances. This is likely to provide an upward pressure on the prices of the emission allowances.

The European emissions trading scheme is still at an early stage, and the market is still far from perfect. Many potential market participants have yet to enter into the market place. This is at least partly due to the fact that the institutional set-up, such as the finalisation of the national allocation plans and national registers, has been delayed in some countries. This naturally limits the possibilities for many players to enter into the market.

Prices have also been very volatile, reflecting the high degree of uncertainty and the lack of transparent information to market participants. Improvement in the basic information provided to the market participants is very important to create a more stable market.

At the moment, the European emissions trading scheme has three fundamental weaknesses. Firstly, it is very short sighted. The trading system only defines the periods 2005 – 2007 and 2008 -12. The lacking banking possibilities strengthen the problem with a too short time perspective even further. Secondly, it is limited to the EU countries. The short trading periods and the narrow geographical scope limits the possibility to invest in low cost abatement technology. The energy costs within EU 25 are increased. This is a major competitive disadvantage for industrial operations that use a lot of electricity, and there is a clear risk that European industry will reallocate to other parts of the globe if the rest of the world declines to adopt reduction targets that add costs to fossil fuel users. If this happens, it is unlikely that the EU's emissions trading system will survive. This would be an enormous setback. Thirdly, the present system covers less than 50 per cent of the total carbon dioxide emissions in EU 25. In the slightly longer

term of course, all emissions must be included, especially those in the transport sector.

3.3. Conclusions

Economic instruments provide the best means of achieving emission abatement at the lowest possible cost. International trade aspects are important; the instruments implemented should facilitate cooperation, exchange and global cost efficiency. In the real, non-deterministic world systems built on tradable permits are judged superior to taxation. Strong arguments are political feasibility, global cost efficiency and the certainty of reaching the necessary reductions. Curbing greenhouse gas emissions seems to be particularly well suited for global trading. The locations of the emissions are unimportant and the opportunities for cost savings are substantial due to differing abatement costs.

4. Implementation - what must be done?

We[26] have to *realize* that there is no such thing as a handful of simple short-term solutions; we have to *realize* that handling the issue on a global scale will take time. Economy, energy and environment are closely interlinked, so we have to *realize* that we are implementing a major shift in the world economy that will ultimately influence everything and everybody and that a long-term perspective must be applied stretching up to 100 years. Combating climate change must and will be a part of everyday life all over the globe. Climate change is a global issue that has to be handled at the global level; solutions and initiatives are needed for both local and global growth.

Regimes and structures for global governance are, unfortunately, in short supply. It is now high time to take action and shoulder responsibilities on this crucial issue. Even though climate change is a global problem, we all have a responsibility to do what we can to contribute to a solution.

[26] Humanity.

At present, the situation regarding climate change, the future of UNFCCC[27], Post-Kyoto, the US – EU relations, the role of the growing economies among the developing countries (China, India, Brazil, South Africa, Mexico) is fairly confused. We note that at the G8 meeting in Gleneagles in July 2005 the leaders of the largest economies clearly stated that the world faces "…serious and linked challenges in tackling climate change, promoting clean energy and achieving sustainable development globally."

No solution is possible if not the entire, or at least most of, the world economy is included, the Gleneagles statement can serve as a platform for a renewed global dialogue.

In this article an adaptive burden-sharing model is suggested. It is based on the assumption than an overwhelming majority of all countries can be convinced to commit themselves to participate in the system on the understanding that they will only face restrictions once the country is wealthy enough in relative terms. The long-term predictability and the flexibility needed for economic growth can thereby be sustained. Agreeing on and implementing a common global system will take time. The most important thing is, however, that we start now by forming a burden-sharing model built on commitments to long-term reductions.

We must do all we can to set the correct price on emissions and the pricing must be as global as possible. The only possible way to do this is to make use of market forces, i.e. a global system for emissions trading must develop. Pricing will create the financial resources needed. If emissions are priced properly and the price formation process is trustworthy, i.e. it mirrors market fundamentals, it will be much easier to motivate as well as finance what each single player out there can do. The price has to be global. Otherwise, we will see a lot of second-best solutions and the comparative advantages will not be exploited. Market forces are driving the globalisation process and are some of the most powerful tools in our hands. Used in the right way, they will help to minimise the consumption of resources and provide the best distribution of labour around the globe. An important prerequisite for such a positive development is that there is a global framework of regulations.

Emissions trading in Europe as it is conducted today is limited in many respects. Getting a majority of the world to participate in an emissions

[27] The United Nations Framework Convention on Climate Change.

trading system is therefore vital. The disputes surrounding the Kyoto Protocol must become a thing of the past. Prestige must be laid aside. The USA and the EU have a responsibility, as the regions that release most emissions of carbon dioxide, to show joint leadership. What we need here is a reasonable and generous compromise between the developing countries' demand for fair development conditions and the industrialised countries' demand that competition throughout the world must not be distorted. It is much more important to get everyone to take part than to focus on short-term emission limits.

The emissions trading system will not be sufficient on its own to solve the problem, but it is a tool for creating the incentives for actions that will result in solutions. Investments in research and development must be focused and significantly increased in order to produce new technology that can replace or radically improve current methods for transportation and the generation of energy. Prices are fundamental market signals and time will give results. Costs will be limited by the technology available for reducing emissions to the desired level. Greater investments in research and development will accelerate technological development. This is obviously a joint responsibility on the part of the political and industrial spheres. We must be open to the use of all available technology in this process. The most important technological development of the next few decades will probably be to achieve sequestration, i.e. to capture and store the carbon dioxide produced in connection with the combustion of fossil fuels. Nuclear power, present and future, will also be a part of the solution. Of course, all the various forms of renewable energy must be used. The transport sector will gradually complete the transition to emission-free engines, probably via hybrid vehicles to fuel cells that use various fuels. Efficiency levels will be up as a consequence of clear market signals.

The introduction of a global regulatory framework will present many business opportunities. This will stimulate the formation of new industries with new workplaces. It will be possible to exploit the market system to the advantage of the environment. The costs of solving the problem will have only a marginal effect on total global growth if price signals and markets are employed in a wise way. Even more important, given that we have a real and serious problem to solve, not taking action will add costs. Being forced into managing recurring crises will definitely be more costly than introducing effective market-based incentives in due time.

Curbing climate change is about combining technology, finance and policy in a wise way. If that is done a worldwide carbon dioxide market will follow. Technology is not an unsolvable problem, given time and incentives, neither is financing. The real challenge is policy. Will it really be possible for policy makers to get their act together in due time? To be very short, there are no alternatives if humanity should be able to curb climate change.

The climate change issue has been compared with the issue of free trade. Free trade has developed gradually since the end of World War II and has still not reached a state of full openness. The same goes for the climate change issue: we are still in the initial stages of dealing with a major problem to which solutions will be developed gradually over the next few decades. We can easily identify threats, but we can also see opportunities, and without being over-optimistic, surely we will see most of the latter given that wise political decisions are made.

An issue of outstanding importance is the future role of the international business community. Up to now, business leaders in general have made a strategic mistake by letting politicians and NGOs handle the challenge mainly on their own. It is high time for the international business community to rethink the entire climate change issue, we, as business leaders, must play a central and very active role in setting up the basic rules and regulations. The business community has unique knowledge that must be taken into account already when the rules and regulations are established. Business and industry can contribute important experience and know-how. Handling climate change purely or mainly in terms of "red tape" will be extremely expensive – high costs and poor results are to be expected. Today, the climate change issue is driven by politicians, public officials and NGOs that are trying to pull business into a low-emissions future. Looking forward, we as representatives of business and industry have to show leadership. Instead of being pulled by society, we should be pushing and in a positive way integrate climate issues into the world of markets and trade on a global scale.

On the political level, Europe and the USA have diverged. This is not a sustainable situation and there is great need for a transatlantic dialogue. This responsibility lies primarily on the political system, but the business community has a vital role to play in contributing to such a dialogue. All company executives, but primarily those on either side of the Atlantic, must commit themselves to working for a global emissions trading system.

Industry should unite to facilitate joint political leadership, first of all from Europe and the USA, on this issue.

Joint action on the part of business leaders can make a major contribution to breaking the deadlock between Europe and the USA. Business leaders, let us form a Trans-Atlantic Forum in order to push society and politicians. We can make a major contribution to finding ways to really globalise the issue and to integrate abatement costs into the global economy. Real progress in combating climate change will, as always, be built on dialogue, mutual acceptance and understanding.

I am prepared to take action. I hope the same goes for many of my colleagues.

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