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Environmental effectiveness and economic consequences of fragmented versus universal regimes: what can we learn from model studies?

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4.1 Introduction

The thirteenth conference of the parties of the climate convention had launched a negotiation process to craft a new international climate change agreement by the end of 2009. This agreement would need to stipulate emission reduction commitments, specify essential actions to adapt to the impacts of climate change and mobilize the necessary funding and technological innovation. Given these enormous challenges, the structure and design of a future climate agreement are still unclear. Besides the negotiations within the UN climate regime, major greenhouse gas emitting countries are also leading ad hoc debates in other forums, for example in the context of the Group of Eight and the Asia–Pacific Partnership on Clean Development and Climate. Depending on the course of these processes, a new climate governance regime could develop in different directions; it could end somewhere between a universal, inclusive governance architecture and a strongly fragmented, heterogeneous governance architecture (Biermann *et al.*, this volume, Chapter 2).

In recent years, numerous universal and fragmented climate regimes have been proposed (for an overview, see Bodansky 2004; Blok *et al*. 2005; Philibert 2005; IPCC 2007: 770–773). Many of these regimes are quantitatively or qualitatively assessed, but no attempt has yet been made to compare the costs estimates of these studies for specific regions under different regimes. Nevertheless, the available material allows us to make an assessment of the regional costs of several universal and fragmented regimes, based on different models. This chapter presents a literature review concerning the economic effectiveness of a number of possible universal and fragmented regimes. We use only studies that quantitatively assess both emission reductions and costs. From a quantitative perspective, this chapter tries to answer the appraisal question of the 'architecture' domain of this book, namely whether a universal or a fragmented regime will be more effective to reduce greenhouse gas emissions.

Global Climate Governance Beyond 2012: Architecture, Agency and Adaptation, eds. F. Biermann, P. Pattberg and F. Zelli. Published by Cambridge University Press. © Cambridge University Press 2010.

The chapter is structured as follows. Section 4.2 describes the methodology, including the criteria used for inclusion of the assessment, a typology of regimes, how we compared the studies and how we dealt with emissions trading (see Flachsland *et al*., this volume, Chapter 5, for a detailed analysis on emissions trading). Section 4.3 analyses the universal and fragmented regimes based on our criteria. Finally, Section 4.4 concludes and briefly maps the policy options discussed.

4.2 Methodology

4.2.1 Criteria for inclusion in the assessment

While there are many criteria to evaluate climate regimes (den Elzen *et al*. 2003: 186; Höhne *et al*. 2003: 33–34; Bell *et al*. 2005: 33), the most important ones according to the IPCC are: environmental effectiveness, cost effectiveness, distributional effects and institutional feasibility (IPCC 2007: 751). Our focus is on the first three criteria, in order to bring our criteria in line with those of Flachsland *et al*. (this volume, Chapter 5). Environmental effectiveness relates to the reduction in greenhouse gas emissions that can be achieved by a regime. Other environmental effects, such as air quality, could also be included, but we focus only on greenhouse gas emissions. We address the economic consequences of climate regimes in terms of their cost effectiveness and distributional effects. Cost effectiveness relates to the extent to which the policy can achieve its objectives at a minimum cost to society (also see Section 4.2.5), while distributional effects relate to the distributional consequences of a policy, which includes dimensions such as equity or fairness (IPCC 2007: 751). These aspects are important because the probability of achieving an agreement will be reduced if the cost effectiveness is low or if the distributional effects – the differences in abatement costs between individual countries or groups of countries – are high.

So far, more than 50 climate regimes with different goals and/or actions have been proposed in the literature (IPCC 2007: 770–773). Our review includes only those studies that quantitatively assess regimes in terms of emission reductions and regional costs and which focus on the post-2012 period. The only exception is the assessment of a carbon tax, for which we use two different models. Direct abatement costs are projected using the Integrated Model to Assess the Global Environment (IMAGE 2.3) framework, which includes the energy model Targets Image Energy Regional (TIMER) 2.0 coupled to the Framework to Assess International Regimes for differentiation of commitments (FAIR) (van Vuuren *et al*. 2007). GDP losses are estimated by linking the IMAGE 2.3 model with the ENV-Linkages model (Bakkes and Bosch 2008). IMAGE is a dynamic integrated assessment modelling framework for global change, aimed at supporting decision-making by quantifying the relative importance of major processes and interactions in the society–biosphere–climate system.[1]

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[1] For more information, see www.mnp.nl/image.

ENV-Linkages is a global macroeconomic general equilibrium model containing 26 sectors and 34 world regions and provides economic projections for multiple time periods.

4.2.2 Typology of regimes

The fundamental difference between a universal and fragmented regime is that the former involves a single comprehensive climate regime that applies to all countries (Biermann *et al*., this volume, Chapter 2). This means that universal climate regimes require full participation of all countries, at least gradually, in the same international agreement, whereas fragmented climate regimes never achieve full participation in a single international agreement.

Figure 4.1 classifies the assessed regimes according to the number of participating countries. Regimes with more than one agreement or without full (gradual) participation are fragmented regimes. Since for our modelling analysis we have to rely on quantifiable criteria, our distinction of fragmented and universal regimes is not completely congruent with the distinction introduced by Biermann *et al*. (this volume, Chapter 2). These authors also refer to participation in terms of 'actor constellation', but in addition, they rely on qualitative criteria, namely 'institutional overlaps' and 'norm conflicts'. We, however, focus on the quantifiable criteria of participation and number of agreements. We regard a regime as more universal when more countries participate and when there are fewer different agreements involved. Therefore, it is possible to have a fragmented regime in which all countries contribute in some way to reduce emissions, although using different agreements. An example would be a regime in which the United States, Australia, India, China, Japan and South Korea continue to focus on cooperation on development and transfer of technology within the Asia–Pacific Partnership on Clean Development and Climate, while the rest of the world uses a system of absolute emission targets with the possibility of emission trading (Biermann *et al*., this volume, Chapter 2). Universal regimes can have a higher or lower degree of participation as well. Regimes in which all countries participate immediately, based on one common rule, are perfectly universal. An example would be 'contraction and convergence', in which all countries participate according to the rule of converging per capita emissions. A number of universal regimes, however, have a gradual participation approach or staged system approach. In the latter approach, countries participate in a system with stages and stage-specific targets, where the transition between stages is a function of various indicators, such as per capita income thresholds (Gupta 1998; Berk and den Elzen 2001; Höhne *et al*. 2003). Another crucial factor that qualifies regimes is the type of target, where two broad distinctions can be made:

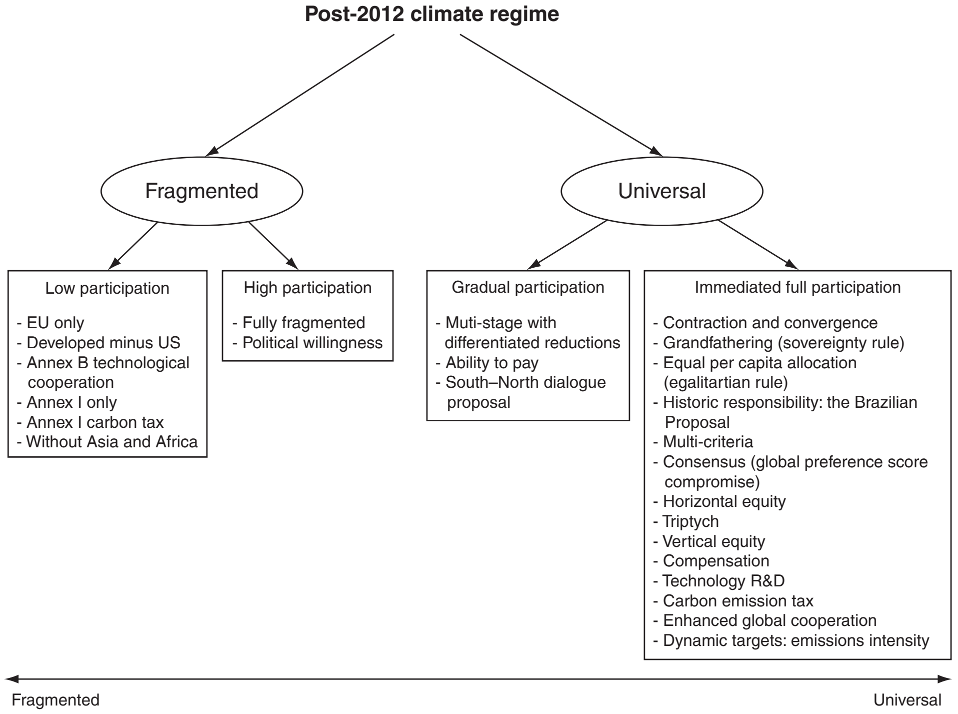

Figure 4.1 Quantitatively assessed post-2012 fragmented and universal climate regimes. Tables 4.1, 4.2 and 4.7 explain the different climate regimes mentioned in Figure 4.1.

(1) *Regimes with predefined emission targets* These regimes specify targets in terms of emission reductions. Often these emission targets are derived from a certain climate target, like the concentration stabilization level. Most universal regimes are of this type.
(2) *Regimes without predefined emission targets* These regimes do not include emission targets, but instead technological cooperation or a carbon emission tax, for instance. Fragmented and universal regimes can both be of this type.

Because these two types of regimes are difficult to compare, we analyse them separately.

4.2.3 Comparing quantitative assessments focusing on costs and reductions

Comparing studies that assess various climate regimes is not always a straightforward task. Studies use different assumptions and report different cost measurements. General equilibrium models usually measure costs in GDP or welfare loss, whereas in partial equilibrium models (energy system models) costs are measured in direct abatement costs. These two cost measurements are in absolute values not directly comparable. Therefore, we focus on the relative costs of different regions using both metrics, while Flachsland *et al*. (this volume, Chapter 5) consider direct abatement costs only.

For most regimes, the actual design ('regime parameters') is crucial for the outcome. Such regime parameters can include the overall concentration target (for example 450, 550 or 650 ppm carbon dioxide-equivalent), the baseline (high or low), discount rate (level and type) and marginal abatement costs. Other assumptions are regime-specific. For example, for the 'contraction and convergence' regime the convergence year can strongly determine the outcomes. Our analysis states for every assessment the major parameter settings, the cost measurement and the details of the regime.

4.2.4 Emission trading

Almost all regimes can be constructed so that emission trading is either allowed or not allowed. Many studies analyse the effect of emission trading or the clean development mechanism on the costs of emission abatement; all studies conclude that emission trading and the clean development mechanism decreases the cost of abatement (see, for example, Leimbach 2003: 1041; Böhringer and Welsch 2004: 32; Bollen *et al*. 2005: 16; Russ *et al*. 2005: 21; European Commission 2007: 48). This holds for all universal regimes (both full and gradual participation) and to a lesser extent for the fragmented climate regimes (depending on the size of coalitions). Emission trading not only reduces the overall costs of the regime, but also decreases the costs for every country participating in the coalition. To effectively compare the economic consequences of various climate regimes, we restrict our study to regimes that assume full emission trading between countries participating in the same coalition. However, in the case of fragmented regimes, none of the studies we consider assumes the possibility of trade between countries belonging to different coalitions. Flachsland *et al*. (this volume, Chapter 5) provide such an analysis of the environmental and cost effectiveness of fragmented carbon markets as compared to more integrated approaches for emission trading.

4.3 Analysis

4.3.1 Universal regimes

The majority of climate regime proposals presume global international climate negotiations with the goal of a single, comprehensive regime (IPCC 2007: 770–773). Most regimes predefine a global emission target and then apply allocation rules specifying the allocation of global emission reductions to countries or regions. In universal regime proposals, the global emission target can be set at any preferred level. In most cases, the authors looked at global short-term emission targets that are compatible with meeting long-term concentration stabilization targets in the range of

Table 4.1 *Universal regimes with a global emission target*

Name	Short description	Evaluated in terms of emission reductions and costs by
Full participation regimes		
Contraction and convergence	Distribute permits so per capita emissions converge in a certain year	Blanchard (2002), Böhringer and Helm (2008), Böhringer and Welsch (2004; 2006), Bollen *et al.* (2004, 2005), Criqui *et al.* (2003), den Elzen and Lucas (2005), den Elzen *et al.* (2005, 2008), Leimbach (2003), Manne and Richels (1995), Manne *et al.* (1995), Nakicenovic and Riahi (2003), Persson *et al.* (2006), Peterson and Klepper (2007)
Grandfathering (sovereignty rule)	Distribute permits in proportion to current emissions	Böhringer and Welsch (2006), Böhringer and Löschel (2005), Bollen *et al.* (2005), Buchner and Carraro (2003), den Elzen and Lucas (2005), Peterson and Klepper (2007), Rose *et al.* (1998)
Equal per capita allocation (egalitarian rule)	Distribute permits in proportion to population	Böhringer and Helm (2008), Böhringer and Welsch (2006), den Elzen and Lucas (2005), Persson *et al.* (2006), Rose *et al.* (1998), Wicke and Böhringer (2005)
Historic responsibility – the Brazilian Proposal	Distribute permits in proportion to the contribution of climate change over a certain period	Blanchard (2002), den Elzen and Lucas (2005), den Elzen *et al.* (2005), Rive *et al.* (2006)
Multi-criteria	Distribute permits based on a formula including several variables, such as population, GDP and others	den Elzen and Lucas (2005), Vaillancourt and Waaub (2006)
Consensus (global preference score compromise)	A combination of per capita allocation and grandfathering	den Elzen and Lucas (2005), Rose *et al.* (1998)
Horizontal equity	Distribute permits to equalize net welfare change as per cent of GDP	Rose *et al.* (1998), Vaillancourt *et al.* (2008)
Vertical equity	Progressively distribute permits proportions inversely correlated with per capita GDP	Rose *et al.* (1998), Vaillancourt *et al.* (2008)

Table 4.1 (*cont.*)

Name	Short description	Evaluated in terms of emission reductions and costs by
Triptych	National emission targets based on sectoral considerations	den Elzen and Lucas (2005)
Gradual participation regimes		
Multi-stage with differentiated reductions	Countries participate with different stages and stage-specific types of targets; countries transition between stages as a function of indicators	Boeters *et al*. (2007), Criqui *et al*. (2003), den Elzen and Lucas (2005), den Elzen *et al*. (2005, 2008)
Ability to pay	Permits are distributed in order to equalize abatement costs as per cent of GDP	Böhringer and Löschel (2005), den Elzen and Lucas (2005)
South–North dialogue proposal	Countries participate in the system with different stages and stage-specific types of targets	den Elzen *et al*. (2007a)

450–650 ppm carbon dioxide-equivalent. A relatively strong point of all universal regimes with predefined targets is that environmental effectiveness is secured. However, in reality this effectiveness is obviously a function of compliance.

Tables 4.1 and 4.2 show allocation proposals with and without predefined global emission targets that have been quantitatively assessed regarding their economic consequences for the post-2012 period. (On studies that evaluated proposals solely in terms of emission reduction targets but not in terms of costs see Höhne *et al*. 2003 and Blok *et al*. 2005.)

Universal regimes with a predefined emission target

'Contraction and convergence'

Of all regimes, the 'contraction and convergence' regime has been analysed most often. The most crucial reason is its simple formulation – which makes it a good reference for any form of allocation. The first step in the 'contraction and convergence' regime is to establish a long-term global emission profile. Then emission rights are allocated so that the per capita emissions converge from their current

Table 4.2 *Economic consequences of universal regimes without a global emission target*

Name	Short description	Evaluated in terms of costs by
Carbon emission tax	All countries agree to a common, international greenhouse gas emission tax	Bollen *et al.* (2005), Manne *et al.* (1995), Peterson and Klepper (2007), Vaillancourt *et al.* (2008)
Dynamic targets: emissions intensity	Targets are defined as a certain reduction of the ratio of carbon dioxide emissions to GDP	Blanchard (2002)
Technology research and development	A regime based on enhanced coordinated technology research and development	Buchner and Carraro (2004)
Enhanced global cooperation	Joint welfare maximization with an additional 10 per cent emission reduction	Buchner and Carraro (2003)

values to a global average in a specific target year. Table 4.3 shows some of the chief parameters used in the various assessments of the 'contraction and convergence' regime.

Comparing the results from these studies is challenging due to the large variations in cost measurements, convergence year and targets. In order to decouple results from specific cost indicators and baseline or reduction targets, we analyse the costs of certain key regions relative to the global average costs as share of GDP. Table 4.4 shows the results.[2] Every study finds substantial cost differences between regions. All studies, except Criqui *et al.* (2003), project high costs for the former Soviet Union and Eastern Europe due to (1) an unfavourable combination of high per capita emissions and low GDP and (2) reduced fossil fuel exports. For the same reasons, most studies also project high costs for the Middle East/North Africa. A few studies, however, expect net benefits for this region. Different projections of the abatement costs in this region are the major reason for these variations in cost projections. All studies agree that India and sub-Saharan Africa will profit from a 'contraction and convergence' regime with a 2050 convergence year, while they expect China to incur lower costs as compared to the global average. Most studies predict that the costs for Europe and the United States will be somewhat above the global average.

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[2] The studies of Nakicenovic and Riahi (2003), Manne and Richels (1995) and Manne *et al.* (1995) are not included in this table because they only reported results from a few highly aggregated regions.

Table 4.3 *Parameters of 'contraction and convergence' regime cost assessments*

Study	Regions	Cost measurement	Convergence year	Target
Blanchard (2002)	17	Direct costs 2030	2050	9.4 GtC in 2030[a]
Böhringer and Welsch (2004, 2006), Böhringer and Helm (2008)	11	NPV[b] income	2050	25 per cent below 1990 in 2050[c]
Bollen *et al.* (2004)	6	GDP and income 2040	2050	S550e[d]
Bollen *et al.* (2005)	13	Income 2020	2024	S550e
Criqui *et al.* (2003)	11	Welfare 2025, direct 2025/2050	2050 and 2100	S550e and S650e
den Elzen and Lucas (2005)	18	Direct costs 2025 and 2050	2050	S550e and S650e
den Elzen *et al.* (2005)	11	Direct costs 2025 and 2050	2050 and 2100	S550e
den Elzen *et al.* (2008)	10	Direct costs 2020 and 2050	2050	S450e and S550e
Leimbach (2003)	11	Consumption loss 1990–2045 and 2050–2100	2025 and 2100	2 °C
Manne *et al.* (1995), Manne and Richels (1995)	5	NPV GDP	2030 and 2200	Several explored
Nakicenovic and Riahi (2003)	5	GDP 2020, 2050 and 2100	2050 and 2100	S400c, S450c[e]
Persson *et al.* (2006)	5	NPV direct	2050	S450c
Peterson and Klepper (2007)	12	Welfare 2030	2050	S550e

[a] Consistent with a 450 to 550 ppm carbon dioxide stabilization goal (Blanchard 2002).
[b] Net Present Value: lifetime change in costs discounted to present values.
[c] Corresponds to a concentration stabilization level of 550 ppm carbon dioxide-equivalent.
[d] Stabilization greenhouse gas concentration level at 550 ppm carbon dioxide-equivalent.
[e] Stabilization concentration level at 400 and 450 ppm carbon dioxide, which corresponds to a greenhouse gas concentration level of 500 and 550 ppm carbon dioxide-equivalent (den Elzen *et al.* 2003).

Criqui *et al.* (2003), den Elzen *et al.* (2005) and Leimbach (2003) look more closely at the effects of a convergence year of 2100 instead of 2050 or 2025. All three studies conclude that delaying the convergence year reduces costs substantially for industrialized countries. On the other hand, convergence in 2100 leads to much higher costs for developing countries, especially for India and countries in Africa.

Table 4.4 *Regional costs compared to global average costs (1)*

Study	USA/ North America	European Union/ enlarged European Union	FSU/ Russia	Middle East/ Middle East and N Africa	Latin/ South America	Africa/ sub-Saharan Africa	China/ East Asia	India/ South Asia
den Elzen and Lucas (2005), den Elzen *et al.* (2005) [a]	2	2	3	3	2	0	1	0
den Elzen *et al.* (2008)[b]	2	2	3	2	1	0	1	0
Böhringer and Welsch (2004, 2006), Böhringer and Helm (2008)[c]	3	2	3	0	0	0	1	0
Criqui *et al.* (2003)[d]	1	1	0	3	1	0	0	0
Peterson and Klepper (2007)[e]	1	1	3	3	2	0	0	0
Blanchard (2002)[f]	3	2	3	3	NA	0	2	0
Leimbach (2003)[g]	2	1	3	0	NA	0	1	0
Persson *et al.* (2006)[h]	NA	NA	NA	0	0	0	1	0
Bollen *et al.* (2005)[i]	2	2	3	3	3	NA	NA	NA
Bollen *et al.* (2004)[j]	2	2	3	3	NA	NA	NA	NA

The table shows regional costs compared to global average costs for the 'contraction and convergence' regime with emission trading and convergence in 2050 (exceptions: Bollen *et al.* 2005 convergence in 2024; Leimbach 2003 convergence in 2025) for a greenhouse gas concentration stabilization target of 550 ppm carbon dioxide-equivalent or 450 carbon dioxide ppm.

Legend: 0 = no costs or gains, 1 = costs less than global average, 2 = costs between global average and twice the global average, 3 = costs more than twice the global average; NA = not available.

[a] Direct costs in 2025.

[b] Direct costs in 2050.

[c] Net Present Value of change in income.

[d] Change in welfare in 2025.

[e] Change in welfare in 2030.

[f] Direct costs in 2030.

[g] Consumption loss in the period 1990–2045.

[h] Net Present Value of direct costs.

[i] Income in 2020. In this study there is one Rest of World region with large benefits, explaining the fact that all regions reported here incur higher costs than the global average.

[j] Income in 2040. In this study there is one Rest of World region with large benefits, explaining the fact that all regions reported here incur higher costs than the global average.

Other emission allocation regimes.

Of the studies that analyse other universal emission allocation regimes, den Elzen and Lucas (2005) is the most comprehensive. In total, they analyse nine universal regimes with full and gradual participation with respect to regional abatement costs. This can be used to explore whether there are also large variations in the distribution of costs for other universal regimes. Table 4.5 summarizes their results.

All regimes analysed by den Elzen and Lucas are subject to substantial cost differences between regions. Interestingly, the Middle East, the former Soviet Union, Canada and Oceania incur high costs no matter what the regime. The regimes with the smallest cost differences between regions are Triptych, 'multi-stage' with differentiated reductions and the Brazilian proposal on historic responsibility (but this strongly depends on the parameter settings).

Rose *et al*. (1998) also compare several universal allocation regimes. They find the largest cost differences in the equal per capita allocation regime. In this regime, the costs for industrialized countries are especially high; this can be expected, since these countries currently have the highest per capita emissions. They also analyse an outcome-based allocation regime called horizontal equity, in which abatements costs are required to be an equal proportion of GDP for all. By definition, there are no cost differences between countries in such a regime.

The large cost differences for almost all allocation regimes are confirmed by other studies that analyse a single emission allocation regime (Blanchard 2002; Bollen *et al*. 2004; Böhringer and Löschel 2005; Wicke and Böhringer 2005 Böhringer and Welsch 2006; Persson *et al*. 2006; Rive *et al*. 2006; Vaillancourt and Waaub 2006; Peterson and Klepper 2007; Böhringer and Helm 2008). The large variation in the distribution of costs in almost every regime analysed will likely pose significant problems for full participation, even if average global costs are modest. At first glance, the horizontal equity allocation regime seems promising for achieving full participation, since in this regime every country incurs proportionally the same costs, figured as a share of GDP. Nevertheless, this regime is unlikely to achieve full participation, for two reasons. First, for many countries, especially developing ones, it might be unfair that they will have to pay the same costs as industrialized countries – even when calculated as a share of GDP. Second, in every universal regime the problem of free-riding remains (Carraro and Siniscalco 1998; Barrett 1999; Carraro 2000; Tol 2001; Dellink *et al*. 2005; Finus *et al*. 2005; 2006; Eyckmans and Finus 2007).

Universal regimes without a global emission target

We analyse cost projections for four universal regimes without a predefined global emission target (Table 4.2).

Table 4.5 *Abatement costs as per cent of GDP for nine regimes*

Region	GC	CSE	AP	MS	C&C	TT	BP	GF	MCC
Canada	3	3	3	3	3	2	2	2	2
USA	3	3	3	3	2	2	1	1	1
OECD Europe	2	2	2	2	2	2	2	2	1
Eastern Europe	3	2	1	1	1	2	1	1	1
FSU	3	3	1	3	3	3	3	2	2
Oceania	3	3	3	3	2	2	2	2	2
Japan	2	2	2	2	2	2	2	2	1
Central America	1	1	2	2	1	1	2	3	2
South America	2	2	2	2	2	1	2	3	2
Northern Africa	0	0	0	0	1	0	1	0	2
Western Africa	0	0	0	0	0	0	0	0	2
Eastern Africa	0	0	0	0	0	0	0	0	0
Southern Africa	2	1	0	0	3	1	0	0	3
Middle East	3	3	3	3	3	3	3	3	3
South Asia	0	0	0	0	0	0	0	0	1
East Asia	1	1	1	1	1	2	1	2	2
South East Asia	0	0	0	0	1	1	2	1	2

The table shows abatement costs as per cent of GDP in Purchasing Power Parity terms for nine regimes (all allowing for emission trading) in 2025 for greenhouse gas concentration stabilization at 550 ppm carbon dioxide-equivalent.
Legend: 0 = no costs or gains, 1 = costs less than global average, 2 = costs between global average and twice the global average, 3 = costs more than twice the global average; GC: Global preference score compromise, CSE: Equal per capita allocation, AP: Ability to pay, MS: 'multi-stage' with differentiated reductions, C&C: Contraction and convergence, TT: Triptych, BP: Historic responsibility: Brazilian proposal, GF: Grandfathering, MCC: Multi-criteria.
Source: based on den Elzen and Lucas (2005).

Dynamic targets: emissions intensity

Blanchard (2002) analyses the economic consequences of a universal regime based on dynamic targets. This regime defines reduction targets as the ratio of carbon dioxide emissions to GDP. Although there is no global emission reduction target, Blanchard set the dynamic emission intensity targets at levels that stabilize carbon dioxide concentrations at 450 to 550 ppm. Emission intensity targets for industrialized countries are set at a reduction rate of approximately 2 per cent annually from business as usual, while developing countries have to improve their emissions intensity by 0.5 per cent annually. Due to these stricter targets for industrialized countries, the abatement costs in industrialized countries in 2030 are much higher than in developing countries. Abatement costs as share of GDP in industrialized countries range from twice the global average in the European Union to more than six times the global average in countries of the former Soviet Union.

Regimes based on cooperation

Two other comparable universal regimes without a fixed global emission target are analysed by Buchner and Carraro (2003, 2004): Enhanced Global Cooperation and Technology Research and Development. Both regimes focus on cooperation between regions. In the Enhanced Global Cooperation regime, all countries cooperate in such a way that their joint welfare is maximized, and reduce emissions by an additional 10 per cent compared to this 'optimal path'. The Technology Research and Development regime focuses on global cooperation on technical innovation and diffusion, rather than maximization of joint welfare. Both of these regimes are sensitive to parameter settings like the discount rate and to uncertainties like the estimated damages of climate change, and might therefore be difficult to implement. With the parameters chosen in their study (which were deduced from the FEEM–RICE model), costs are low for all regions, but the environmental effectiveness is also very low. The disadvantage of the Technology Research and Development regime is that – as a consequence of the intensified research and development efforts – production and therefore emissions increase. In other words, for a technology regime to be successful, a carbon-free direction of technology development must to be clearly specified (Alfsen *et al*., this volume, Chapter 13; Knopf and Edenhofer 2010).

Global carbon emission tax

Finally, the implementation of a global carbon emission tax is perhaps the most straightforward universal regime without a predefined emission target. Many studies have used a global carbon tax as a means to achieve emission reductions, but the regional results of such a regime have not regularly been reported. Table 4.6 summarizes the results of a global carbon emission tax from three studies, extended with our own calculations from the IMAGE framework and the ENV-Linkages model (see Section 4.2.1).[3] The carbon tax in these studies was raised over time to reach a certain concentration stabilization level, with the exception of Bollen *et al*. (2005), who set the carbon emission tax at a constant €20 per tonne of carbon dioxide.

The various studies report similar results for most regions. All studies project that costs as share of GDP would be somewhat less than the global average for the European Union and the United States, and higher, or much higher, for the Middle East, the former Soviet Union, East Asia and Africa. Costs tend to be higher in developing countries because the burdens of a tax regime are carried mostly by those regions with high carbon intensity or with high opportunities to reduce emissions. In

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[3] Not included in the table are the results by Manne *et al*. (1995), who analysed a low carbon tax starting at USD 1 per tonne, increasing at 5 per cent per year. Results are reported for five regions only and are modest, as can be expected from such a low carbon tax.

Table 4.6 *Regional costs compared to global average costs (2)*

	USA	European Union/ enlarged European Union	FSU/ Russia	Middle East/ Middle East and N Africa	Latin/ South America	Africa/ sub-Saharan Africa	China/ East Asia	India/ South Asia
Peterson and Klepper (2007): welfare effects in 2030	1	1	3	3	2	3	3	1
Vaillancourt *et al.* (2008): discounted direct costs	1	1	2	2	2	2	2	1
Based on IMAGE framework: direct costs in 2050	1	1	2	2	1	2	2	2
Based on ENV-Linkages: GDP loss in 2050	1	1	3	2	1	1	2	3
Bollen *et al.* (2005): income loss in 2020	1	1	3	3	2	NA	NA	NA

The table shows regional costs compared to global average costs for a carbon emission tax of €20 per tonne (Bollen *et al.* 2005) and an increasing carbon emission tax in order to reach a greenhouse gas concentration stabilization level of 450 ppm carbon dioxide-equivalent (IMAGE and ENV-Linkages) or 550 ppm carbon dioxide-equivalent (other studies).
Legend: 1 = costs less than global average, 2 = costs between global average and twice the global average, 3 = costs more than twice the global average; NA = not available.

theory, a differentiated tax could equalize the cost burden among countries, although this would complicate the carbon tax implementation.

4.3.2 *Fragmented regimes*

Table 13.2 of the Working Group III contribution to the IPCC's Fourth Assessment Report (IPCC 2007: 770–773) mentions five fragmented regimes,

Table 4.7 *Economic consequences of fragmented climate regimes*

Name	Short description	Evaluated by
European Union only	Only European Union sets emission targets	Bollen *et al*. (2005), den Elzen *et al*. (2007b), European Commission (2007), Russ *et al*. (2005)
Industrialized countries technological cooperation	Replacement of international cooperation on emission reductions with international cooperation between industrialized countries on technological innovation and diffusion	Buchner and Carraro (2004)
Developed minus US	Developed countries except the United States set emission targets, rest of world does not	Böhringer and Löschel (2005)
Industrialized countries only	Only industrialized countries set emission targets	Bollen *et al*. (2005; 2005), Böhringer and Löschel (2005), Russ *et al*. (2005)
Industrialized countries carbon tax	Only industrialized countries levy a carbon tax	Bollen *et al*. (2005)
Without Asia and Africa	Only developing Asian and African countries do not set emission targets	Bollen *et al*. (2005)
Political willingness	Regional emission constraints on levels considered to be politically acceptable according to a number of research institutes	den Elzen *et al*. (2007a)
Fully fragmented	A palette of internationally fragmented climate policies	Boeters *et al*. (2007)

The table shows fragmented climate regimes that have been analysed regarding their economic consequences, from low to high participation.

which are rather generally defined. Most quantitative studies on fragmented regimes make assumptions about the level of participation: only one climate regime is adopted, but not all countries participate in this regime. The participating countries adopt reduction targets based on expert judgements about what they might be willing to do, or reduction targets would be set at such levels in order to reach a global emission target. Only two studies analyse the costs of fragmented regimes with several different climate agreements (Boeters *et al*. 2007; den Elzen *et al*. 2007a). We will discuss a range of fragmented regimes from low to high participation (see Table 4.7).

Emission targets for the European Union only

The regime with the lowest participation analysed is one in which only the European Union sets emission targets. According to this analysis, if the European Union were to set a target of 20 per cent emission reduction in 2020 or 2025 (compared to 1990), and joint implementation and the clean development mechanism are available, abatement costs and welfare losses for the European Union would be very small – less than 0.3 per cent in 2020 (Russ *et al*. 2005; den Elzen *et al*. 2007b; European Commission 2007, 2008). Two studies look at the implications of a 30 per cent reduction target for the European Union only. Bollen *et al*. (2005) estimates income losses for the European Union of such a target of 2 per cent in 2020; a study by the European Commission (2007) finds GDP losses of 0.9 per cent in 2025. Even with the more stringent target of a 30 per cent emission reduction, the effectiveness of such a regime on a global scale is very low: by 2020, the global emission reduction would be less than 5 per cent compared to the no-climate policy case.

Technological cooperation between industrialized countries

This fragmented regime is slightly different than the rest as the focus is not on emission reduction targets, but on technological cooperation between industrialized countries. The advantage of such a coalition is that the consequences can be relatively easily assessed by decision-makers. Buchner and Carraro (2004) assess this regime with the same assumptions as in their Enhanced Global Cooperation regime (see Section 4.1.2). The results are similar: environmental effectiveness is very low, because global emissions and even the emission/output ratio increase in this regime. This is the result of production increases due to intensified research and development efforts (as in the universal Technology Research and Development regime). Emissions per unit of output also increase, because the overall impact of accumulated research and development expenditure on economic growth is larger than the impact of accumulated research and development on emission abatement.

Emission targets for industrialized countries only

Böhringer and Löschel (2005) analyse the possibility of all industrialized countries except the United States setting emission targets. Although the United States and developing countries do not set emission targets, the study assumes that these regions can sell project-based emission reductions to the reducing countries (leading to mutual benefits). The global emission reduction target is set at 10 per cent below baseline in 2020. Different allocation rules are used to allocate this global reduction to Australia and New Zealand, Canada, the European Union, the former Soviet Union and Japan. The sovereignty rule (also called grandfathering, that is, reduction obligations based on current emissions) and the polluter-pays principle (that is, reduction obligations based on past emissions) lead to emission reductions of 30–38 per cent compared to baseline in 2020 in each of the regions. The allocation rule ability-to-pay (that is, reduction obligations based on welfare), on the other hand, leads to an emission reduction target for the former Soviet Union by only 5 per cent, whereas Japan has to reduce emissions by 66 per cent. Figure 4.2a summarizes the abatement costs (measured in consumption loss).

A fragmented climate regime in which all industrialized countries participate (thus including the United States) leads to similar results. The results of Böhringer and Löschel (2005) are shown in Figure 4.2b. The participation of the United States leads to small reductions of costs for other industrialized countries. Bollen *et al.* (2005) analyse a similar regime, but with a more stringent target and allocation based on per capita emission convergence in 2024. Consistent with the results of Böhringer and Löschel, this leads to high costs for the former Soviet Union. In contrast with that study, however, they conclude that there are benefits for the Middle East and that the European Union and United States will incur higher costs. The latter can be explained by the more stringent target and the early convergence year (which is less beneficial for industrialized countries, see Section 4.3.1). Their main conclusion is that switching from a global coalition (universal regime) to a smaller coalition of industrialized countries (fragmented regime) more than doubles the cost of the European Union objective of 2 °C, even with the possibility of the clean development mechanism in its current form. With such a regime, developing countries (except energy exporting countries) would benefit and thus effectively become free-riders. This might create an obstacle for establishing a coalition in which only industrialized countries participate.

Carbon emission tax for industrialized countries only

Besides setting emission targets, industrialized countries also could levy a carbon tax. Like the universal Global Carbon Emission Tax, Bollen *et al.* (2005) analyse the carbon tax for industrialized countries with a tax of €10 and €20 per tonne carbon dioxide. Whereas a global carbon tax of €20 per tonne carbon dioxide would reduce emissions by 25 per cent compared to baseline, a carbon tax limited to industrialized countries would reduce emissions only by 10 per cent. The costs are distributed differently as well; as expected, industrialized countries (especially the former Soviet Union) carry the burden in this regime.

Emission targets for all countries except developing countries in Africa and Asia

Bollen *et al.* (2004) analyse a fragmented regime in which only developing African and Asian countries refuse to join a climate coalition. They assume that the rest of

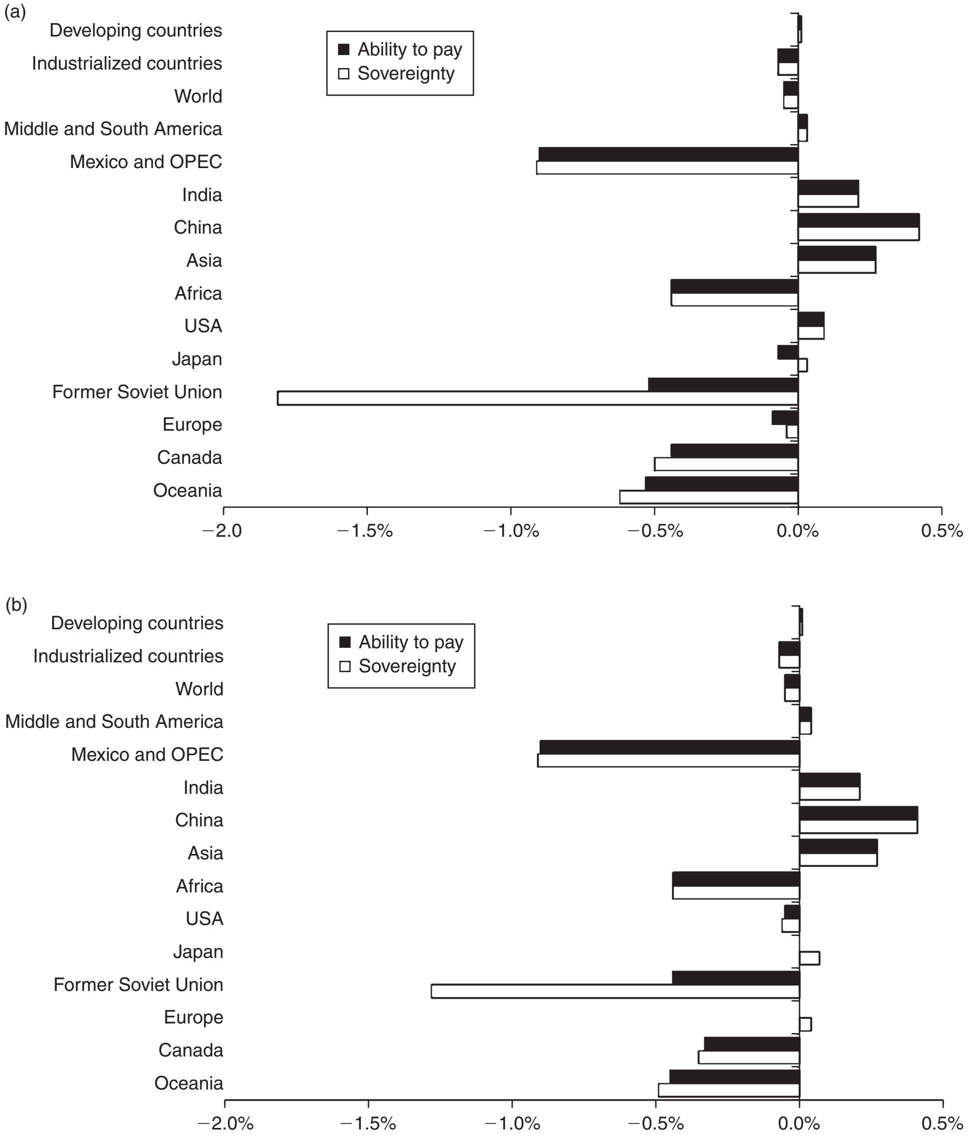

Figure 4.2 Change in consumption in 2020 relative to business-as-usual. This analysis applies in a regime where only industrialized countries set emission targets, allocated based on the sovereignty rule or ability to pay, so that global emissions are reduced by 10 per cent compared to business as usual. (a) Coalition without the United States; (b) coalition with the United States. *Source:* based on Böhringer and Löschel (2005).

the world sets an emission target of 30 per cent below 1990, allocated according to ‘contraction and convergence’. The EU objective could be reached with such a regime, but the global income loss in 2020 would be almost three times higher compared to a universal ‘contraction and convergence’ regime.

Political willingness scenario

The Political willingness scenario, an outcome of the South–North dialogue, is an example of a fragmented regime with large participation (den Elzen *et al*. 2007a). In this proposal, emission reduction targets for different regions are set at levels based on an assessment by a number of research institutes involved in the South–North dialogue proposal. This scenario neither establishes a global emission target, nor requires regions to base their emission reduction targets on a universal regime. This proposal resembles the fragmented bottom–up or multifaceted approach, in which each country creates its own initial proposal relating to what it might be able to commit to (Reinstein 2004). According to the proposal, the European Union reduces emissions by 30 per cent in 2020 as compared to 1990; other industrialized countries by 15 per cent; newly industrialized countries by 30 per cent; and rapidly industrializing countries by 10 per cent. Developing countries continue their baseline emissions until 2020. It is implicitly assumed that all regions will comply because of political will. The costs of the political willingness scenario as a share of GDP would be similar among industrialized countries, while most developing countries would gain from financial transfers from emission trading. With the global emission reduction by 2020 resulting from this scenario, the stabilization at a concentration of 500 ppm carbon dioxide-equivalent is kept just within reach.

A fully fragmented regime compared with a universal regime

Boeters *et al*. (2007) analyses yet another fragmented regime. In contrast to the previous regimes, here even the type of goals varies by region. The United States, Australia and Canada would focus on technology improvement, while the European Union and Japan would continue with emission targets combined with emissions trading. Fast-developing countries would not set emission targets, but would invest mainly in local air quality. For a more detailed description of this fragmented regime, see Boeters *et al*. (2007). Table 4.8 compares this fragmented regime with a universal 'multi-stage' regime, also analysed in the same study.

As the table shows, the global costs of the universal 'multi-stage' regime and the fragmented regime are the same, even though the 'multi-stage' regime achieves much higher emission reductions. Another important conclusion is that no country involved in the 'multi-stage' regime is worse off as compared to the proposed fragmented regime, with the notable exception of the United States. In other words, there might be an incentive for the United States not to join a universal regime (however, allocation rules other than the ones of the 'multi-stage' proposal can limit the costs for the United States; see Table 4.5).

Table 4.8 *Comparison of a fully fragmented regime with a universal regime*

	Target (2020, relative to 1990)		Emission price (€/tonne carbon dioxide)		Change in national income (by 2020)	
	Universal	Fragmented	Universal	Fragmented	Universal	Fragmented
Industrialized countries	−20 per cent	−1 per cent	24	25	−0.3 per cent	−0.3 per cent
European Union-25	−23 per cent	−15 per cent	24	51	−0.4 per cent	−0.6 per cent
USA	−24 per cent	+25 per cent	24	14	−0.3 per cent	−0.0 per cent
FSU	−13 per cent	−25 per cent	24	7	+0.8 per cent	−0.7 per cent
Rest OECD	−16 per cent	+3 per cent	24	34	−0.4 per cent	−0.4 per cent
Non-Annex I	+100 per cent	+147 per cent	–	–	0.0 per cent	0.0 per cent
China	+101 per cent	+105 per cent	24	2	+0.4 per cent	0.0 per cent
India	+210 per cent	+203 per cent	24	4	+0.1 per cent	0.0 per cent
World	+28 per cent	+45 per cent	–	–	−0.2 per cent	−0.2 per cent

The table shows targets, emission prices and national income changes for a fully fragmented regime compared to a universal regime based on a multi-stage emission allocation rule.
Source: Boeters *et al*. (2007).

4.4 Conclusions and policy recommendations

This chapter reviewed several quantitative studies about the costs and environmental effectiveness of different universal and fragmented regimes. A large number of studies exist that qualitatively discuss different climate regimes or discuss only the emission reductions resulting from these regimes. The number of studies also discussing regional economic consequences is much more limited. In the studies that do provide costs analyses, different tools are used, such as macroeconomic models. We find that, in general, studies agree on what regions will experience high, medium or low costs under different regimes, even when using different tools.

The chief conclusions from the review of universal regimes are that (1) theoretically, binding universal regimes with high emission reduction targets or a carbon tax can achieve ambitious reduction targets at relatively low costs; and (2) almost all examined allocation regimes result in significant cost differences (in terms of costs as share of GDP) between regions. The last conclusion is obviously a major challenge for forming international coalitions. There is no single formula for emission allocation that satisfies all possible country conditions, as there is a generic conflict between a simple transparent formula and incorporating many national circumstances. As an example, both energy system and general equilibrium models indicate that Africa and South Asia would benefit from a universal climate regime based on ‘contraction and convergence’ with 2050 as the convergence year, while the former Soviet Union and Middle East are projected to incur high costs. In that context, for any real-world agreements, the outcomes of specific allocation rules will at best serve as a starting point for negotiations. The cost differences could be smaller after a negotiation process, which would increase the likelihood of accepting such a proposal.

From the studies that have analysed fragmented regimes, we learn that in general, it is more cost-effective to reduce emissions in a universal regime than in a fragmented regime. One reason is that with lower participation, it is more difficult for the participating regions to reach a certain global emission target (they need to compensate the higher emissions of the non-participating regions). In addition, even with high participation fragmentation implies that emission reductions are not made where it is cheapest to do so (no emission trading is usually possible between regions participating in different agreements). However, despite the higher overall costs, a fragmented regime consisting of multiple agreements could be more feasible to attain. This is mainly because individual countries have an incentive to free-ride on a universal regime.

There are many criteria to assess climate regimes. The current study mainly focused on environmental effectiveness and cost efficiency (and for instance not on institutional feasibility). Based on the long-term advantages of universal regimes for these criteria, but also the difficulties in establishing such regimes, one may argue that some kind of transition from a fragmented regime to a universal regime could provide the best possibility to achieve strong emission reductions. To simplify negotiations, a transitional, ambitious, fragmented regime consisting of all major emitting countries could be established in the short term. Such a coalition could provide the basis for a larger, universal regime in the long term. Transfer schemes or other interlinkages (Flachsland *et al.*, this volume, Chapter 5; and Zelli and van Asselt, this volume, Chapter 6) might help to achieve such a universal regime.

In terms of the mapping criteria applied in this volume, the political dimension of this recommendation is purely policy-based, since the institutional settings and type of actors involved were not subject of our analysis. This means that we do not have concrete recommendations about the international institutional environment, the type of actors involved in decision-making and the mode of governance applied to implement the policy suggestions. This notwithstanding, our recommendation of transitional fragmented regime could be interpreted as a cross-institutional solution which involves the UN climate regime along with several other institutions.

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