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Assessment of the impacts of different post-Kyoto regime proposals on China and India

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Abstract
China and India are increasingly important for global climate policy and the literature show that if ambitious climate targets are to be met, mitigation effort in these large developing countries is necessary. This report presents a detailed overview of how different climate policy regimes may affect China and India. It compares the available scientific literature on burden sharing regimes, with respect to allowances, peaking year and macro-economic impact or direct costs of mitigation.

We find that reductions for both China and India differ greatly between studies, and hence, not only across regimes but also within regimes.

Two indicators are important for allocation of emission allowances: emissions per capita and GDP per capita ('capability"). China is currently close to the global average CO_2 emissions per capita, but its GDP per capita is still considerably below the global average. As a result, allocated allowances are below baseline expectations or even below 2005 emission levels in many studies and regimes. For China, Multi-stage, Common but Differentiated Convergence, Triptych and Historic Responsibility show the highest emission allowances and lowest costs / economic impact of mitigation costs (net of abatement costs and allowance import/export). Grandfathering and C&C lead to large reductions in allocated emissions for China. For 2050, most low stabilisation scenarios (IPCC cat I) show that the allocated emission allowances to China would be 50-80% below emissions levels prevailing in 2005 levels, with hardly any differentiation by regimes. Still, mitigation costs (net of abatement costs and allowance import/export) or macro-economic impact in many regimes remains below the global average. Low stabilisation scenarios show emissions that peak relatively early. The mean peaking year of allowances in low stabilisation scenarios is before 2020.

India emissions and GDP per capita are currently far below the global average, and as a result its allocated allowances are mostly above baseline expectation and it can potentially have large revenues from excess allowances if regimes allow so. India can increase its emissions considerably and still emit below its allocated allowances, relative to 2005 – but the allocated allowances are below baseline emissions in a number of studies and regimes. Many regimes seem attractive: Equal per capita and Multi-stage allow for small surpluses, whereas Common but Differentiated Convergence and the South-North proposal contain slightly lower allowances than baseline. Grandfathering and a global carbon tax are clearly unattractive regimes. Due to revenues from excess allowances, climate policy seems beneficial for India, except in regimes that are clearly unattractive, like Grandfathering and taxation. Most regimes require Indian emissions to peak towards mid-century. In most low stabilisation scenarios, the peaking year is around 2030-2040.

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1. Introduction

With the approaching expiration of the first commitment period of the Kyoto protocol in 2012, there is a need for a new global climate policy regime. The contours of such regime are still very uncertain, certainly after indecisive results of COP 15 in Copenhagen (see for example den Elzen et al., 2010a; Den Elzen et al., 2010b; Rogelj et al., 2010 for assessments). Evaluations of current policy trends show that it is unlikely that greenhouse gas emissions will be reduced to a level that allows stabilizing greenhouse gas concentrations in the next decades, let alone achieving ambitious climate targets such as limiting the global mean temperature increase to less than two degrees from pre-industrial levels.

China and India are increasingly important for global climate policy, as their rapid economic growth leads to an increasing share in the world's greenhouse gas emissions. However, as income levels in both countries are still relatively low and both countries have historically contributed less to the current level of greenhouse gas concentrations than developed countries, they are not eager to take on (ambitious) emission reduction targets. This position is in fact also recognized in article 3.1 of the UNFCCC Framework Convention that indicates that countries have a "common but differentiated responsibility" in international climate policy.

In the discussion on meaningful reduction targets for developed and developing countries several factors play a role. The first factor is the overall ambition of international climate policy (e.g. the 1.5 and 2°C targets, but also less ambitious proposals). The second factor is the way the emission reduction effort is distributed across the different countries. Underlying this, there are different opinions on what would be fair distribution (i.e. different approaches to equity, see den Elzen and Höhne, 2008; Den Elzen and Höhne, 2010; Rose et al., 1998). The timing, form, as well as stringency of commitments (and hence reduction effort of individual countries) vary greatly between the numerous proposals for a post-Kyoto architecture that have been put forward (Bodansky, 2004; Gupta et al., 2007; Kameyama, 2004; Philibert, 2005). These differences can lead to economic costs as well as economic benefits for developing countries in joining a regime (den Elzen et al., 2008b).

Notwithstanding the different concepts of fairness, it is clear that if one would like to achieve ambitious climate targets some mitigation effort in large developing countries like India and China is necessary. Otherwise, emissions from non-Annex B countries alone will soon exceed the global allowance for reaching a 450 ppm (CO_2) goal (Blanford et al., 2009; Clarke et al., 2009; Metz et al., 2002).[1] This point is even more relevant because the USA has indicated that it is only willing to reduce its emissions provided a meaningful contribution of major developing countries.

Earlier, den Elzen and Höhne (2008; 2010) and Hof et al. (2009b) have evaluated the impact of different regimes on regional mitigation targets and costs but for relatively large country groupings. The aim of this report is to present a more detailed overview of how different regimes may affect China and India and to discuss which future regimes can be recommended to use in the POEM project. In the analysis, we study changes in emissions and allowances, the peaking year after which allowances start declining, and the costs and economic impact. Compared to the above mentioned studies, this report also includes more studies and discusses the results vis-à-vis current policy initiatives and scientific literature in India and China.

This report is structured as follows. Section 2 describes the methodological aspects, the subsequent sections present the results for regimes with direct participation (section 3) or gradual participation

[1] This is regardless of the reductions carried out in developed countries and would even hold when developed countries reduce their emissions to zero due to the fact that emissions are growing so fast in developing countries.

(section 4), and recently published literature from Indian and Chinese authors (section 5). Section 6 discusses the findings and plausibility of regimes with respect to reductions, peaking of emissions and mitigation costs. Finally, Section 7 draws conclusions.

2. Methodology

Comparing different proposals for future climate regimes is not straightforward, as it involves choices with respect to classification and grouping of regimes, studies to be included and quantitative comparative measures to be used in order to make the results of different studies comparable. This section describes the choices made on these issues, and shows the baseline emissions of the included studies.

2.1 Characterisation and classification of regimes

The term climate mitigation regime (or climate change agreement) is defined here as a set of rules that specify international commitments between countries to reduce GHG emissions. A regime can be characterized by a *certain goal*, a set of rules that determine the *participation* and a *defined form of action* (Gupta et al., 2007).

For many climate regimes, the *goal* is to avoid dangerous climate change, mostly technically specified top-down as a GHG concentration target or corresponding global emission target, after which certain rules for allocating the global reduction effort are applied. By contrast, in a bottom-up approach the emission allowances are allocated among regions without a predefined global reduction effort. Most studies that are reviewed in this report follow a top-down approach, and we express the goal of regimes as a GHG concentration stabilisation target, using the categorisation of the IPCC to distinguish different levels of ambition (IPCC, 2007).

The *participation level* relates to the number of countries that actively participate in the prescribed actions. A distinction can be made between direct participation regimes and gradual participation regimes. In the first category, all countries join a grand scheme of emission allocation, while in the second category participation of a country depends on the ascribed responsibility and capability of the country.

The *prescribed actions* vary widely. Many regimes include explicit binding emission reductions, but other regimes are more flexible, as they include relative or dynamic targets or non-binding targets.
Regimes might also be classified on the basis of problem definition. The climate change problem can be defined either as a pollution problem or as a property-sharing issue. In the first approach, '*burden-sharing*', the differentiation of commitments will focus on defining who should reduce or limit emissions and by how much. In the second approach, '*resource-sharing*', the problem is defined as an allocation of emission *rights*; the reduction of emissions will be in line with the user rights. An important implication of these different approaches is that with resource sharing hot air is possible, since the emission rights can be completely different than the currently existing emission situation. With burden-sharing approaches, this is not the case, since it focuses on sharing the reduction efforts, using the existing situation as starting point.

Finally, regimes can also be classified on the basis of the equity principle on which regimes are based. These principles refer to general concepts of distributive justice or fairness. However, since no globally shared interpretation of equity exists, regimes are based on many different principles, and hence, many attempts of classification have been made as well. Den Elzen et al. (2003) distinguish four major types of equity principles:

1. *Egalitarian*: i.e. all human beings have equal rights in the 'use' of the atmosphere.
2. *Sovereignty and acquired rights*: all countries have a right to use the atmosphere, and current emissions constitute a 'status quo right'.
3. *Responsibility/polluter pays*: the greater the contribution to the problem, the greater the share of the user in the mitigation or economic burden.
4. *Capability*: the greater the capacity to act or Ability to Pay, the greater the share in the mitigation or economic burden.

A complicating factor, when comparing different regimes, is that a given regime strongly depends on many assumptions for parameter settings. For example, the outcomes of 'Contraction & convergence' (C&C) strongly depend on the assumed cap for meeting a climate target (e.g. stabilisation at 450, 550 or 650 ppm CO_2-equivalent) and the convergence year. Especially the more advanced and complex regimes, like Multi-stage, are sensitive to changes in parameter settings for participation thresholds and burden-sharing rules.

Classifying the different regimes for comparison can be done along all different aspects discussed above: the ambition level, the participation level, the form of prescribed actions, the problem definition or the underlying equity principle. We here build upon the categorisation of climate regimes put forward in Hof et al. (2009b), grouping regimes in three categories on the basis of participation level. The first group consists of regimes in which all countries are fully included with absolute emission targets from the start (direct participation). The second group consists of regimes in which gradually more countries are included, based on a predefined criterion or a combination of criteria (gradual participation). The third group consist of regimes in which only part of the world is included. As most often these regimes exclude India and China, this group of fragmented regimes is not included in this study.

In many studies, it is assumed that all countries with emission reduction targets can immediately participate in emissions trading. This ensures that global abatement costs are minimized as marginal abatement costs are equalized. The motivation for gradual participation regimes is that countries should only join in international climate policy once their economic status reaches a certain level. This not only ensures that there will be no economic burden for poorer countries, but also that participating countries have sufficient institutional capacity to ensure a functioning international carbon market. This comes at cost: limited initial participation also implies higher costs, as low costs mitigation options in developing countries are not available on the international market (the regimes normally do not take into account the possibility of CDM).

Table 1 shows an overview of the regimes that are included in this report, as well as the abbreviations that will be used throughout this study and a brief description. Table 2 shows the studies from literature that are included in this report, including the regimes that are analysed in those studies and the costs measurement that is used (see next section).

Table 1: overview and brief description of regimes included in this study

Name	Abbreviation	Short description
Direct participation		
Contraction & convergence	C&C	Emission targets based on a convergence of per capita emission levels of all Parties under a contraction of the global emission level
Grandfathering	GF	Distribute permits in proportion to current emissions
Equal per capita allocation	EqPC	Distribute permits in proportion to population
CSE convergence	CSE	Per capita emission convergence (C&C) combined with basic sustainable emission rights, by Centre of Science and Environment
Historic responsibility*	HR	Distribute permits in proportion to the contribution of climate change over a certain period of time
Multicriteria	MC	Distribute permits based on a formula including several variables, such as population, GDP and others
Global compromise	GC	Allocation of the global emission allowances based on a population-weighted preference score voting for either emission (Grandfathering) or per capita allocation
Triptych	TY	National emission targets based on sectoral considerations
Horizontal equity	Hor	Distribute permits to equalise net welfare change as % of GDP
Vertical equity	Vert	Progressively distribute permits proportions inversely correlated with per capita GDP
Emission Intensity*	EI	Emission reductions related to improvements in the emissions per unit of output, with a participation threshold
Carbon tax	Tax	All countries agree to a common, international GHG emission tax
Gradual participation		
Multi-stage	MS	Countries participate at different stages and with stage-specific types of targets; countries transition between stages as a function of indicators such as income and emission level
Common but differentiated convergence	CDC	All countries' per capita emissions converge, but differentiated, as countries only start to converge when their per capita emissions are at a certain percentage above the global average
South-North Dialogue proposal	S-N	Countries participate in the system at different stages and with stage-specific types of targets
Ability to Pay	AtP	Emission reduction requirements based on per capita income levels, with a participation threshold
Income Distribution	ID	Distribute permits in proportion to the share of rich or poor people in a country, with a participation threshold

* The historical responsibility and emission intensity approaches are placed under full participation, but there are also some applications of this approach with a participation threshold that could be placed under gradual participation.

Table 2: Overview of studies and regimes analysed in this report

	Regimes												
Studies	**AtP**	**C&C**	**EI**	**EqPC**	**GF**	**HR**	**ID**	**MS**	**CDC**	**Tax**	**TY**	**Other**	**Cost Measurement**
(Baer et al., 2008)							yes						f
(Berk and den Elzen, 2001)		yes				yes		yes					
(Blanchard, 2002)		yes	yes			yes							f
(Bode, 2004)						yes							
(Boeters et al., 2007)								yes					b
(Böhringer and Helm, 2008)		yes		yes									g
(Böhringer and Löschel, 2005)	yes				yes								a
(Böhringer and Welsch, 2006)		yes		yes	yes								g
(Chakravarty et al., 2009)							yes						
(Criqui et al., 2003)		yes						yes					d
(den Elzen and Lucas, 2005)	(T)	yes	(T)		(T)	(T)		yes			yes	CSE, MC, GC	f
(den Elzen and Meinshausen, 2006)		yes						yes					f
(den Elzen et al., 2005b)		yes				yes		yes					f
(den Elzen et al., 2007)												S-N	f
(den Elzen et al., 2008a)											yes		
(den Elzen et al., 2008c)		yes						yes					f
(Ekholm et al., 2010)		yes						yes			yes		f
(Groenenberg et al., 2004)											yes		
(Hof et al., 2010)		yes						yes	yes				f
(Höhne and Moltmann, 2008)		yes					yes	yes	yes		yes		
(Höhne and Moltmann, 2009)							yes	yes	yes				
(Höhne et al., 2005)		yes						yes	yes		yes		
(Höhne et al., 2006)		yes							yes				
(Höhne et al., 2007)		yes	yes					yes	yes		yes		
(Jacoby et al., 2008)	yes			yes	yes*								a
(Knopf et al., 2009)		yes				yes							
(Kuntsi-Reunanen and Luukkanen, 2006)		yes											
(Leimbach et al., 2010)		yes	yes					yes					e
(Leimbach, 2003)		yes											e
(McKibbin and Wilcoxen, 2009)				yes	yes								b
(Nordhaus, 2010)										yes			c
(Persson et al., 2006)		yes		yes									f
(Peterson and Klepper, 2007)		yes			yes					yes			d
(Rose et al., 1998)				yes	yes							MC, Hor/Vert	f
(Vaillancourt and Waaub, 2006)												MC	
(Vaillancourt et al., 2008)												Hor/Vert	
(van Vuuren et al., 2009)										yes			f
(WBGU, 2003)		yes											b

* refers to a sovereignty based approach with a differentiated reduction targets between developed and developing countries. (T) refers to a threshold has to be met for inclusion in the regime.

[a] Percentage change in consumption compared to baseline

[b] Percentage change in GDP compared to baseline

[c] Percentage change in GDP compared to baseline, including climate damages,
[d] Percentage change in welfare compared to baseline
[e] Consumption loss over the period 1990-2045 compared to baseline
[f] Direct costs as percentage of GDP
[g] Net present value of change in income

2.2 Comparability of studies and measurements

We collected data from many different studies (see Table 2). The main indicators that we collected were baseline emissions, emission allowances, actual emissions, costs or economic impact and the peaking year of emission allowances. Moreover, global indicators on economic impacts and direct costs were collected.

Comparing these indicators between regimes and studies is not an easy task. There are a number of reasons for this, the most important being i) a bias in literature towards certain regimes, ii) different regional definitions between studies, iii) different timescales used in studies, iv) different measurements for reduction implied by emission allowances and v) different measurements for costs.

2.2.1 Literature bias

While some regimes are analysed in many studies (such as Contraction and Convergence or Multi-stage), analysis of other regimes is scarce (e.g. Ability to Pay, or global carbon tax). This bias in literature towards certain regimes complicates the comparison of different regimes: what seems a difference between regimes might well be a difference between studies or models. On the other hand, for widely analysed regimes it is possible to study the impact of different regime parameters, such as the stringency of the goal or convergence year. A similar problem comes from overrepresentation of certain models in published literature, especially the FAIR model (den Elzen and Lucas, 2005) and the EVOC model (Höhne et al., 2003).

2.2.2 Regional definitions

Differences in regional definition are another issue for comparison between studies. Not all studies in literature report regional emissions and reduction targets for India and China explicitly. Some studies (e.g. Bollen et al., 2004; Manne et al., 1995) do report these indicators but do not disaggregate Asia into smaller regions and are therefore not included in this study. If results are reported for regions where China or India is the dominant country (e.g., East Asia and South Asia), we did include results of these studies in our assessment. In these cases, it should be noted that the absolute figures for baseline emissions and allowance are biased upward.

2.2.3 Timescales

The time resolution across studies did not always match – in general we aimed to get data for 2020, 2030 and 2050, but some studies only had model evaluations in other years. In these cases, the results were compared with nearest year to 2020, 2030 or 2050.

2.2.4 Cost measurement

Comparing the costs or macro economic impact in studies that assess various climate regimes is not always straightforward, as studies report very different cost measurements (see Table 2, right column). The type of cost measurement is generally related to the type of model that is used in the

study. Usually, general equilibrium models measure costs as loss of GDP, consumption or welfare compared to a baseline scenario without emission mitigation. Partial equilibrium models (mostly energy system models) measure costs as direct abatement costs, usually expressed as percentage of GDP. Costs even may include climate change damages or benefits of mitigating climate change (in our analysis only Nordhaus, 2010). Other differences in cost measurement are cumulative costs vs. costs in a particular year and discounted costs or not. Due to all these differences, we categorise these measurements as type a through g in tables (see description below Table 2). Finally, in some cases numbers were estimated by reading graphs, which obviously leads to some imprecision.

All these different cost measurements are not directly comparable in absolute values. Therefore, we have chosen to present the costs estimates as given in the different studies in the description of regimes (see Section 3-4). When comparing the regimes, we have instead focussed on the relative costs of regions compared to the global average costs as presented in the studies, irrespective of which measurement is used. We classified those after (but slightly different than) Hof et al. (2009b) as: 'no cost or gains', 'costs lower than half of global average', 'costs between half global average and global average', 'costs above global average'.

2.2.5 Emission reduction measurement

Another issue is comparing the emissions and emission reductions across different studies. Emissions are reported as either CO_2 only or as CO_2-equivalent (Kyoto gasses), with studies reporting different sources (energy, industry, land-use) and gases. We expressed all emission reductions for China and India relative to the baseline, as this is the best measure to compare the reduction effort between different studies.

2.3 Current situation in India and China

Table 3 presents some major statistics on India and China in 2005 to provide some context to the discussions below (World Bank, 2009). Both countries have a large population, with 20 and 17% of the global population for China and India, respectively. China produces 5% of global GDP calculated in market-exchange rates (MER) (9% in purchasing power parity, PPP), while India produces only 2% of global GDP in MER (4% in PPP). GDP per capita is well below the global average in both countries, furthermore the Indian per capita GDP is much lower than the Chinese. This difference is also reflected in the poverty situation of both countries. In India, more than 75% of population lives below 2 $\$_{ppp}$/day, and almost 42% at less than 1.25 $\$_{ppp}$/day. In China, poverty is also still a major issue, though to a lesser extend with 36.3% and 15.9% of population below 2 and 1.25 $\$_{ppp}$/day, respectively. China's economy shows to be very intensive in terms of energy and emissions, with resp. 15% and 19% of the global energy use and CO_2 emissions. Per capita emissions of China approach the global average. The Indian economy has a share of nearly 5% in both energy use and carbon emissions.

Table 3: Key data of the economy, energy use and CO_2 emissions of India and China in 2005 compared to global levels (World Bank, 2009)

	China	India	Global
Population (billion persons)	1.30	1.09	6.46
GDP, MER (billion US $\$_{2000}$/yr)	1893	645	36610
GDP per capita, MER (US $\$_{2000}$/yr)	1452	589	5665
GDP, PPP (billion int $\$_{2005}$/yr)	5314	2445	56667
GDP per capita, PPP (int $\$_{2005}$/yr)	4076	2233	8769
Poverty (% population below 1.25 $\$_{PPP}$/day)	15.9	41.6	
Poverty (% population below 2 $\$_{PPP}$/day)	36.3	75.6	
Energy use (MTOE[2]/yr)	1700	538	11253
Energy use per capita (GJ/capita/yr)	54.8	20.7	72.9
CO_2 emissions ($GtCO_2$/yr)	5.5	1.4	29.2
CO_2 emission intensity (kg CO_2/US $\$_{2000}$)	2.9	2.2	0.8
CO_2 emissions per capita (tCO_2/capita/yr)	4.3	1.3	4.5

2.4 Baseline scenarios

An important factor determining the outcomes of studies on future climate regimes are the assumed developments of population, income, technology, energy use and resulting emissions. Especially the relative growth of various regions plays an important role. However, most of the studies that focus on burden sharing only provide data on emissions, not on the other factors. Hence, Figure 1 and Figure 3 present an overview of the baseline emissions assumed in the analysed studies. We provide separate graphs for regional aggregation and the distinction between CO_2 only and all GHGs (see also 2.2). However, even taking these factors into account, it is clear that a very wide variation in baseline projections exists throughout the literature, especially on the longer term.

[2] MTOE – million tons of oil equivalent

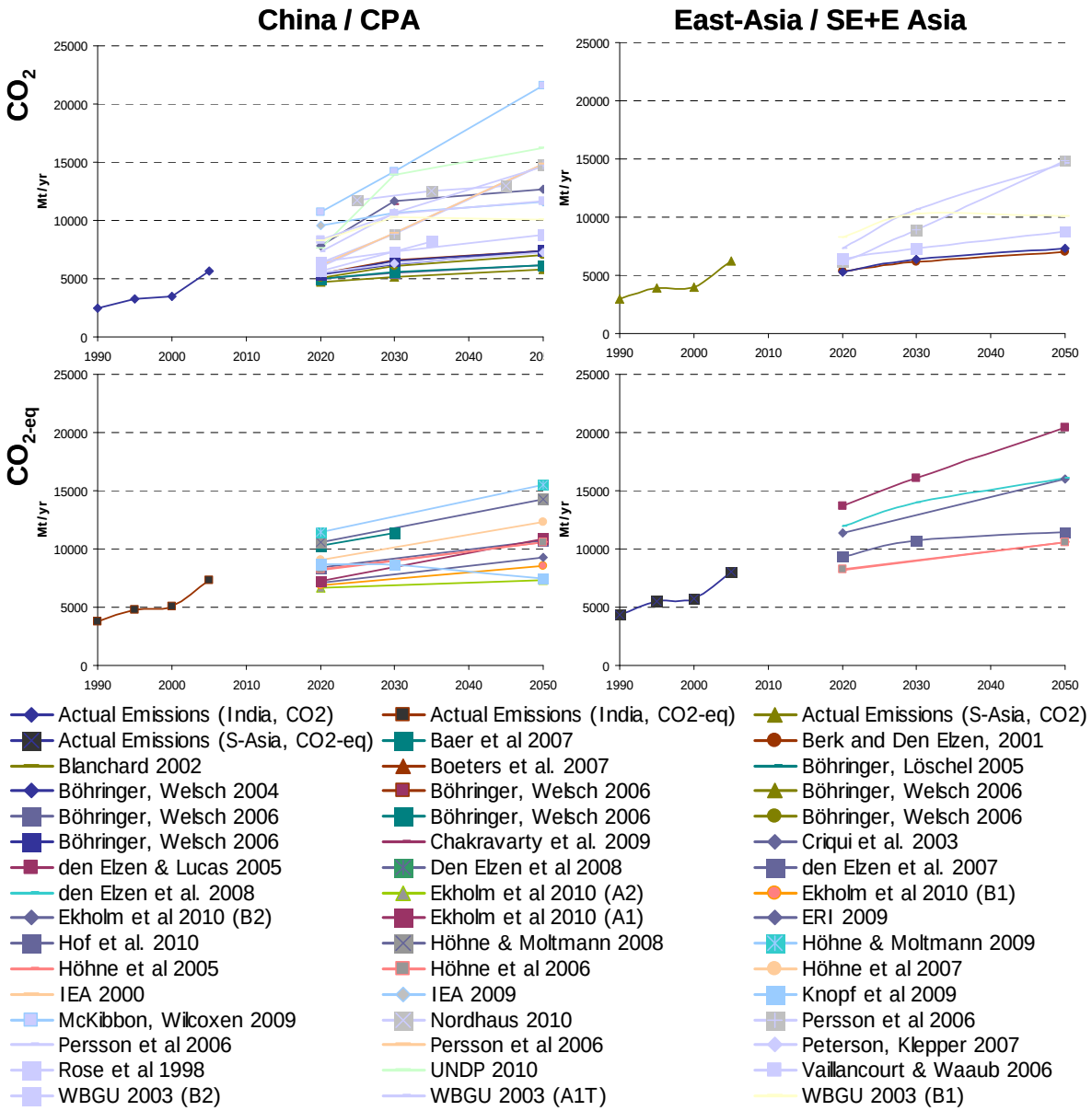

Figure 1: Baseline emissions for China. The top row shows baselines with CO_2 only, the bottom row includes all GHGs. At the left, studies with a regional aggregation of "China" are displayed, while in the right column China is part of a larger region. Actual emission data are taken from World Bank's WDI (World Bank, 2009).

The graph showing CO_2 emissions for China indicates the largest variance, stemming from the fact that this graph contains the most diverse group of authors and models. Interestingly, many studies have baseline estimates for 2020 that are below actual emissions in 2005. This is mostly explained by the accelerated growth after 2000, which has not been factored in by models which are calibrated on data collected prior to the growth spike. This unexpected growth is also reflected in the IEA forecast for 2020 (Figure 2) In 2004, the IEA estimated CO_2 emissions of 5700 Mt while the latest estimate is 9990 Mt (see also Blanford et al., 2009 for the need to update emission projections for China). While the current growth is high, studies that assume continued fast growth until 2020 assume a slowing growth rate in the long run until 2050. Similarly, van Vuuren and Riahi (2008) argue that the current acceleration is probably a temporary phenomenon (see also van Vuuren et al., 2010).

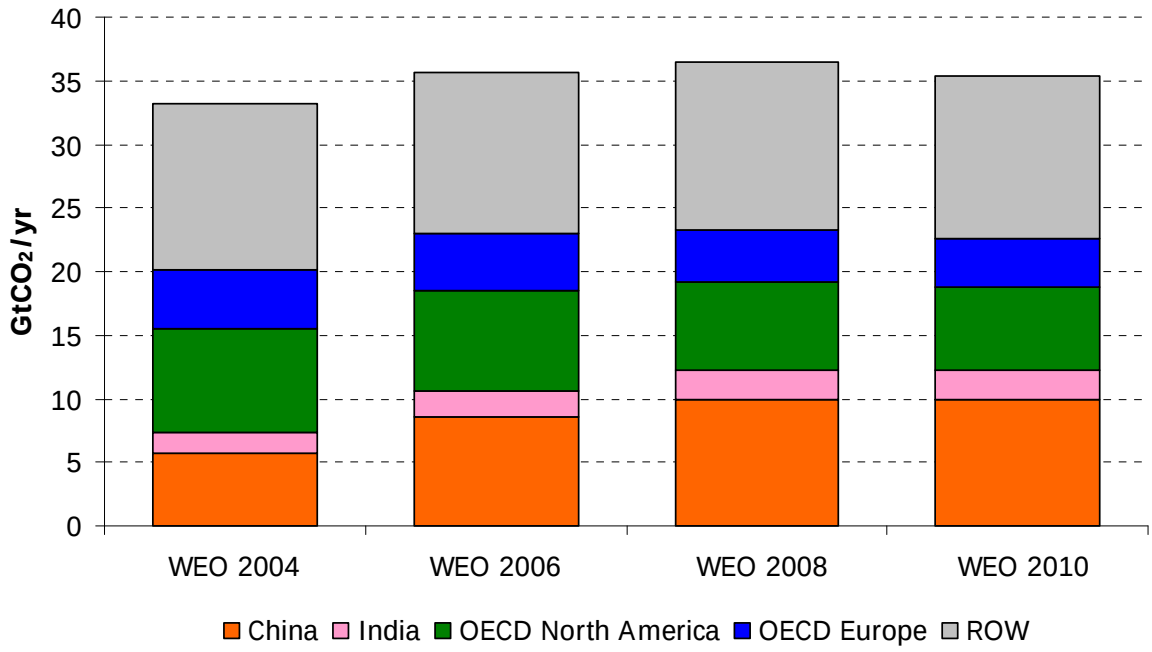

Figure 2: Baseline projections of global CO2 emissions from energy use in 2020 from several world regions as published in IEA World Energy Outlooks during the last decade (IEA, 2004, 2006, 2008, 2010).

The rapid Chinese growth does have implications for emission reduction projections. While Chinese emissions have been growing rapidly, a large share of this growth was caused by relocation of production to China. Hence, emissions of other regions increase slower than was projected in earlier studies. Between 2004 and 2010, the baseline projections of the World Energy Outlook for 2020 have been revised upward for China with 75%, whereas the global emission projections for 2020 have only increased 6.7%. This is mainly because the emission projections for Western Europe and North America have been revised downwards with almost 20%. The implications of these changes for mitigation regimes are discussed in Chapter 5.

India's emissions are at much lower level than China, but the projected growth of emissions in India is generally faster than in China. In contrast to China, most studies further assume that the growth rate remains high for a longer period and may even increase.[3] For India, the change from CO_2 to CO_2-eq emissions is an important one as the contribution of non- CO_2 GHGs emissions are about the same as CO_2 emissions. This is mainly caused by a large contribution of methane from agriculture and livestock (Garg et al., 2004). The regional aggregation seems to matter less, as India's emissions make up the largest share of South Asian emissions.

[3] Interestingly, older studies (Rose et al. 1998, Berk and den Elzen 2001, Blanchard et al 2002) are at the upper range of the estimates for India, but the lower end for China. This can be seen as an indicator that China exceeded the growth expectations while India remains short of them.

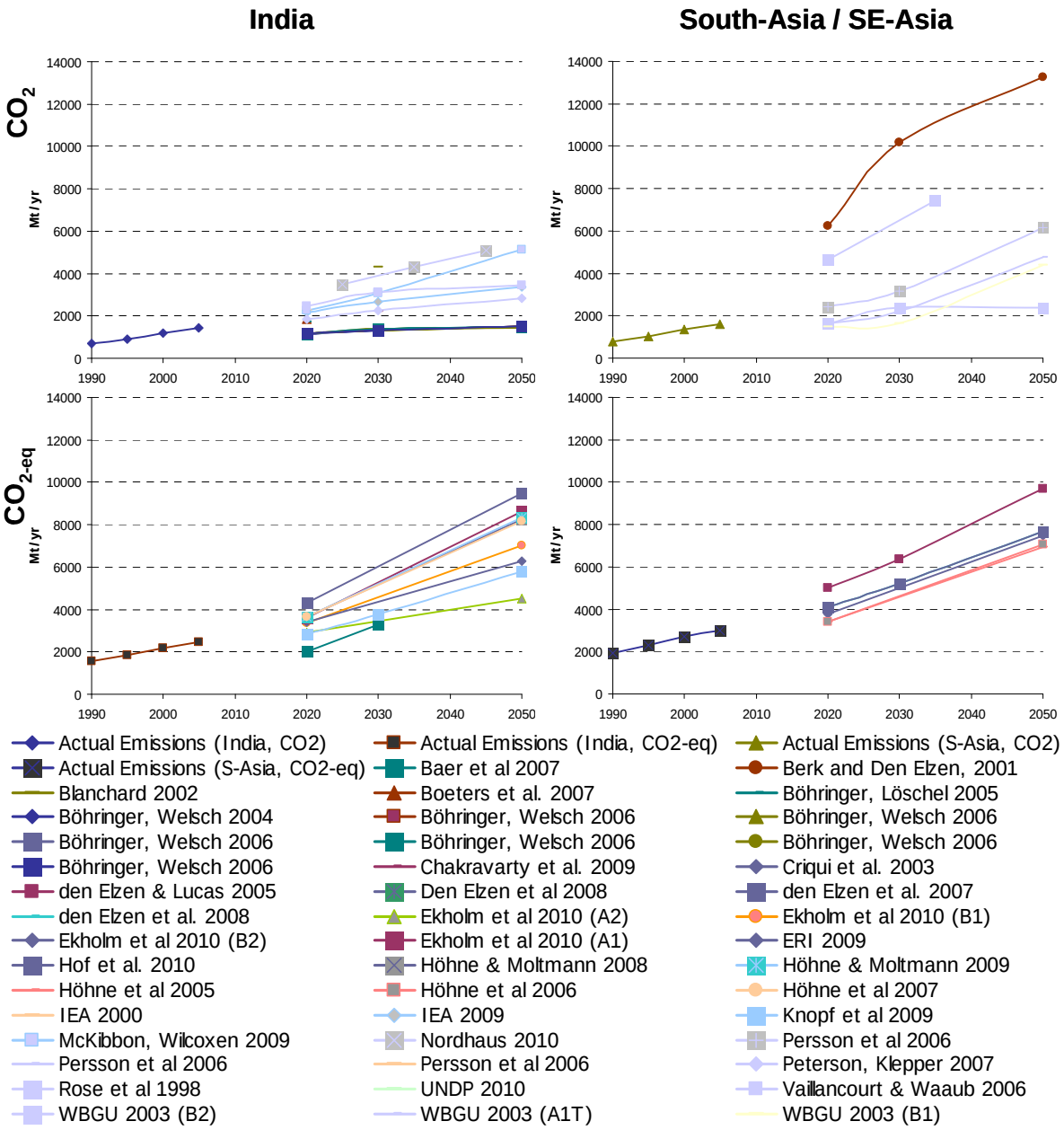

Figure 3: Baseline emissions for India. The top row shows baselines with CO_2 only, the bottom row includes all GHGs. At the left, studies with a regional aggregation of "India" are displayed, while in the right column India is part of a larger region. Actual emission data are taken from World Bank's WDI (World Bank, 2009).

3. Direct participation regimes

By far the most analysed "full and immediate participation" regime is Contraction and Convergence (C&C), which involves relatively simple allocation rules and combines a Grandfathering allocation in the early phase with an allocation based on per capita emissions in later periods. Other regimes are more particularly based on a single equity principle: Grandfathering, Equal per capita allocation, or Historic responsibility. So-called Multicriteria regimes combine several variables that could determine a possible allocation. This chapter describes the different proposed regimes (based on Blok et al., 2005) and presents detailed results of the assessed studies.

3.1 Contraction and convergence

In a Contraction and Convergence (C&C) regime (Meyer, 2000), all countries participate with quantified emission targets. In a first step, countries agree on a path of future global emissions that leads to an agreed long-term stabilisation level for greenhouse gas concentrations ('Contraction'). In a second step, the targets for individual countries are set so that per-capita emissions converge from the current level of the country to a level equal for all countries within a convergence period ('Convergence'). The convergence is calculated in a way that resulting global emissions follow the agreed global emission path.

Because the current per-capita emissions differ greatly between countries, the C&C regime implies that some developing countries could be allocated more emission allowances than necessary to cover their emissions ("hot air"). This would generate a flow of resources from developed to developing countries.

The strengths of this regime are the certainty about global emissions and the simple and clear concept. It also includes cost-effective reduction options in developing countries through full international emissions trading, support for the least developed countries through excess emission rights. The main weakness is that national circumstances (including historical responsibility) are not accommodated. The regime requires a substantial decrease in allowances relative to baseline emissions for developed countries with high per capita emissions, but also for some developing countries. Least developed countries need to be capable of participating in emissions trading (including national greenhouse gas inventories and emission trading authorities) and finally, excess emission rights for least developed countries need to be compensated by more stringent reduction targets for developed countries.

India's current position towards C&C regimes is generally positive. Though there is a general preference for Equal per capita allocation, in their National Action Plan on Climate Change, India states that their per capita GHG emissions will never exceed the average per capita GHG emissions of the developed industrialised countries (Government of India, 2008). The current position of China on C&C regimes is negative: China's per-capita emissions are currently around the global average and growth in emissions would be limited in the early part of the century.

Many studies analyse C&C regimes, as is shown in Table 4 for China and Table 5 for India. Most models show that a C&C regime requires larger reductions for China than for India, given the expected baseline development. Depending on the stabilisation target, substantial emission reductions are needed for China, whereas India has excess emission allowances in most cases. Hence, India can sell a large amount of permits on the international carbon market, while China can only sell permits in the near future and would buy additional permits in 2050.

Table 4: Comparison of allowances below baseline, costs and peaking year of several contraction and convergence analyses for China

China			Allowances			Costs			Cost	Peaking
Study	Regime	Stabilisation	2020	2030	2050	2020	2030	2050	measurement	
Berk and Den Elzen, 2001	C&C 2050	450 CO_2	-15%	-28%	-47%					2025
Blanchard 2002	C&C 2050	550 CO_2		-26%			0.1		f	
Böhringer, Helm 2008	C&C 2050	550 CO_2e						1.1	g	
Böhringer, Welsch 2004	C&C 2050	550 CO_2e	-22%	-38%	-58%			0.7	g	
Böhringer, Welsch 2006	C&C 2050	550 CO_2e	-22%	-37%	-58%			0.7	g	
Criqui et al. 2003	C&C 2050	650 CO_2e	-21%			-0.2			d	
Criqui et al. 2003	C&C 2100	650 CO_2e	-21%			-0.3			d	
Criqui et al. 2003	C&C 2050	550 CO_2e	-38%			-1.8			d	
Criqui et al. 2003	C&C 2100	550 CO_2e	-27%			-1.7			d	
den Elzen, Meinshausen 2006	C&C 2050	400 CO_2e	-57%	-72%	-86%	0.2	0.6	1.1	f	2010
den Elzen, Meinshausen 2006	C&C 2050	450 CO_2e	-46%	-62%	-80%	0.1	0.4	0.7	f	2015
den Elzen, Meinshausen 2006	C&C 2050	500 CO_2e	-32%	-51%	-75%	0.1	0.2	0.5	f	2020
den Elzen, Meinshausen 2006	C&C 2050	550 CO_2e	-24%	-42%	-66%	0.1	0.2	0.3	f	2020
den Elzen et al. 2005	C&C 2050	550 CO_2e	-18%	-42%	-64%	0.1	0.5	0.8	f	2015
den Elzen et al. 2005	C&C 2100	550 CO_2e	-20%	-44%	-66%	0.1	0.5	0.8	f	2015
den Elzen et al. 2005	C&C 2050	650 CO_2e	-9%	-17%	-38%	-0.1	0.1	0.2	f	2030
den Elzen et al. 2008	C&C 2050	450 CO_2e	-19%	-41%	-67%	0.2	0.7	0.8	f	2015
den Elzen et al. 2008	C&C 2050	550 CO_2e	-8%	-23%	-51%	0.0	0.1	0.5	f	2025
Hof et al. 2010	C&C 2050	500 CO_2e	-24%	-50%	-77%	0.5	1.6	1.2	f	
Hof et al. 2010	C&C 2050	550 CO_2e	-10%	-27%	-55%	0.0	0.3	0.6	f	2015
Hof et al. 2010	C&C 2050	620 CO_2e	-8%	-17%	-38%	0.0	0.1	0.2	f	2030
Höhne, Moltmann 2008	C&C 2050	450 CO_2e	-39%		-80%					
Höhne, Moltmann 2008	C&C 2050	550 CO_2e	-28%		-71%					
Höhne et al 2005	C&C 2050	550 CO_2e	-8%		-39%					
Höhne et al 2005	C&C 2050	450 CO_2e	-21%							
Höhne et al 2005	C&C 2050	400 CO_2e	-32%		-75%					
Höhne et al 2006	C&C 2050	550 CO_2e	-22%		-59%					
Höhne et al 2006	C&C 2050	650 CO_2e	-13%		-32%					
Höhne et al 2007	C&C 2050	450 CO_2e	-35%		-77%					
Höhne et al 2007	C&C 2050	550 CO_2e	-23%		-66%					
Knopf et al 2009	C&C 2050	400 CO_2	-43%	-59%	-84%					2015
Knopf et al 2009	C&C 2050	450 CO_2	-41%	-53%	-74%					2015
Kuntsi-Reunanen, Luukanen 2006	C&C 2050	400 CO_2								2015
Leimbach 2003	C&C 2025	450 CO_2						0.7	e	2025
Leimbach 2003	C&C 2100	450 CO_2						4.0	e	2030
Persson et al 2006	C&C 2050	450 CO_2	-41%	-48%	-66%	2.8	4.5	5.0	f	
Persson et al 2006	C&C 2100	450 CO_2	-38%	-54%	-71%	3.4	5.6	6.1	f	
Peterson, Klepper 2007	C&C 2050	550 CO_2e	-27%	-45%	-71%	-0.1	-0.6	3.0	d	2010
WBGU 2003 (A1T)	C&C 2050	450 CO_2	-25%	-41%	-69%	1.3		2.2	b	2030
WBGU 2003 (B1)	C&C 2050	400 CO_2	-40%	-54%	-78%	4.1		4.0	b	2020
WBGU 2003 (B2)	C&C 2050	400 CO_2	-26%	-38%	-79%	1.0		2.8	b	2020
WBGU 2003 (A1T)	C&C 2100	450 CO_2	-25%	-43%	-69%	1.4		2.1	b	2030
WBGU 2003 (B1)	C&C 2100	400 CO_2	-40%	-55%	-78%	4.2		4.0	b	2020
WBGU 2003 (B2)	C&C 2100	400 CO_2	-26%	-40%	-79%	1.0		2.8	b	2020

[b] Percentage change in GDP compared to baseline
[d] Percentage change in Welfare compared to baseline
[e] Consumption loss over the period 1990-2045 compared to baseline
[f] Direct costs as percentage of GDP
[g] Net present value of change in income

For China, the economic impacts of C&C regimes are generally negative. For 2020, some studies with relatively high stabilisation targets expect a minor gain, but most studies show costs increasing over time. For India, the economic impact of a C&C regime is mostly positive. Only Person et al. (2006) expect minor losses for India. Also Leimbach et al. (2010) find large economic losses of more than 4% of GDP on average over time (not in the table), but they combine a late convergence year (2100) with a stringent stabilisation target. The changes in GDP for China appear to correlate with the quantity of permits sold on the international carbon market, though for India this is less the case. One reason could be that India can possibly gain from selling fewer permits at a higher price.

Table 5: Comparison of allowances below baseline, costs and peaking year of several contraction and convergence analyses for India

India			Allowances			Costs			Cost	Peaking
Study	Regime	Stabilisation	2020	2030	2050	2020	2030	2050	measurement	
Berk and Den Elzen, 2001	C&C 2050	450 CO_2	-35%	-53%	-57%					2050
Blanchard 2002	C&C 2050	550 CO_2		13%			-0.4		f	
Böhringer, Helm 2008	C&C 2050	550 CO_2e						-17.3	g	
Böhringer, Welsch 2004	C&C 2050	550 CO_2e	19%	38%	86%			-15.2	g	
Böhringer, Welsch 2006	C&C 2050	550 CO_2e	18%	38%	85%			-15.2	g	
Criqui et al. 2003	C&C 2050	650 CO_2e	0%			-2.9			d	
Criqui et al. 2003	C&C 2100	650 CO_2e	-18%			-1.3			d	
Criqui et al. 2003	C&C 2050	550 CO_2e	-21%			-6.6			d	
Criqui et al. 2003	C&C 2100	550 CO_2e	-35%			-3.6			d	
den Elzen, Meinshausen 2006	C&C 2050	400 CO_2e	-13%	-38%	-72%	-0.3	-0.5	-0.4	f	2025
den Elzen, Meinshausen 2006	C&C 2050	450 CO_2e	11%	-15%	-61%	-0.2	-0.4	-0.5	f	2035
den Elzen, Meinshausen 2006	C&C 2050	500 CO_2e	39%	10%	-50%	-0.2	-0.5	-0.4	f	2045
den Elzen, Meinshausen 2006	C&C 2050	550 CO_2e	54%	30%	-32%	-0.2	-0.5	-0.5	f	2050
den Elzen et al. 2005	C&C 2050	550 CO_2e	5%	-12%	-33%	-0.2	-0.5	-0.7	f	2035
den Elzen et al. 2005	C&C 2100	550 CO_2e	-13%	-35%	-57%	0.0	0.2	0.4	f	2020
den Elzen et al. 2005	C&C 2050	650 CO_2e	17%	26%	16%	-0.1	-1.0	-1.3	f	
den Elzen et al. 2008	C&C 2050	450 CO_2e	12%	-1%	-31%	-0.9	-1.7	-1.1	f	2040
den Elzen et al. 2008	C&C 2050	550 CO_2e	27%	31%	2%	-0.3	-1.2	-1.5	f	
Hof et al. 2010	C&C 2050	500 CO_2e	7%	-13%	-48%	-3.5	-6.1	-2.0	f	
Hof et al. 2010	C&C 2050	550 CO_2e	26%	28%	0%	-1.4	-4.0	-3.5	f	2025
Hof et al. 2010	C&C 2050	620 CO_2e	30%	44%	38%	-0.8	-2.5	-3.2	f	> 2050
Höhne, Moltmann 2008	C&C 2050	450 CO_2e	-21%		-59%					
Höhne, Moltmann 2008	C&C 2050	550 CO_2e	-6%		-39%					
Höhne et al 2005	C&C 2050	550 CO_2e	11%		6%					
Höhne et al 2005	C&C 2050	450 CO_2e	-3%		-45%					
Höhne et al 2005	C&C 2050	400 CO_2e	-17%		-56%					
Höhne et al 2006	C&C 2050	550 CO_2e	0%		-35%					
Höhne et al 2006	C&C 2050	650 CO_2e	5%		9%					
Höhne et al 2007	C&C 2050	450 CO_2e	-20%		-59%					
Höhne et al 2007	C&C 2050	550 CO_2e	-5%		-39%					
Knopf et al 2009	C&C 2050	400 CO_2	-12%	-35%	-77%					2025
Knopf et al 2009	C&C 2050	450 CO_2	-9%	-26%	-61%					2030
Kuntsi-Reunanen, Luukanen 2006	C&C 2050	400 CO_2								2030
Leimbach 2003	C&C 2025	450 CO_2						-4.7	e	2025
Leimbach 2003	C&C 2100	450 CO_2						-1.0	e	2055
Persson et al 2006	C&C 2050	450 CO_2	-13%	-10%	-25%	0.1	0.1	-0.1	f	
Persson et al 2006	C&C 2100	450 CO_2	-31%	-37%	-59%	0.2	0.2	0.5	f	

Peterson, Klepper 2007	C&C 2050	550 CO_2e	-9%	-13%	-16%	-1.1	-6.3	-43.2	d	2010
WBGU 2003 (A1T)	C&C 2050	450 CO_2	78%	150%	35%	-5.3		0.3	b	2040
WBGU 2003 (B1)	C&C 2050	400 CO_2	75%	167%	-25%	-4.0		-4.5	b	2040
WBGU 2003 (B2)	C&C 2050	400 CO_2	67%	85%	15%			-2.5	b	2030
WBGU 2003 (A1T)	C&C 2100	450 CO_2	33%	33%	8%	-2.0		1.8	b	2050
WBGU 2003 (B1)	C&C 2100	400 CO_2	25%	56%	-42%	-0.2		-2.5	b	2040
WBGU 2003 (B2)	C&C 2100	400 CO_2	11%	8%	-15%	0.2		-3.8	b	2040

[b] Percentage change in GDP compared to baseline
[d] Percentage change in Welfare compared to baseline
[e] Consumption loss over the period 1990-2045 compared to baseline
[f] Direct costs as percentage of GDP
[g] Net present value of change in income

The results of regime calculations are sensitive to the parameter setting. Convergence takes place in most studies in 2050 or 2100. A convergence year in 2100 is basically a pro-industrialised countries proposal with Grandfathering for quite some time. Generally, choosing a later convergence year can have a slightly positive effect for China in the near future, as it postpones the reduction of emissions. However, later convergence years generally reduce allowances for later years and for India. In terms of economic effects, a later convergence year is negative for India in all studies that report multiple convergence years, for China the gain from moving to an earlier convergence year is less obvious. Aiming for a more stringent regime unambiguously reduces the allocation of permits available; this however does not necessarily imply higher costs. For China, a more stringent regime is more costly (except in Criqui et al. (2003)). For India, however, a more stringent regime is more preferable in the short run, since it leads to higher prices for its excess permits.

3.2 Grandfathering

In a Grandfathering regime, emission allowances are allocated on the basis of present day emissions. Hence, the currently larger emitters (industrialised countries) have acquired larger rights for future emission. For India and China, this implies a limited emission space, since current emissions are relatively low compared to expected baseline emissions. The strength and weakness of this approach is its advantage for industrialised countries and disadvantage for developing countries, which make it a preferred option for Annex I countries and a non-acceptable option for non-Annex I countries. We found no official positions of India and China on Grandfathering, but it can be expected that these will be negative.

In general, the results of Grandfathering are not favourable for India and China. In contrast to other regimes, India would not be allowed to have growing emissions from the very beginning despite having per capita emissions below the global average and is dependent on some emission growth to achieve economic development.[4] In contrast to other regimes, India would need to buy permits – a result that all studies find that assess this regime.

The specific results of this regime depend on the parameter setting for the allocation, and the base year for emission allocation. Especially the fact that Chinese emissions increased rapidly over the last years, influences the allocated emission allowances for China. Peterson and Klepper (2007) find that in spite of having to reduce emissions quite substantially below baseline, China would still be able to sell permits due to its low abatement cost, so that the economic burden is not excessive. Böhringer and Löschel (2005), Böhringer and Welsch (2006), and Rose et al. (1998) find that China would not be

[4] To address this issue, some studies include an income threshold, only countries with an average per capita income above this level are bound to reduce emissions, see e.g. den Elzen and Lucas (2005). However, this makes the regime one that is no longer “direct”.

a large player on the carbon market, but its cost would be higher than the global average. McKibbin and Wilcoxen (2009) allow China a fast growth until 2012 when the allocation rule is fixed, hence giving it a high allocation. The implementation of den Elzen and Lucas (2005) includes an income threshold for participation, which allows India to follow baseline developments until 2030.

Table 6: Comparison of allowances below baseline, costs and peaking year of several Grandfathering analyses for China.

China			Allowances			Costs			Cost	Peaking
Study	Regime	Stabilisation	2020	2030	2050	2020	2030	2050	measurement	
Böhringer, Löschel 2005	GF	550 CO_2e	-25%			0.5			a	
Böhringer, Welsch 2006	GF	550 CO_2e	-26%	-42%	-64%			2.1	g	
Böhringer, Welsch 2006	GF	550 CO_2e	-26%	-42%	-64%			2.1	g	
den Elzen, Lucas 2005	GF	550 CO_2e	-14%	-48%	-72%	0.0	0.6	1.2	f	2015
den Elzen, Lucas 2005	GF	650 CO_2e	-9%	-23%	-47%	0.0	0.1	0.3	f	2025
Jacoby et al 2008	GF	450 CO_2e				0.1		0.4	a	
McKibbon, Wilcoxen 2009	GF	550 CO_2e	-16%	-34%	-60%	1.3	1.9	1.6	b	2030
Peterson, Klepper 2007	GF	550 CO_2e	-31%	-49%	-73%	-0.1	-0.2	7.5	d	2010
Rose et al 1998	GF	Other[5]	-17%	-14%		0.2	0.2		f	

[a] Percentage change in consumption compared to baseline
[b] Percentage change in GDP compared to baseline
[d] Percentage change in Welfare compared to baseline
[f] Direct costs as percentage of GDP
[g] Net present value of change in income

Table 7: Comparison of allowances below baseline, costs and peaking year of several Grandfathering analyses for India.

India			Allowances			Costs			Cost	Peaking
Study	Regime	Stabilisation	2020	2030	2050	2020	2030	2050	measurement	
Böhringer, Löschel 2005	GF	550 CO_2e	-17%			0.2			a	
Böhringer, Welsch 2006	GF	550 CO_2e	-23%	-39%	-60%			1.7	g	
Böhringer, Welsch 2006	GF	550 CO_2e	-23%	-39%	-60%			1.7	g	
den Elzen, Lucas 2005	GF	550 CO_2e	0%	0%	-41%	-0.1	-0.5	-0.5	f	2035
den Elzen, Lucas 2005	GF	650 CO_2e	0%	0%	-35%	-0.1	0.0	0.1	f	2035
Jacoby et al 2008	GF	450 CO_2e				4.9		11.4	a	
McKibbon, Wilcoxen 2009	GF	550 CO_2e	-18%	-36%	-64%	2.1	3.7	6.0	b	2035
Peterson, Klepper 2007	GF	550 CO_2e	-34%	-54%	-77%	1.4	4.9	25.8	d	2010
Rose et al 1998	GF	Other[6]	-16%	-14%		0.1	0.1		f	

[a] Percentage change in consumption compared to baseline
[b] Percentage change in GDP compared to baseline
[d] Percentage change in Welfare compared to baseline
[f] Direct costs as percentage of GDP
[g] Net present value of change in income

3.3 Equal per capita allocation and CSE convergence

Equal per capita allocation of emission allowances is based on the egalitarian equity principle: all humans have the same right to economic wealth and thus arguable to emit greenhouse gases. An immediate start of allocating emission rights according to this approach implies a huge transfer of allowances from industrialised countries to developing countries. Countries that are currently below the global average emissions per capita, would gain large excess emission rights (which can be

[5] 20% below 1990 in 2010, keep this level until 2050
[6] 20% below 1990 in 2010, keep this level until 2050

traded), while countries with high emissions per capita would need to buy extra allowances. The strength of this approach is its relatively simple egalitarian basis, providing similar rights to all humans. Its weakness is that it deviates so much from the current situation of emissions, that it will not be acceptable to industrialised countries. The Indian government has stated for a long time that a future regime should be based on Equal per capita emission rights (Government of India, 2002).

Generally, the results of Equal per capita allocation is beneficial for India, due to its currently low emissions per capita. Rose et al. (1998) as well as Böhringer and Welsch (2006) find much higher gains for India under Equal per capita than in other regimes that are analysed in these studies. For China, however, they find gains higher than other scenarios, but much lower than for India. Person et al. (2006) who look into ambitious stabilisation level, and generally find high mitigation costs for China in all regimes, conclude that China would face a loss in the long run in this regime. The same study finds that India would gain relatively little (0.1 to 0.3%). Jacoby et al. (2008) find large gains for both China and India a population based allocation approach.

Contrary, McKibbon and Wilcoxen (2009) argue that China would be better off with an allocation based on 2012 emissions which would yield a higher allocation for China because of its fast growth until 2012. Therefore, under a pure population based scenario welfare losses are higher for China, reducing its ability to sell permits on the international market and China is hence confronted with welfare losses of up to 3.5% in 2050. India on the other hand would profit from such an allocation scheme and gain (although little) over almost the whole simulation time span, as revenue can make up for income losses.

An alternative to the Equal per capita regime is CSE-convergence, named after a proposal by the Centre for Science and Environment (CSE, 1998). This is a contraction and convergence regime, though with a minimum per capita level of emissions at the global sustainable emission level. For both India and China, the results of this regime do not deviate significantly from other convergence regimes. Emission allowances for China, up to 60% below baseline in 2050, are comparable to other regimes. For India, this regime yields initially a surplus of allowances, comparable to C&C regimes, but lower than instantaneous Equal per capita regimes. In terms of economic impact, this Indian surplus allowances lead to gains of over 1% of GDP, whereas for China the costs increase with the emission reductions, up to 0.8% of GDP.

Table 8: Comparison of allowances below baseline, costs and peaking year of several Equal per capita analyses for China.

China Study	Regime	Stabilisation	Allowances 2020	Allowances 2030	Allowances 2050	Costs 2020	Costs 2030	Costs 2050	Cost measurement	Peaking
Böhringer, Helm 2008	Equal PC	550 CO_2e						-1.3	g	
Böhringer, Welsch 2006	Equal PC	550 CO_2e	-4%	-28%	-58%			-0.2	g	
Jacoby et al 2008	Equal PC	450 CO_2e				-5.3		-2.2	a	
McKibbon, Wilcoxen 2009	Equal PC	550 CO_2e	-44%	-60%	-78%	1.8	3.0	3.5	b	
Persson et al 2006	Equal PC	450 CO_2	-11%	-36%	-66%	-0.6	2.6	5.0	f	
Rose et al 1998	Equal PC	Other[7]	14%	-4%		-0.7	-0.1		f	
den Elzen, Lucas 2005	CSE	550 CO_2e	-13%	-40%	-64%	0.0	0.4	0.8	f	2015
den Elzen, Lucas 2005	CSE	650 CO_2e	-2%	-14%	-38%	0.0	0.0	0.2	f	2030

[a] Percentage change in consumption compared to baseline
[b] Percentage change in GDP compared to baseline
[f] Direct costs as percentage of GDP
[g] Net present value of change in income

[7] 20% below 1990 in 2010, keep this level until 2050

Table 9: Comparison of allowances below baseline, costs and peaking year of several Equal per capita analyses for India

India Study	Regime	Stabilisation	Allowances 2020	2030	2050	Costs 2020	2030	2050	Cost measurement	Peaking
Böhringer, Helm 2008	Equal PC	550 CO_2e						-26.8	g	
Böhringer, Welsch 2006	Equal PC	550 CO_2e	269%	190%	85%			-21.6	g	
Jacoby et al 2008	Equal PC	450 CO_2e				-20.9		-21.0	a	
McKibbon, Wilcoxen 2009	Equal PC	550 CO_2e	161%	95%	19%	-0.6	-0.7	0.3	b	
Persson et al 2006	Equal PC	450 CO_2	130%	71%	-22%	-0.3	-0.3	-0.1	f	
Rose et al 1998	Equal PC	Other[8]	108%	70%		-2.4	-1.1		f	
den Elzen, Lucas 2005	CSE	550 CO_2e	54%	14%	-33%	-1.0	-1.3	-0.7	f	2020
den Elzen, Lucas 2005	CSE	650 CO_2e	82%	61%	16%	0.0	-0.6	-0.5	f	

[a] Percentage change in consumption compared to baseline
[b] Percentage change in GDP compared to baseline
[f] Direct costs as percentage of GDP
[g] Net present value of change in income

3.4 Historic Responsibility

Historic responsibility (HR) regimes are based on the equity principle of responsibility and the polluter pays principle. Historic responsibility is also often referred to as the Brazilian Proposal, since Brazil proposed in 1997 HR as a method to differentiate emission reduction targets between Annex I countries for the Kyoto Protocol (UNFCCC, 1997).The proposal suggested that reductions towards an overall emission ceiling were to be shared among individual countries proportional to their relative share of responsibility for climate change. The relative share of responsibility for climate change of different countries can be estimated based on their contribution to the increase of global-average surface temperature over a certain period of time (den Elzen et al., 2005a). This requires a complex analysis to attribute country's contributions to temperature change based on historic emissions (see e.g. Höhne et al., 2010). In general, HR implies that countries with a longer process of industrialisation and thus a longer record of greenhouse gas emissions will have a greater share of responsibility for emission reductions than countries, which industrialised later. If emissions from land-use change and forestry are taken into account, also some developing countries will have relatively high contributions.

The Brazilian proposal is the only proposal made officially by a developing country and is still officially discussed under the UNFCCC. Its weakness, however, is that the original method can only be applied to absolute emission reductions, that contributions to temperature increase involve relatively complex calculations and that the method generally leads to very high reductions requirements for countries with large historical emissions.

In general, both the Chinese (NDRC, 2009) and Indian (Government of India, 2009) governments favour approaches based on historic responsibility. In China, a more stringent implementation of this approach is often discussed, in which historic responsibility is not defined on the country level (as in the Brazilian Proposal) but on a per capita basis (see Section 5).

Blanchard (2002) provides a quantitative estimate for this proposal, finding very small gains of about 0.05% of GDP in 2030 for both India and China. Rive et al. (2006) further investigate the effect of updating emission data and the rising share of responsibility for India and China. They conclude that with updating, developing countries would have a similar burden in terms of percent GDP as

[8] 20% below 1990 in 2010, keep this level until 2050

developed countries in 2045, thus violating the polluter pays principle. Some studies include an income threshold, rendering it a regime with gradual participation. This is especially important for India, as e.g. in den Elzen et al. (2005b) and den Elzen and Lucas (2005) India is not committed to emission reductions in the early stage.

Table 10: Comparison of allowances below baseline, costs and peaking year of several Historic responsibility analyses for China.

China			Allowances			Costs			Cost	Peaking
Study	Regime	Stabilisation	2020	2030	2050	2020	2030	2050	measurement	
Berk and Den Elzen, 2001	HR	450 CO_2	-13%	-28%	-45%					2015
Blanchard 2002	HR	550 CO_2		-12%			0.0		f	
den Elzen et al. 2005	HR	550 CO_2e	-15%	-41%	-65%	0.0	0.3	0.7	f	2020
den Elzen et al. 2005	HR	650 CO_2e	0%	0%	-26%	0.0	-0.3	-0.1	f	2040
Knopf et al 2009	HR	550 CO_2	-32%	-42%	-60%					2015
Bode et al. 2004	HR	450 CO_2	10%	5%	5%					

[f] Direct costs as percentage of GDP

Table 11: Comparison of allowances below baseline, costs and peaking year of several Historic responsibility analyses for India.

India			Allowances			Costs			Cost	Peaking
Study	Regime	Stabilisation	2020	2030	2050	2020	2030	2050	measurement	
Berk and Den Elzen, 2001	HR	450 CO_2	-37%	-62%	-74%					2015
Blanchard 2002	HR	550 CO_2		-9%			-0.1		f	
den Elzen et al. 2005	HR	550 CO_2e	0%	0%	-33%	-0.1	-0.6	-1.3	f	2035
den Elzen et al. 2005	HR	650 CO_2e	0%	0%	0%	-0.4	-0.6	-0.5	f	>2050
Knopf et al 2009	HR	550 CO_2	5%	-9%	-41%					2050
Bode et al. 2004	HR	450 CO_2	25%	19%	19%					

[f] Direct costs as percentage of GDP

3.5 Multicriteria and other regimes

Multicriteria approaches attempt to combine several of the above described approaches that are more directly based on equity principles into a more balanced regime. This type of regime is more flexible, but at the same time involves a large number of parameters which implies less transparency and many differences between studies.

Combinations of possible criteria are analysed by Vaillancourt and Waaub (2006). The authors implement a concept where several criteria are used – and countries put weights on criteria that are beneficial for their allocation. This gives a good overview what criteria might be preferred from a Chinese or Indian perspective. According to the results, there is an overlap in attractiveness for cumulative and per capita emissions. For India, however, also other factors like land area and emissions per area of land might be attractive (as several other developing countries) which are not shared with China. In most cases, China has substantial costs which in several cases could even exceed those of developed countries. In contrast, India could have income gains in the best scenario. A comparable regime is the Global Compromise (GC) of Müller (1999), analysed by den Elzen and Lucas (2005). In this regime, countries “vote” according to their most beneficial options: distributing emission allowances by Grandfathering or equal per capita. The emission shares per region are determined as the weighted mean between population and Grandfathering. Under this regime, China’s emission allowances are comparable to many other scenarios. India receives a large surplus of allowances, and corresponding economic gains.

Vaillancourt et al. (2008) evaluate outcome based allocation scenarios, i.e. allocation carried out in a way that a certain welfare outcome is achieved. This is assuming no region should profit from a international climate regime and permits are allocated so that abatement cost per capita are set in a fixed ratio to per capita GDP (PPP) or per capita GDP (PPP) squared. The later would be beneficial for poorer regions. In fact, for India this would be attractive and for China not. Vaillancourt et al. (2008) use the global MARKAL model that indicates rather high abatement costs for China due to its coal based energy system, and China and India both reduce their emissions relative to the baseline more than the world average. Rose et al. (1998) come to similar results for horizontal equity, a regime that allocates emission rights such that percentage cost in GDP is equalized across all countries: by definition, both India and China face the same costs in terms of per capita GDP as the rest of the world, and both will sell some permits as they are compensated somewhat for abating much. For the vertical equity approach that puts a higher burden on higher income countries, the results in Rose et al. differ in that both India and China would not face any costs, i.e. are allocated a number of permits that just offsets the cost of abatement. One reason for this result for China is that the estimated economic growth was lower than in the later study by Vaillancourt et al. (2008).

The Multicriteria approach of den Elzen and Lucas (2005) is a variant of the C&C, with a time-dependent Multicriteria index based on population, economy and emissions. The weight of emissions is initially equal to 1 (Grandfathering) but converge to an equal weight of each indicator over time. This approach is not beneficial for China and India. Although China's reduction requirements are less in 2050 than for other regimes, they are relatively high in 2020. India faces considerable reductions of 10-14% below baseline in 2020 as well in this approach (Table 12 and Table 13).

In the comparison of regimes (Section 6) we lump these regime together as Multicriteria group.

Table 12: Comparison of allowances below baseline, costs and peaking year of several Multicriteria analyses for China

China			Allowances			Costs			Cost	Peaking
Study	**Regime**	**Stabilisation**	**2020**	**2030**	**2050**	**2020**	**2030**	**2050**	**measurement**	
den Elzen, Lucas 2005	MCC	550 CO_2e	-20%	-44%	-63%	0.2	0.5	0.7	f	2015
den Elzen, Lucas 2005	MCC	650 CO_2e	-12%	-21%	-38%	0.0	0.1	0.2	f	2030
Rose et al 1998	MCC	Other[9]	-28%	-35%		0.3	0.5		f	
Vaillancourt, Waaub 2006	MCC	550 CO_2	-22%	-36%	-34%			-0.4	f	
Vaillancourt, Waaub 2006	MCC	550 CO_2	-18%	-32%	-28%			-0.1	f	
Vaillancourt et al. 2008	Hor	550 CO2	-27%	-40%	-44%			-0.7	f	
Vaillancourt et al. 2008	Vert	550 CO2	-28%	-41%	-48%			-0.8	f	
Rose et al 1998	Hor	Other[10]	-12%	-9%		0.1	0.1		f	
Rose et al 1998	Vert	Other[11]	-9%	-7%		0.0	0.0		f	
den Elzen, Lucas 2005	GC	550 CO_2e	-10%	-37%	-63%	0.0	0.3	0.7	f	2015
den Elzen, Lucas 2005	GC	650 CO_2e	-1%	-9%	-34%	0.0	0.0	0.1	f	2030

[f] Direct costs as percentage of GDP

[9] 20% below 1990 in 2010, keep this level until 2050
[10] 20% below 1990 in 2010, keep this level until 2050
[11] 20% below 1990 in 2010, keep this level until 2050

Table 13: Comparison of allowances below baseline, costs and peaking year of several Multicriteria analyses for India.

India			Allowances			Costs			Cost	Peaking
Study	Regime	Stabilisation	2020	2030	2050	2020	2030	2050	measurement	
den Elzen, Lucas 2005	MCC	550 CO_2e	-14%	-34%	-47%	0.1	0.2	-0.1	f	2020
den Elzen, Lucas 2005	MCC	650 CO_2e	-10%	-17%	-32%	-0.5	0.0	0.1	f	
Rose et al 1998	MCC	Other[12]	27%	8%		-0.8	-0.2		f	
Vaillancourt, Waaub 2006	MCC	550 CO_2	-25%	-31%	-23%			-0.5	f	
Vaillancourt, Waaub 2006	MCC	550 CO_2	0%	-10%	-3%			0.2	f	
Vaillancourt et al. 2008	Hor	550 CO2	-23%	-36%	-13%			-0.4	f	
Vaillancourt et al. 2008	Vert	550 CO2	-21%	-34%	-12%			-0.4	f	
Rose et al 1998	Hor	Other[13]	-16%	-12%		0.1	0.1		f	
Rose et al 1998	Vert	Other[14]	-11%	-8%		0.0	0.0		f	
den Elzen, Lucas 2005	GC	550 CO_2e	59%	16%	-34%	-1.1	-1.3	-0.7	f	2015
den Elzen, Lucas 2005	GC	650 CO_2e	73%	74%	11%	-0.4	-0.7	-0.4	f	2030

[f] Direct costs as percentage of GDP

3.6 Regimes without a global cap on emissions

Next to the regimes discussed in the previous sections, which were based on allocating a global cap on emissions, there are many other regime proposals that are based on rather loose targets and proposals by (groups of) countries. These are firstly the Triptych approach, a sector-based mechanism to distribute emission reductions among countries. This is a method that is still closely related to the regimes discussed above. Secondly, a global carbon tax scheme is a straightforward way to reduce emissions. Thirdly, emission intensity targets, which can be interpreted bottom-up, in line with the Chinese and Indian submitted action targets at the COP 15 in Copenhagen, or as top-down method to express a burden-sharing regime. Finally, technology regimes have been proposed, like the Asia Pacific Partnership for Clean Development and Climate, and could be used for the diffusion of clean technologies without a global climate agreement. This section briefly discusses the main arguments of these regimes, the findings of existing studies and the implication for India and China.

3.6.1 Triptych & sectoral approaches

Sectoral approaches can either be absolute or indexed targets for sectors within a country, such as heavy industry, the power sector or agriculture. Advantages of sectoral approaches are that these could potentially increase the coverage of climate policy, because developing countries are reluctant to approach with a fixed cap. Furthermore, sectoral approaches might reduce competitiveness issues and account of differences in the national industry structures. The Triptych approach (Groenenberg et al., 2004) is a sectoral approach that includes only few economic sectors, and can be used to determine national targets. Other approaches start from the assumption that not all sectors and countries are included or face different (implicit) carbon prices (see e.g. Akimoto et al., 2008; Schmidt et al., 2008), hence these regimes do not minimize global abatement costs. These proposals also include measures to promote technology transfer (see section 3.6.4).

The Triptych approach originally covered three sectors (the heavy industry sector, the power sector and the domestic sector) and was later extended to include also process emissions from industry, agriculture, waste and land-use change and forestry. The emissions of the sectors are treated

[12] 20% below 1990 in 2010, keep this level until 2050
[13] 20% below 1990 in 2010, keep this level until 2050
[14] 20% below 1990 in 2010, keep this level until 2050

differently: For 'electricity production and industrial production', a growth in the physical production is assumed together with an improvement in production efficiency. This takes into account the need for economic development but constant improvement of efficiency. For the 'domestic' sectors, convergence of per-capita emissions is assumed. This takes into account the converging living standard of the countries. For the remaining sectors similar rules are applied. The allowances of the sectors are added up to a national allowance for each country (i.e., no sectoral targets are set to allow countries the flexibility to pursue any cost-effective emission reduction strategy). The implications of a Triptych regime would be substantial reductions for the industrialised countries, especially those with carbon intensive industries. For most developing countries substantial emission increases are allowed.

The strength of this approach is that is takes account of national circumstances, it explicitly allows for economic growth at improving efficiency in all countries and aims to treat internationally competitive industries on same level. The methodology has been successfully applied on the EU level as basis for negotiating targets. The weaknesses are the high complexity, the approach requires many decisions and sectoral data, making global application a challenge, and it may be perceived as not transparent. Also, agreement on required projections of production growth rates for heavy industry and electricity may be difficult.

There is no official position of China or India on this approach. However, India would be one of the countries with high allowed increases, and might support the approach (Blok et al., 2005). For China, a cap on emissions could be required relatively early, but it might be attractive due to its competitive industry sector.

The results of analyses of this regime are very dependent on parameter settings. Den Elzen and Lucas (2005) conclude that this regime leads to an outcome where costs are spread out more evenly across countries than other proposals. The scenarios by Ekholm et al. (2010) show initial allowances above baseline for China, followed by reductions on the long-term. In most studies of Höhne et al. (2008; 2007; 2005), Chinese emissions have to be below baseline already by 2020. For India, most studies require emissions below baseline on the short term.

Table 14: Comparison of allowances relative to baseline, costs or economic impact and peaking year of several trypich analyses for China.

China			Allowances			Costs			Cost	Peaking
Study	Regime	Stabilisation	2020	2030	2050	2020	2030	2050	measurement	
den Elzen, Lucas 2005	TY	650 CO_2e	-10%	-22%	-43%	0.0	0.1	0.2	f	2030
den Elzen et al 2008	TY	450 CO_2	-3%	-16%	-34%					2020
Ekholm et al 2010 (A1)	TY	450 CO_2e	5%		-77%	-0.1		1.5	f	
Ekholm et al 2010 (A2)	TY	450 CO_2e	3%		-63%	-0.1		1.8	f	
Ekholm et al 2010 (B1)	TY	450 CO_2e	2%		-73%	-0.2		1.8	f	
Ekholm et al 2010 (B2)	TY	450 CO_2e	9%		-73%	-0.2		2.1	f	
Ekholm et al 2010 (A1)	TY	550 CO_2e	12%		-54%	-0.1		-0.2	f	
Ekholm et al 2010 (A2)	TY	550 CO_2e	10%		-36%	-0.1		-0.2	f	
Ekholm et al 2010 (B1)	TY	550 CO_2e	10%		-47%	-0.1		-0.6	f	
Ekholm et al 2010 (B2)	TY	550 CO_2e	16%		-46%	-0.2		-0.4	f	
Groenenberg et al, 2004	TY	450 CO_2								2020
Höhne, Moltmann 2008	TY	450 CO_2e	-36%		-77%					
Höhne, Moltmann 2008	TY	550 CO_2e	-24%		-66%					
Höhne et al 2005	TY	550 CO_2e	-7%		-32%					
Höhne et al 2005	TY	450 CO_2e	-23%		-69%					
Höhne et al 2005	TY	400 CO_2e	-30%		-81%					
Höhne et al 2007	TY	450 CO_2e	-34%		-75%					
Höhne et al 2007	TY	550 CO_2e	-22%		-62%					

[f] Direct costs as percentage of GDP

Table 15: Comparison of allowances relative to baseline, costs or economic impact and peaking year of several trypich analyses for India.

India			Allowances			Costs			Cost	Peaking
Study	Regime	Stabilisation	2020	2030	2050	2020	2030	2050	measurement	
den Elzen, Lucas 2005	TY	650 CO_2e	-1%	-4%	-25%	0.0	-0.1	0.0	f	
den Elzen et al 2008	TY	450 CO_2	-9%	-7%	-38%					2050
Ekholm et al 2010 (A1)	TY	450 CO_2e	-15%		-70%	-0.1		-1.5	f	
Ekholm et al 2010 (A2)	TY	450 CO_2e	-6%		-49%	-0.1		-1.8	f	
Ekholm et al 2010 (B1)	TY	450 CO_2e	-15%		-64%	-0.1		-1.5	f	
Ekholm et al 2010 (B2)	TY	450 CO_2e	-11%		-58%	-0.1		-0.6	f	
Ekholm et al 2010 (A1)	TY	550 CO_2e	-2%		-47%	-0.1		-1.6	f	
Ekholm et al 2010 (A2)	TY	550 CO_2e	6%		-19%	-0.1		-1.5	f	
Ekholm et al 2010 (B1)	TY	550 CO_2e	-2%		-40%	-0.1		-1.7	f	
Ekholm et al 2010 (B2)	TY	550 CO_2e	1%		-31%	-0.1		-1.7	f	
Groenenberg et al, 2004	TY	450 CO_2								2045
Höhne, Moltmann 2008	TY	450 CO_2e	-42%		-68%					
Höhne, Moltmann 2008	TY	550 CO_2e	-21%		-49%					
Höhne et al 2005	TY	550 CO_2e	6%		-21%					
Höhne et al 2005	TY	450 CO_2e	-14%		-63%					
Höhne et al 2005	TY	400 CO_2e	-29%		-75%					
Höhne et al 2007	TY	450 CO_2e	-39%		-68%					
Höhne et al 2007	TY	550 CO_2e	-21%		-52%					

[f] Direct costs as percentage of GDP

3.6.2 Global carbon tax

One of the most straightforward proposals for future climate policy is a global carbon tax. This approach would lead to the global equalisation of marginal abatement costs. Hence, a cost efficient

reduction of emissions is ensured without emissions trading. Most proposed taxes increase progressively over time, in order to reduce emissions in line with climate goals. The strength of the approach are its advantages with respect to simplicity, dynamic flexibility, associated uncertainties and administrational and political feasibility (Nordhaus, 2006), although not all authors agree with these arguments (e.g. van Drunen et al., 2009). Also, in the case of uncertainty of marginal abatement costs, a price mechanism can reduce the volatility of carbon prices e.g. in case of a growth shock (McKibbin and Wilcoxen, 2009).

The weakness of such approach is that it is easy for governments to devise schemes to weaken the effects of the harmonized tax by domestically refunding revenues (depending on the approach) or merely replace existing energy taxes in order to keep the total tax rate as low as possible in an international context (see for example Hoel, 1993). Another disadvantage is that a global carbon tax does not distinguish between developed and developing countries. Studies generally find a larger burden from global tax regimes for developing countries than for developed countries (e.g. Hof et al., 2009b; van Vuuren et al., 2009). In theory, a differentiated tax or introduction of financial transfers could equalize the cost burden amongst countries, but this would complicate the carbon tax implementation. A differentiated tax lead to lower tax rate in developing countries, hence cheap abatement options there would not be exploited and effectiveness of the tax is reduced. There is no official position of China or India on a global carbon tax regime, but given the relatively high costs for developing countries, it is not likely that China or India will support such regime.

Only a few papers explicitly show the outcomes of a regime with harmonized global taxes (see Table 16 and Table 17). As no emission trading is applied under a globally harmonized tax, it is possible to separate the abatement effect and the permission trade effect where both are reported, even though this ignores general equilibrium effects of a different distribution of wealth. Also cap-and trade studies that report who is selling and who is buying emission rights provide information on whether a tax or a cap-and trade system is preferable for certain countries.

Table 16: Comparison of allowances below baseline, costs and peaking year of several carbon tax analyses for China.

China			Emissions			Costs			Cost	Peaking
Study	**Regime**	**Stabilisation**	**2020**	**2030**	**2050**	**2020**	**2030**	**2050**	**measurement**	
Nordhaus 2010	Tax	500 CO_2	-25%	-30%	-36%	0.1	0.1	0.2	c	2015
Nordhaus 2010	Tax	430 CO_2	-40%	-53%	-70%	0.5	0.8	1.3	c	2020
Peterson, Klepper 2007	Tax	550 CO_2e	-53%	-64%	-76%	1.8	3.3	9.4	d	2010
van Vuuren et al. 2009	Tax	450 CO_2e	-18%	-40%	-73%	0.6	1.6	1.7	f	2015

[c] Percentage change in GDP compared to baseline, including climate damages,
[d] Percentage change in Welfare compared to baseline
[f] Direct costs as percentage of GDP

Table 17: Comparison of allowances below baseline, costs and peaking year of several carbon tax analyses for India.

China			Emissions			Costs			Cost	Peaking
Study	**Regime**	**Stabilisation**	**2020**	**2030**	**2050**	**2020**	**2030**	**2050**	**measurement**	
Nordhaus 2010	Tax	500 CO_2	-19%	-23%	-28%	0.0	0.0	0.0	c	2035
Nordhaus 2010	Tax	430 CO_2	-31%	-42%	-54%	0.2	0.3	0.5	c	2035
Peterson, Klepper 2007	Tax	550 CO_2e	-30%	-48%	-72%	1.0	3.0	17.4	d	2010
van Vuuren et al. 2009	Tax	450 CO_2e	-17%	-41%	-71%	0.7	2.1	2.3	f	2015

[c] Percentage change in GDP compared to baseline, including climate damages,
[d] Percentage change in Welfare compared to baseline
[f] Direct costs as percentage of GDP

Under simplified theoretical conditions, such as perfect markets, a globally harmonized carbon tax is equivalent to a cap and trade system where emission rights are auctioned and where the allocation is the same as the resulting emission levels under the tax. Compared to a tax system, sellers of emission rights in a cap and trade system with the same carbon price and global emission reductions are better off, while buyers are worse off. Table 18 gives an overview on whether China and India are buyers or sellers in the different cap and trade studies analysed so far. In most of them, India and China are sellers of carbon permits, so that they are better off than under a harmonized global carbon tax. This is also the case in Peterson and Klepper (2007) who conclude that carbon taxes compared to a C&C regime are not favourable for developing countries in general and imply a wrong burden-sharing so that they are not acceptable. Yet, this argumentation does not hold for China anymore when considering more recent emission estimates[15]. Person et al. (2006) or Leimbach (2003) also find that China would need to buy permits even in a C&C regime. In such case a tax system might be preferable for China compared to a regime where China needs to buy permits.

Summarized, while India has certainly to carry a much larger burden under a globally harmonized carbon tax than in the cap-and-trade scenarios discussed so far, the evidence for China is mixed. An additional transfer system to ensure an equitable burden-sharing is likely to be necessary in any case.

[15] In unpublished runs with more recent data, China is buying permits in later years (personal communication).

Table 18: India's and China's position in the emission trading market in the cap-an-trade studies. In brackets sub-periods or specific parameter settings. (*) refers to differentiated emission reductions for developed and developing countries.

	China		India	
Regime	Buyer	Seller	Buyer	Seller
C&C	Leimbach 2003, Person et al. 2006, WBGU 2003 (after 2020)	Blanchard 2002, Böhringer and Welsch 2006, Criqui et al 2003, Peterson and Klepper 2007, Boeters et al 2007, WBGU 2003 (after 2020)	Person et al 2006 (convergence year 2100)	WBGU 2003, Blanchard 2002, Böhringer and Welsch 2006, Criqui ert al 2003, Leimbach et al 2003, Person et al (convergence year 2050), Peterson and Klepper 2007
HR		Blanchard 2002		Blanchard 2002
TY		Ekholm et al 2010		Ekholm et al 2010
EI		Blanchard 2002		Blanchard 2002
Horizontal		Rose et al 1998		Rose et al 1998
Vertical		Rose et al 1998		Rose et al 1998
AtP		Böhringer and Welsch 2006, Jacoby et al 2008		Böhringer and Welsch 2006, Jacoby et al 2008
MS		Criqui et al 2003, Boeters et al 2007		Criqui et al 2003, Boeters et al 2007
Sov	Böhringer and Welsch 2006 (2020), Rose et al (2030)	Böhringer and Welsch 2006 (2030-2050), Peterson and Klepper 2007, Böhringer and Löschel 2005, Rose et al 1998 (2020), Jacoby et al 2008 (*), McKibbon and Wilcoxen 2009	Böhringer and Welsch 2006, Peterson and Klepper 2007, Böhringer and Löschel 2005, McKibbon and Wilcoxen 2009	Rose et al 1998, Jacoby et al 2008 (*)
Equal per Capita	Person et al 2006 (2020), McKibbon and Wilcoxen 2009	Böhringer and Welsch 2006, Person et al 2006 (2030-2050), Rose et al 1998, Jacoby et al 2008		Böhringer and Welsch 2006, Person et al 2006, Rose et al 1998, Jacoby et al 2008, McKibbon and Wilcoxen 2009

3.6.3 Intensity Targets

To establish emission targets without affecting the development process negatively, dynamic emission targets are proposed that depend on GDP growth. The Chinese and Indian proposals as well as the studies analysed assume a target for emission intensity, defined as emissions relative to GDP. Intensity targets reduce the impact of uncertainty of future economic growth on a countries obligations, especially in developing countries (Peterson, 2008). The weakness of this approach is its uncertainty on emissions: when economic growth increases, emissions will increase as well.

The position of China and India on intensity targets seems positive, since the domestic mitigation actions proposed after the Copenhagen Conference by China and India are also expressed as such. China aims to reduce its intensity by 40-45% in 2020 relative to 2005; India's target is 20-25% improvement in the same time frame.

In literature on burden sharing, the concept of intensity targets is interpreted in different ways. Some studies regard it a bottom-up method, in which countries place their own targets, such as currently under the Copenhagen Accord (Blanchard, 2002). Other studies use a top down approach, starting with a global cap and expressing regional emission reductions in terms of a conversion in emission intensity (den Elzen and Lucas, 2005), as a way to allocate emission allowances (Leimbach et al., 2010).

Leimbach et al. (2010) assume a uniform emission intensity, to allocate emission permits as a linear function of GDP. This allocation favours countries with low carbon intensity but also countries that have a high (per capita) GDP. Under this rule, developed countries receive more permits than they would obtain in e.g. a per-capita allocation. For developing countries, this is particularly harmful in the beginning, when these countries are still lagging behind in terms of both emission intensity and GDP. Such a regime would be costly for India and China. Relative to other regimes, however, an equal intensity target is not always more expensive for China. It would only be little more expensive than a C&C regime for China, but much more expensive for India.

Blanchard (2002) implemented a scenario in which emission intensities are expressed relative to the baseline. Such a regime would still lead to gains for India, but compared to a C&C regime, the gains from carbon trading would be lower as the initial allocation is lower. Blanchard concludes that for China an intensity target regime would be better than a C&C regime. One reason for this might be that there is already a strong downward trend in intensities in China and not so much in India.

Table 19: Comparison of allowances below baseline, costs and peaking year of other regime analyses for China.

China			Allowances			Costs			Cost	Peaking
Study	**Regime**	**Stabilisation**	**2020**	**2030**	**2050**	**2020**	**2030**	**2050**	**measurement**	
Blanchard 2002	EI	550 CO_2		-10%			-0.1		f	
den Elzen, Lucas 2005	EI	550 CO_2e	-20%	-42%	-73%	0.2	0.6	1.5	f	2015
den Elzen, Lucas 2005	EI	650 CO_2e	-3%	-12%	-37%	0.0	0.0	0.2	f	2030

[f] Direct costs as percentage of GDP

Table 20: Comparison of allowances below baseline, costs and peaking year of other regime analyses for India.

India			Allowances			Costs			Cost	Peaking
Study	**Regime**	**Stabilisation**	**2020**	**2030**	**2050**	**2020**	**2030**	**2050**	**measurement**	
Blanchard 2002	EI	550 CO_2		-9%			0.0		f	
Den Elzen, Lucas 2005	EI	550 CO_2e	-4%	-19%	-59%	-0.5	-0.6	0.9	f	2030
Den Elzen, Lucas 2005	EI	650 CO_2e	0%	0%	-21%	0.0	-0.2	-0.1	f	2045

[f] Direct costs as percentage of GDP

3.6.4 Technology regimes

Another type of regimes aims at providing better technological cooperation (Barrett, 2007; de Coninck et al., 2008). Instead of focusing on participation and compliance, such an approach would give an incentive to cooperate. This is also the strength of this regime; there is a greater incentive to participate because of gains from sharing new technologies. However, without a given reduction

target the weakness of this regime lies in its environmental effectiveness, i.e. it is not clear whether an ambitious emission target can be met. Since there is no global target for emissions, modelling such a policy needs a different framework than those used for burden-sharing; technological progress has to be addressed explicitly. Therefore it is difficult to obtain a quantitative comparison to many of the burden-sharing regimes.

A model approach with directed technological change has been carried out in the WITCH model, coming to the conclusion that if effort is put into R&D this might reduce the negative impact on GDP but it is questionable whether an ambitious climate target can be reached (Bosetti et al. 2008). Buchner and Carraro (2005) reach similar results when they use a technology agreement as sole regime. They argue that under certain conditions, technology regimes can still be stable and lead to a shift in the optimal abatement pathway when a quantitative goal is agreed on. From the environmental effectiveness perspective, technology cooperation should act as a complement rather than a substitute to an international agreement. Arguing qualitatively, there are several channels of how China and India could be affected from such a policy regime. One key question is here how funding for a global R&D activity is derived. In McKibbins and Wilcoxen's proposal, funding should be relative to GDP (Bodanski 2004), therefore China and India would be confronted with a rising burden over time. On the other hand, all countries might profit from lower marginal abatement costs as research is assumed to bring technologies that either provide low carbon substitutes or reduce the cost of carbon abatement. Depending on what technology is developed, this could have different implementations on India and China. As both countries are dependent on coal, the availability of CCS, for example, would be beneficial for these countries in order to reduce their emissions.[16] Technological innovations that improve energy efficiency could likewise be preferable for China and India as their energy efficiency lags behind developed countries. Technology improvements could also bring ancillary benefits, e.g. in aspects of health or energy security, or spill-overs to other sect. On the other hand, if a R&D policy is not coupled with a price for carbon, this might mean that cheap abatement potentials might not be exploited in China or India. While in this second best policy without a tax or cap-and-trade scheme no direct economic impacts would be the consequence, this would mean efficiency is not adhered to on a global scale, i.e. reaching a given climate target might become more costly.

[16] China and India are already participating in technology initiatives aiming at knowledge sharing in the area of CCS and hydrogen technology. Both countries also participate in the Asia Pacific Partnership on Clean Development and Climate which aims at improvements in several industries. However, budgets are relatively small and have lead to little effect so far (de Coninck et al., 2008). These existing examples show that there is much greater willingness from the Chinese or Indian side to contribute to an agreement compared to joining a regime with fixed emission caps.

4. Gradual participation regimes

The regimes discussed in this section are all based on gradual participation; countries join international climate policy when they reach certain thresholds. These thresholds are mostly related to mitigation capability (i.e. income levels) and responsibility (emission level). The most well-known example here, the Multi-stage approach, is a rather flexible regime, in which countries follow consecutive stages with different types of commitments, depending on their capacity and responsibility. Variants of this approach are common but differentiated convergence (CDC) and the South-North proposal. A rather straightforward approach is Ability to Pay (AtP) in which emission reductions are allocated according to the economic capacity of countries. Income Distribution (ID, or development rights) is basically a refinement of Ability to Pay, in which the share of rich or poor people are taken into account when distributing emission allowances.

4.1 Multi-stage

In the Multi-stage regime (Berk and den Elzen, 2001; den Elzen et al., 2006), countries follow consecutive stages with different commitments. For instance, the first stage could involve no commitments, the second stage could involve emission intensity targets and the third stage could involve absolute emission reduction targets (e.g. based on per capita convergence). Graduation of countries to the next stage can, for instance, be dependent on economic activity (GDP per capita), average per capita emissions relative to the global average or a combination of these two. The Multi-stage approach is rather flexible as the number of stages, the targets in the different stages and the graduation criteria can vary between different studies. In order to reach stringent targets, more countries will need to participate relatively early. Such participation in climate policy would be at substantially lower per capita emissions and GDP levels than when Annex I countries joined. Model outcomes critically depend on the time when large countries such as China and India enter the system.

The strength of the Multi-stage approach is the gradual phasing in of countries, in line with UNFCCC's spirit of taking into account national circumstances. It is a general framework that can accommodate many ideas and satisfy many demands and it allows for gradual decision making. It should also contribute to trust-building, as industrialized countries have to take the lead. The weakness of Multi-stage is that it is a relatively complex concept that requires many decisions and allows for exceptions. There is a risk that countries enter too late, so that some long-term low stabilisation options are lost. Finally, countries would need an incentive to participate (although this might apply to other regimes as well).

Table 21 and Table 22 show the results of Multi-stage analysis for India and China of several publications. They show that emission allowances for China are, depending on the stabilisation target, generally increasing from 10-15% below baseline in 2020 to 40-80% below baseline in 2050. Correspondingly, costs increase from low levels to 1-4% of GDP in 2050. Peaking of emissions takes place rather soon, 2020-2025 for the more stringent climate targets.

Table 21: Comparison of allowances below baseline, costs and peaking year of several Multi-stage analyses for China.

China			Allowances			Costs			Cost	Peaking
Study	Regime	Stabilisation	2020	2030	2050	2020	2030	2050	measurement	
Berk, den Elzen, 2001	MS	450 CO_2	-1%	-21%	-43%					2025
Boeters et al. 2007	MS	450 CO_2e	-10%			-0.4			b	
Criqui et al. 2003	MS	550 CO_2e	-30%			-3.8			d	
Criqui et al. 2003	MS	550 CO_2e	-35%			-2.7			d	
Criqui et al. 2003	MS	550 CO_2e	-10%			-7.1			d	
Criqui et al. 2003	MS	650 CO_2e	-11%			-0.9			d	
Criqui et al. 2003	MS	650 CO_2e	-11%			-0.9			d	
Criqui et al. 2003	MS	650 CO_2e	-7%			-1.1			d	
den Elzen, Meinshausen 2006	MS	400 CO_2e	-25%	-52%	-79%	0.2	0.6	1.2	f	2015
den Elzen, Meinshausen 2006	MS	450 CO_2e	-21%	-45%	-73%	0.1	0.4	0.8	f	2015
den Elzen, Meinshausen 2006	MS	500 CO_2e	-13%	-31%	-64%	0.0	0.2	0.5	f	2020
den Elzen, Meinshausen 2006	MS	550 CO_2e	-12%	-28%	-57%	0.0	0.1	0.4	f	2020
den Elzen et al. 2005	MS	550 CO_2e	-13%	-37%	-69%	0.0	0.3	1.0	f	2015
den Elzen et al. 2005	MS	650 CO_2e	-1%	-9%	-34%	-0.1	-0.1	0.1	f	2040
den Elzen et al. 2008	MS	450 CO_2e	-23%	-43%	-70%	0.3	0.8	0.9	f	2010
den Elzen et al. 2008	MS	550 CO_2e	-4%	-21%	-54%	0.0	0.1	0.5	f	2020
Ekholm et al 2010 (A1)	MS	450 CO_2e	-2%		-83%	0.0		3.7	f	
Ekholm et al 2010 (A2)	MS	450 CO_2e	-6%		-75%	-0.1		3.6	f	
Ekholm et al 2010 (B1)	MS	450 CO_2e	-11%		-81%	0.0		3.9	f	
Ekholm et al 2010 (B2)	MS	450 CO_2e	1%		-81%	-0.1		3.6	f	
Ekholm et al 2010 (A1)	MS	550 CO_2e	7%		-66%	-0.1		-0.3	f	
Ekholm et al 2010 (A2)	MS	550 CO_2e	5%		-35%	-0.1		0.3	f	
Ekholm et al 2010 (B1)	MS	550 CO_2e	-1%		-54%	-0.1		0.2	f	
Ekholm et al 2010 (B2)	MS	550 CO_2e	12%		-53%	-0.1		1.1	f	
Hof et al. 2010	MS	500 CO_2e	-2%	-38%	-90%	-1.0	0.4	2.1	f	
Hof et al. 2010	MS	550 CO_2e	-2%	-20%	-54%	-0.2	0.1	0.5	f	2020
Hof et al. 2010	MS	620 CO_2e	-1%	-8%	-30%	-0.1	-0.1	0.0	f	2030
Höhne, Moltmann 2008	MS	450 CO_2e	-36%		-91%					
Höhne, Moltmann 2008	MS	550 CO_2e	-16%		-83%					
Höhne, Moltmann 2009	MS	350 CO_2e	-39%		-94%					
Höhne et al 2005	MS	550 CO_2e	0%		-22%					
Höhne et al 2005	MS	450 CO_2e	-10%		-66%					
Höhne et al 2005	MS	400 CO_2e	-28%							
Höhne et al 2007	MS	450 CO_2e	-35%		-89%					
Höhne et al 2007	MS	550 CO_2e	-17%		-63%					

[b] Percentage change in GDP compared to baseline
[d] Percentage change in Welfare compared to baseline
[f] Direct costs as percentage of GDP

For India, starting at a much lower level of emissions and economic activity than China, the mitigation effort under Multi-stage regimes increases from no obligations (or positive allowances, under specific implementations, see Ekholm et al. (2010)) to 10-60% below baseline in 2050. Mitigation costs are low, or even gains in most scenarios, and peaking of emissions is late, in the period 2030-2045.

Table 22: Comparison of allowances below baseline, costs and peaking year of several Multi-stage analyses for India.

India			Allowances			Costs			Cost	Peaking
Study	Regime	Stabilisation	2020	2030	2050	2020	2030	2050	measurement	
Berk and Den Elzen, 2001	MS	450 CO_2	-14%	-34%	-58%					2030
Boeters et al. 2007	MS	450 CO_2e	-5%			-0.1			b	
Criqui et al. 2003	MS	550 CO_2e	-8%			-8.6			d	
Criqui et al. 2003	MS	550 CO_2e	-8%			-8.5			d	
Criqui et al. 2003	MS	550 CO_2e	-19%			-7.3			d	
Criqui et al. 2003	MS	650 CO_2e	0%			-3.0			d	
Criqui et al. 2003	MS	650 CO_2e	0%			-3.0			d	
Criqui et al. 2003	MS	650 CO_2e	0%			-3.0			d	
den Elzen, Meinshausen 2006	MS	400 CO_2e	0%	-4%	-61%	-0.4	-1.5	-0.2	f	2035
den Elzen, Meinshausen 2006	MS	450 CO_2e	0%	-4%	-47%	-0.2	-0.7	-0.4	f	2040
den Elzen, Meinshausen 2006	MS	500 CO_2e	0%	-4%	-37%	-0.1	-0.4	-0.2	f	2045
den Elzen, Meinshausen 2006	MS	550 CO_2e	0%	-4%	-29%	-0.1	-0.3	-0.2	f	2045
den Elzen et al. 2005	MS	550 CO_2e	0%	-4%	-29%	-0.2	-0.8	-1.1	f	2045
den Elzen et al. 2005	MS	650 CO_2e	0%	0%	0%	-0.1	-0.2	-0.7	f	
den Elzen et al. 2008	MS	450 CO_2e	0%	0%	-32%	-0.5	-1.8	-1.0	f	2040
den Elzen et al. 2008	MS	550 CO_2e	0%	0%	-8%	-0.1	-0.5	-1.2	f	
Ekholm et al 2010 (A1)	MS	450 CO_2e	24%		-63%	-0.3		-11.4	f	
Ekholm et al 2010 (A2)	MS	450 CO_2e	30%		0%	-0.4		-8.6	f	
Ekholm et al 2010 (B1)	MS	450 CO_2e	18%		-31%	-0.4		-9.5	f	
Ekholm et al 2010 (B2)	MS	450 CO_2e	32%		-26%	-0.5		-2.0	f	
Ekholm et al 2010 (A1)	MS	550 CO_2e	26%		-33%	-0.2		-3.9	f	
Ekholm et al 2010 (A2)	MS	550 CO_2e	32%		15%	-0.4		-3.6	f	
Ekholm et al 2010 (B1)	MS	550 CO_2e	20%		-11%	-0.3		-4.4	f	
Ekholm et al 2010 (B2)	MS	550 CO_2e	33%		-1%	-0.4		-3.2	f	
Hof et al. 2010	MS	500 CO_2e	0%	0%	-8%	-1.3	-10.1	-10.9	f	
Hof et al. 2010	MS	550 CO_2e	0%	0%	-8%	-0.3	-1.6	-3.0	f	> 2050
Hof et al. 2010	MS	620 CO_2e	0%	0%	0%	-0.2	-0.5	-0.8	f	> 2050
Höhne, Moltmann 2008	MS	450 CO_2e	0%		-32%					
Höhne, Moltmann 2008	MS	550 CO_2e	0%		-14%					
Höhne, Moltmann 2009	MS	350 CO_2e	-20%		-87%					
Höhne et al 2005	MS	550 CO_2e	0%		-2%					
Höhne et al 2005	MS	450 CO_2e	-2%		-23%					
Höhne et al 2005	MS	400 CO_2e	0%		-20%					
Höhne et al 2007	MS	450 CO_2e	0%		-32%					
Höhne et al 2007	MS	550 CO_2e	0%		-15%					

[b] Percentage change in GDP compared to baseline
[d] Percentage change in Welfare compared to baseline
[f] Direct costs as percentage of GDP

4.2 Common but Differentiated Convergence

The Common but Differentiated Convergence (CDC) regime (Höhne et al., 2006; Höhne et al., 2005) is an alternative, staged implementation of per capita convergence regimes. This regime leaves room for developing countries to have temporarily higher emissions. In this approach, Annex I countries'

per capita emission allowances converge within a certain time period (e.g., from 2010 to 2050) to an equal level for all countries. Individual Non-Annex I countries' per capita emissions also converge within 40 years to the same level but convergence starts from the date when their per capita emissions reach a certain percentage threshold of the (gradually declining) global average. Non-Annex I countries that do not pass this percentage threshold do not have binding emission reduction requirements. Either they take part in the Clean Development Mechanism or they voluntarily take on "positively binding" emission reduction targets. The CDC approach aims at Equal per capita allowances in the long run. However, in contrast to C&C it takes into account historical responsibility. Annex I countries would have to reduce emissions similarly to C&C, but many Non-Annex I countries have more time to develop without emission reduction requirements. Non-Annex I country participation is conditional to Annex I action through the gradually declining world average threshold. In this regime, no "hot air" would occur.

The strengths of the CDC regime are that it applies simple rules, making it a transparent and comprehensive approach. The delayed action of Non-Annex I countries takes account of the responsibility for past emissions. It provides certainty about global emissions and eliminates the component of "hot air", as no excess allowances for low emission countries are included. The main weakness is that this regime is possibly too simple and not considering detailed national circumstances.

The numeric results of analyses of CDC regimes in literature are shown in Table 23 and Table 24. For low atmospheric greenhouse gas stabilisation levels, this regime requires average effort from China on the short term. On the longer term (2050) the Chinese emission allowances are comparable to other regimes, 60-80% below baseline for low stabilisation levels. This pattern is also reflected in the economic impacts. On the short term, the low targets in CDC lead to economic gains for China, but on the longer term the costs increase with higher emission reductions. For India, the CDC regime does hardly yield any reduction requirements on the short term, but for 2050 the studies show significant reductions below baseline.

Table 23: Comparison of allowances below baseline, costs and peaking year of several CDC analyses for China.

China			Allowances			Costs			Cost	Peaking
Study	Regime	Stabilisation	2020	2030	2050	2020	2030	2050	measurement	
Hof et al. 2010	CDC	500 CO_2e	-4%	-41%	-82%	-0.7	0.6	1.5	f	
Hof et al. 2010	CDC	550 CO_2e	0%	-20%	-53%	-0.2	-0.2	0.3	f	2020
Hof et al. 2010	CDC	620 CO_2e	0%	0%	-21%	-0.2	-0.2	0.0	f	2035
Höhne, Moltmann 2008	CDC	450 CO_2e	-7%		-83%					
Höhne, Moltmann 2008	CDC	550 CO_2e	-33%		-74%					
Höhne, Moltmann 2009	CDC	350 CO_2e	-46%		-94%					
Höhne et al 2005	CDC	550 CO_2e	-1%		-25%					
Höhne et al 2005	CDC	450 CO_2e	-14%		-71%					
Höhne et al 2005	CDC	400 CO_2e	-39%		-86%					
Höhne et al 2006	CDC	550 CO_2e	-22%		-58%					
Höhne et al 2006	CDC	650 CO_2e	-2%		-19%					
Höhne et al 2007	CDC	450 CO_2e	-41%		-81%					
Höhne et al 2007	CDC	550 CO_2e	-24%		-67%					

† Direct costs as percentage of GDP

Table 24: Comparison of allowances below baseline, costs and peaking year of several CDC analyses for India.

India			Allowances			Costs			Cost	Peaking
Study	Regime	Stabilisation	2020	2030	2050	2020	2030	2050	measurement	
Hof et al. 2010	CDC	500 CO_2e	0%	0%	-36%	-2.4	-11.8	-4.9	f	
Hof et al. 2010	CDC	550 CO_2e	0%	0%	0%	-0.6	-1.3	-1.8	f	2040
Hof et al. 2010	CDC	620 CO_2e	0%	0%	0%	-0.4	-0.7	-0.9	f	> 2050
Höhne, Moltmann 2008	CDC	450 CO_2e	-30%		-52%					
Höhne, Moltmann 2008	CDC	550 CO_2e	0%		-26%					
Höhne, Moltmann 2009	CDC	350 CO_2e	0%		-86%					
Höhne et al 2005	CDC	550 CO_2e	0%		0%					
Höhne et al 2005	CDC	450 CO_2e	-2%		-36%					
Höhne et al 2005	CDC	400 CO_2e	-5%		-67%					
Höhne et al 2006	CDC	550 CO_2e	0%		-28%					
Höhne et al 2006	CDC	650 CO_2e	-2%		0%					
Höhne et al 2007	CDC	450 CO_2e	-16%		-52%					
Höhne et al 2007	CDC	550 CO_2e	0%		-26%					

† Direct costs as percentage of GDP

4.3 South North Dialogue proposal

The South North Dialogue proposal (den Elzen et al., 2007; Ott et al., 2004) can be seen as a developing country alternative to the Multi-stage regime. This approach includes differentiated obligations for different classes of developing countries. In this proposal, non-Annex I countries are divided in newly industrialised countries (NIC), rapidly industrialising developing countries (RIDC), least developed countries (LDC) and "other" developing countries. All these groups have different emission reduction objectives. LDC's and other DC's have no reduction targets, RIDC's have absolute emission limitations, if funding is provided by Annex I countries and NIC's have absolute emission limitation or reduction targets.

China is classified as rapidly industrialising developing country, which means that it has to take absolute emission targets, but has access to financial and technological resources from Annex I countries. This leads to "average" emission reductions compared to other regimes (Table 25). India is initially classified as "other DC", and only becomes a rapidly industrialising developing country by 2040. This means that there are no obligations in the short term, but that meaningful emission reductions of 25-64% below baseline are required by 2050 (Table 26), depending on the atmospheric stabilisation level.

Table 25: Comparison of allowances below baseline, costs and peaking year of several S-N analyses for China.

China			Allowances			Costs			Cost	Peaking
Study	Regime	Stabilisation	2020	2030	2050	2020	2030	2050	measurement	
den Elzen et al. 2007	S-N	400 CO_2e	-16%		-78%					
den Elzen et al. 2007	S-N	450 CO_2e	-13%		-67%					
den Elzen et al. 2007	S-N	500 CO_2e	-10%		-44%					
den Elzen et al. 2007	S-N	550 CO_2e	-10%		-31%					

Table 26: Comparison of allowances below baseline, costs and peaking year of several S-N analyses for India.

India			Allowances			Costs			Cost	Peaking
Study	Regime	Stabilisation	2020	2030	2050	2020	2030	2050	measurement	
den Elzen et al. 2007	S-N	400 CO_2e	0%		-64%					
den Elzen et al. 2007	S-N	450 CO_2e	0%		-63%					
den Elzen et al. 2007	S-N	500 CO_2e	0%		-30%					
den Elzen et al. 2007	S-N	550 CO_2e	0%		-25%					

4.4 Ability to pay

The Ability to Pay regimes take financial resources of countries into account for the allocation of emission allowances. This regime is directly based on the equity principle of capability: the richer a country is, the more capable it is expected to be in mitigating greenhouse gas emissions. The original of Ability to Pay was launched by Jacoby et al. (1999) as a bottom up approach for burden-sharing. This approach included a welfare threshold, above which emission reductions between countries are allocated according to welfare per capita. In the current literature, two different approaches exist for Ability to Pay regimes. Jacoby et al. (2008) take a resource sharing approach and allocate the emission rights on the basis of the inverse share of a countries' GDP (hence, richer countries obtain less emission rights than poorer countries). Contrary, Böhringer and Löschel (2005) and den Elzen and Lucas (2005) use a burden-sharing approach in which the emission reduction requirements are distributed according to regional shares in GDP (hence, richer countries have to reduce emissions further than poorer countries).

The strength of Ability to Pay is that it is in principle a rather straightforward allocation mechanism that simply allows differentiation between developed and developing countries. However, it takes no account of responsibility (either historic or current). Also, the variants of this regime with thresholds have a tendency to become rather complicated and strongly dependent on parameterisations.

While Indian and Chinese per capita GDP is currently relatively low compared to developed countries, especially China is seen to be catching up. Hence an Ability to Pay scheme is attractive for China only in the near future (Table 27). For India, with its lower per capita GDP, the prospects of receiving a large share of emission rights even in the longer term is much better (Table 28). Jacoby et al. (2008) conclude that there would be large positive changes in welfare in India, which is allowed to grow and able to sell a large share of its allowances in 2050. China is worse off, as it would still be a seller on the carbon market, but the gains from permit selling do not fully compensate for domestic abatement cost.

Table 27: Comparison of allowances below baseline, costs and peaking year of several Ability to Pay analyses for China.

China			Allowances			Costs			Cost	Peaking
Study	Regime	Stabilisation	2020	2030	2050	2020	2030	2050	measurement	
Böhringer, Löschel 2005	AtP	550 CO_2e	-3%			-0.3			a	
den Elzen, Lucas 2005	AtP	550 CO_2e	-11%	-37%	-64%	0.0	0.2	0.7	f	2020
den Elzen, Lucas 2005	AtP	650 CO_2e	0%	-7%	-36%	0.0	-0.1	0.1	f	2030
Jacoby et al 2008	AtP	450 CO_2e				2.7		7.7	a	

[a] Percentage change in consumption compared to baseline
[f] Direct costs as percentage of GDP

Table 28: Comparison of allowances below baseline, costs and peaking year of several Ability to Pay analyses for India.

India			Allowances			Costs			Cost	Peaking
Study	Regime	Stabilisation	2020	2030	2050	2020	2030	2050	measurement	
Böhringer, Löschel 2005	AtP	550 CO_2e	-4%			-0.1			a	
den Elzen, Lucas 2005	AtP	550 CO_2e	0%	0%	-35%	-0.1	-0.5	-0.8	f	2035
den Elzen, Lucas 2005	AtP	650 CO_2e	0%	0%	-1%	0.0	-0.1	-0.3	f	
Jacoby et al 2008	AtP	450 CO_2e				-39.9		-48.9	a	

[a] Percentage change in consumption compared to baseline
[f] Direct costs as percentage of GDP

4.5 Income distribution

Two proposed regimes allocate emission allowances on the basis of income distribution (Baer et al., 2008; Chakravarty et al., 2009), which can be seen as an advanced variation on the principle of Ability to Pay. The proposals for Income Distribution regimes are framed in two different ways. First, the approach of Greenhouse Development Rights (GDR) (Baer et al., 2008) starts from the point that poor people (in developing countries) have a need for further development. In this approach, emission allowances are allocated on the basis of both responsibility and capability, with the latter being represented by a countries population share below a global poverty line. The second approach, by Chakravarty et al. (2009), starts from the opposite direction, as it allocates emission reductions according to "high emitting individuals" in a country. Population above a certain income threshold is a dominant parameter in this equation.

The strength of these approaches is their attempt to take into account the real responsibility or capability of a country, based on the behaviour of citizens. The weakness is that it requires detailed information on poverty or income distribution, which is generally not reliably available for many developing countries.

In terms of reductions below baseline, these proposals do not deviate much from other regimes (Table 29 and Table 30). The 25-40% reduction for China is around the average of all regimes. For India, there is a clear distinction between reduction up to 22% below baseline for Baer et al. (2008) and zero to five percent reduction in the approach of Chakravarty et al. (2009). Economic impacts are only available from Baer et al. (2008) in 2020, and are in line with the reductions targets, i.e. higher for China than for India.

Table 29: Comparison of allowances below baseline, costs and peaking year of other regime analyses for China.

China			Allowances			Costs			Cost	Peaking
Study	Regime	Stabilisation	2020	2030	2050	2020	2030	2050	measurement	
Baer et al 2007	ID	400 CO_2e	-16%	-40%		0.7			f	
Chakravarty et al. 2009	ID	400 CO_2		-25%						
Chakravarty et al. 2009 (P)	ID	400 CO_2		-28%						
Höhne, Moltmann 2008	ID	450 CO_2e	-28%		-78%					
Höhne, Moltmann 2008	ID	550 CO_2e	-19%		-66%					
Höhne, Moltmann 2009	ID	350 CO_2e	-17%		-74%					

[f] Direct costs as percentage of GDP

Table 30: Comparison of allowances below baseline, costs and peaking year of other regime analyses for India.

India			Allowances			Costs			Cost	Peaking
Study	Regime	Stabilisation	2020	2030	2050	2020	2030	2050	measurement	
Baer et al 2007	ID	400 CO_2e	-9%	-22%		0.2			f	
Chakravarty et al. 2009	ID	400 CO_2		0%						
Chakravarty et al. 2009 (P)	ID	400 CO_2		5%						
Höhne, Moltmann 2008	ID	450 CO_2e	-11%		-60%					
Höhne, Moltmann 2008	ID	550 CO_2e	-7%		-47%					
Höhne, Moltmann 2009	ID	350 CO_2e	-6%		-56%					

[f] Direct costs as percentage of GDP

5. Recent literature from Asia

5.1 Chinese proposals and considerations

As part of the Copenhagen accord, the mitigation action plan of China for 2020 pledges to reduce CO_2 emissions per unit of GDP by 40-45% compared to 2005, to increase non-fossil fuels in primary energy consumption to around 15% and to increase forest coverage by 40 million ha and forest stock volume by 1.3 billion m^3 relative to 2005 levels.

Recently, two climate policy scenarios for China have been published. ERI (2009) explores the possibilities for low-carbon development in China, under two scenarios: low-carbon and enhanced low carbon development. Both scenarios include a reduction of 9% below baseline in 2020, increasing to 31% and 60% in 2050. The emission control and emission abatement scenarios of the UNDP (2010) China Human Development Report are slightly more ambitious, with 11% reduction below baseline in 2020 and 41%/66% in 2050. In the latter case, the underlying modelling study from Renmin University, foresees rather fierce macro economic impacts, up to 10% reduction of GDP compared to baseline.

Table 31: Overview of recent low carbon scenarios for China

China			Emissions			Costs			Cost
Study	Regime	Stabilisation	2020	2030	2050	2020	2030	2050	measurement
ERI 2009	Low-carbon		-9%	-26%	-31%				
ERI 2009	Enhanced low-carbon		-9%	-30%	-60%				
UNDP 2010	Emission control		-11%	-37%	-41%	-1.6	-2.9	-4.6	b
UNDP 2010	Emission abatement		-11%	-37%	-66%	-1.6	-2.9	-9.9	b

[b] Percentage change in GDP compared to baseline

Recent literature on burden-sharing regimes from Chinese authors focuses mainly on Historic responsibility. While the Brazilian proposal is based on Historic responsibility of countries, Chinese considerations focus on the concept of cumulative emissions per capita. Hu et al. (2009) determined the historic emissions of greenhouse gases in terms of cumulative per capita emissions since pre-industrial levels. They find that China's contribution to climate change in terms of cumulative per capita emissions is about 50% below the global average, whereas the Historic responsibility of China in national terms is above the global average of countries.

Several studies have put forward proposals for burden-sharing regimes on the basis of cumulative per capita emissions. The Project Team of the Development Research Centre of the State Council (2009) developed a theoretical framework for National Emission Accounts that distinguishes

between historic emissions and future emissions under a future climate regime. In a theoretical example, equal cumulative per capita emissions are the basis for calculations of both periods. Historic emissions are balanced on the basis of the historic global average per capita emissions (i.e. a carbon debt for developed countries and a surplus for developing countries), while the emission rights for a future period are allocated on Equal per capita basis as well. Balancing both historic and future emission rights leads to a total negative emission space for industrialised regions and a large positive emission surplus for developing countries.

Ding et al. (2009) published a global implementation of such equal cumulative per capita regime under a 470 ppm CO_2 stabilisation target. They determined future emission quota's on the basis of Equal per capita emissions for the period 1900-2050, using population of 2005. Countries were classified in four groups: countries that 1) have emission deficits, 2) need to reduce gross emissions, 3) need to reduce emission growth rates and 4) can maintain current growth rates. The future quotas were compared to expected future emissions on the basis of announced climate policy and some simple assumptions for other countries and the authors find that expected global emissions exceed the target with 15 ppm CO_2 by 2050 (no attempt is made to reduce emissions further). The authors estimated the monetary value of the excess emissions of industrialised countries at 5.53 trillion USD historically and 6.3 trillion USD for the 2006-2050 period, using a carbon price of 20 \$/tCO_2. In this study, future emissions for China are peak in 2035 at a level of 14000 MtCO_2/year, and decrease to 8700 MtCO_2/year in 2050. Ding et al. (2010) published an updated analysis for China under a cumulative per capita regime using four emission scenarios: the highest scenario peaking in 2035 at 14000 MtCO_2/year and decreasing to 8700 MtCO_2/year in 2050, the lowest scenario peaking in 2025 at 10300 MtCO_2/year and decreasing to 3300 MtCO_2/year in 2050. All these emissions are considerably higher than the allowances in the studies with low stabilisation levels that were analysed above. Ding et al. (2010) analysed several existing proposals in terms of cumulative per capita emissions and conclude that regimes that aim at convergence of annual per capita emissions are more attractive for industrialised countries.

He et al. (2009) propose an allocation scheme, which is an extension of the two-convergence approach of China's National Assessment Report on Climate Change. In this approach, developing countries gain room for development by allowing the per capita emission allowances of non-Annex 1 countries to exceed per capita allowances of industrialized countries for some time, after which both levels converge to a sustainable emission level. The peaking level of per capita allowances decreases over time as result of technology development and more stringent emission budgets. This regime is comparable to the Common but Differentiated Convergence approach, described in Section 4.2.

Other authors discuss the current position of China in the climate debate and propose ways forward. For instance, Zhang (2010) highlights several reasons for China's currently fast growing CO_2 emissions and why these cannot be reduced on the short term. For instance, there is a large difference between central and decentral governments, and decentral governments have to be convinced of the urgency of GHG emission mitigation. Also, the current tax system stimulates local governments to enhance GDP growth on the expense of the environment. As way forward, Zhang proposes to set longer term targets for 2030, since 2020 is becoming increasingly short term. For long-term Chinese climate policy, Zhang (2009) proposes to peak Chinese emissions in 2030. He regards 2020 not realistic, due to grace periods, implementation time of treaties and the fact that CCS has to be available before China can reduce its (coal-based) CO_2 emissions. A proposed roadmap towards 2030 includes first intensity targets (45-50% reduction in 2020 on 2005 levels), a target below baseline for 2025 and an absolute emission cap for 2030.

5.2 Indian proposals and considerations

As part of the Copenhagen accord, the mitigation action plan of India for 2020 pledges to reduce CO_2 emissions per unit of GDP by 20-25% compared to 2005.

Recent Indian literature on climate policy is rather broadly and qualitatively oriented. Most papers are that we identified are intellectual writings about the developing country perspective on climate policy. Interestingly, the literature from Indian authors includes many review articles and explanations of historic climate policy as well. Two main themes dominate the discussion: 1) Equity principles and grand designs of future climate policy, and 2) the implementation of voluntary Sustainable Development policies and measures as developing countries' contribution to climate policies.

The discussions on equity are generally forward looking, combined with proposals for the design of future climate policies. In that respect, Equal per capita allocation is generally more dominant than Historic responsibility (Pandey, 2004; Sanwal, 2009; Shukla, 2005). Both Pandey (2004) and Sanwal (2009) argue that Equal per capita allocation should be the basis of future climate regimes. They both also favour to broaden the scope of climate policies from a focus on reduction targets alone to sustainable development in general (Pandey, 2004) or a globally shared vision on the future sustainable global economy (Sanwal, 2009). This broadening of the debate is supported by Hourcade et al. (2008), who propose a fairly detailed but flexible approach for future climate policy. This proposal includes mainly a global carbon market to induce mitigation measures and non-binding quotas for developing countries, combined with sectoral targets and clean development mechanisms. Shukla (2005) discusses the role of both justice (equity principles) and efficiency (economic optimal solutions) in future climate regimes. He favours two proposals for future climate policy. The first is an adjusted, more equitable, implementation of Contraction and Convergence, in which per capita emissions of developing countries temporarily exceed those of industrialised countries. This is comparable to the Chinese two-convergence approach (see He et al., 2009) or the CDC approach (Höhne et al., 2006).

The second issue is the implementation of voluntary Sustainable Development policies and measures (SD-PAMS) as option for developing countries to contribute meaningful to climate policies in the short term. This is more often discussed in recent Indian literature (Bhandari, 2006; Srivastava, 2006). Examples of such measures are the Brazilian PRO-ALCOOL biofuel programme and the Chinese and Indian national policies on renewable energy and energy efficiency (Halsnæs and Shukla, 2008). Halsnæs and Shukla (2008) further discuss required policy mechanisms to successfully implement SD-PAMS. They argue in favour of a broad Sustainable Development – Climate Finance Mechanism (SDCFM) that finances broad measures (such as infrastructures) that contribute to low-carbon development and whose carbon evaluation can be ex-ante (based on baseline development, as the CDM) or ex-post (based on actual reductions in the past 5-10 years). Further, programs for technology development and transition and technology standards are important prerequirements for successful implementation of SD-PAMS. Finally Sudhakara Reddy and Assenza (2009a, 2009b) argue that many benefits of broad sustainable development policies are not quantified and measured in current practice (such as health benefits) and therefore are not included when evaluating policies.

6. Discussion & comparison

This section discusses and compares the above presented regimes and proposals for India and China with respect to three main aspects: the reduction below baseline, the timing of peaking emissions and the economic impacts and costs. Finally, we discuss some other relevant issues, like baseline uncertainty and timing of emission reduction, and discuss options to move forward.

6.1 Emission reduction targets

The ranges of emission reduction targets for China and India between and within burden-sharing regimes are shown in Figures 4-7. Figure 5 and Figure 7 show the change in emission allowances relative to baseline. In these graphs, a value of zero indicates that allowances are equal to baseline emissions, positive values represent a surplus of emission allowances and negative values an emission reduction requirement. Figure 6 and Figure 8 show emission allowances relative to the observed 2005 emissions, corrected for the regional definition and greenhouse gases included in the study. In these graphs, the value zero indicates that allowances are equal to 2005 emissions and positive and negative values represent emissions above or below 2005 values, respectively. The latter graphs contain more data points, since no information on the baseline scenario is required and, hence, more studies could be included. However, it should be noted that the observed 2005 emission level that we used, might deviate considerably from the numbers actually used in the study and, hence, the results may be inconsistent with the reductions compared to baseline. In each figure, the coloured areas reflect the total range, within which we have indicated the median value and the 15/85 percentile studies. The latter is mainly to indicate whether wide ranges are caused by outliers, or whether there is just wide variation in the bulk of literature. We only applied the statistical analysis (median, percentiles) if at least 8 scenarios were available. Each figure contains three graphs: the upper graph reflects the total range of literature analysed in this study, and the middle and lower graphs only include studies with a certain stabilisation target, as categorised by the IPCC (Metz et al., 2007). Category I contains scenarios aiming for less than 3 W/m^2, or < 490 ppm CO_2-eq and category II and III aim for 3-4 W/m^2 or 490-590 ppm CO_2-eq. We clustered categories II and III because of a lack of studies in category II.

Generally, across all regimes and stabilisation levels, the figures show a fairly diverse picture for China. In 2020, emissions of the 15/85 percentile of all literature are between zero and 35% below baseline, or +40 to -20% compared to 2005. For IPCC cat. II&III scenarios, the reduction over all regimes is zero to -30% below baseline (or +40 to -20% on 2005 levels), and for IPCC cat. I scenarios it is -5 to -40% below baseline (or +5 to -20% compared to 2005). For 2050, the 15/85 percentile of all literature is between 38-80% below baseline or +12 to -66% compared to 2005 emissions. The stringent climate target scenarios are on the low side, with 70-80% reduction below baseline (or 50-80% below 2005).

It is important to note that low stabilisation scenarios have only been evaluated for a small selection of studies and regimes. Still, all regimes show for 2050 a reduction of 70-80% below baseline for China in order to reach low stabilisation levels (or 60% below 2005). For the 2020-2030 period, there are very relevant differences between regimes for low stabilisation levels. For instance, the C&C regime, Grandfathering, or Equal PC would involve significant reductions for China – while the Multi-stage, Income Distribution and Tax regimes would require less reductions.

As can be expected, the Category II&III climate targets require less stringent targets for China. Much more studies have evaluated regimes for these targets – and consequently broader ranges for future reductions are shown. Nevertheless, also here, the difference between the regimes is mainly relevant for the shorter term. By 2050, reductions vary between 40-80% below baseline in all regimes. Regimes with the lowest reduction effort for China on the short term seem Historic Responsibility, Multi-stage, CDC, S-N and Triptych. Grandfathering, C&C and Tax require generally high emission reductions in the short term. The fact that the Tax regime seems attractive for China under the low stabilisation scenarios, and unfavourable under the IPCC cat. II&III studies, shows that one has to be very careful with drawing conclusions from this limited amount of studies.

For India, in 2020, emission reduction requirements of the 15/85 percentile of all literature are between +25 and -20% of the baseline, or between +9 and +90% compared to 2005. For IPCC cat. II&III scenarios, the reduction over all regimes is +30 to -20% of the baseline (or 30 to 150% above 2005 levels), and for IPCC cat. I scenarios it is +13 to -20% of the baseline (or zero to 70% above 2005 levels). For 2050, the 15/85 percentile of all literature is between zero and 60% below baseline or 18-185% above 2005 emissions. The stringent climate target scenarios are on the low side, with 30-70% reduction below baseline (or +84 to -15% on 2005 levels).

Many regimes involve surplus emission allowances for India. Because India has a smaller share in global emissions than China, and its per capita emissions are also much lower than those of China, there is generally more flexibility in reaching low stabilisation levels. This leads to a much wider bandwidth of results across regimes and even within a single regime the allowances range in 2050 from a surplus to 50% reduction below baseline (C&C). For the low stabilisation scenarios, on the short term, Equal PC, C&C and Multi-stage allow small surpluses, whereas CDC, S-N, Income Distribution and Triptych require minor reductions. Grandfathering requires clearly most reductions for India, as it is the only regime with allowances below the 2005 level in 2020. In the less stringent stabilisation scenarios, C&C and Equal PC allow considerable surpluses, whereas Grandfathering requires most efforts here as well. The gradual participation regimes seem for India on the middle of the road, not allowing as much surpluses as Equal PC, but not requiring fierce reductions either.

Generally, the difference within regimes seems just as large as differences between regimes. That implies that the parameterization of regimes might matter as much as the regime itself. Interestingly, this seems to be much more the case for China than for India. This can probably be explained from the fact that China is much closer to the global average, than India in terms of emissions per capita and GDP per capita (see Section 2.3).

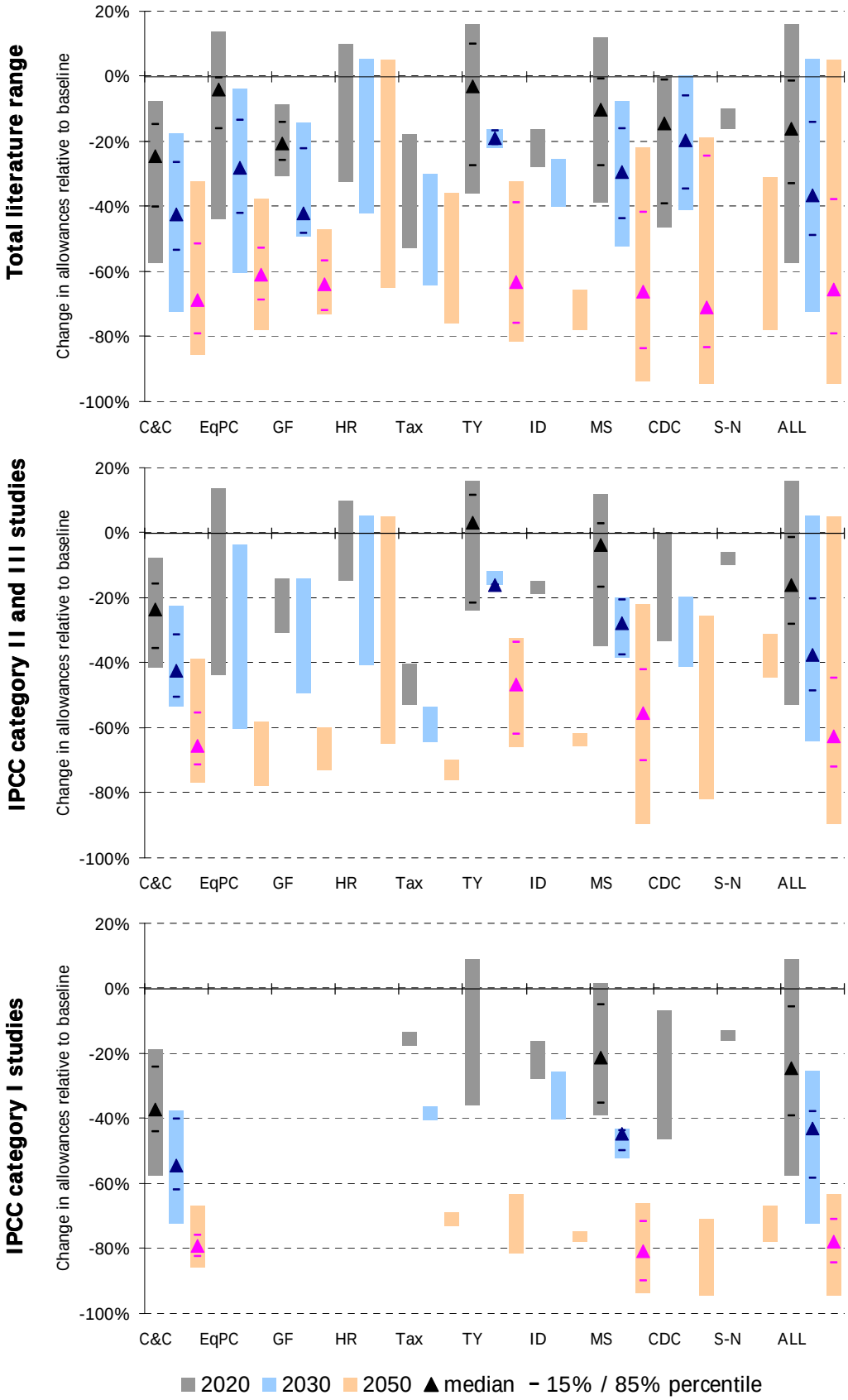

Figure 4: Emission allowances relative to baseline for China for several regimes for the total range of reviewed literature, IPCC category I and II&III studies. Statistical indicators are only shown if more than eight studies were involved.

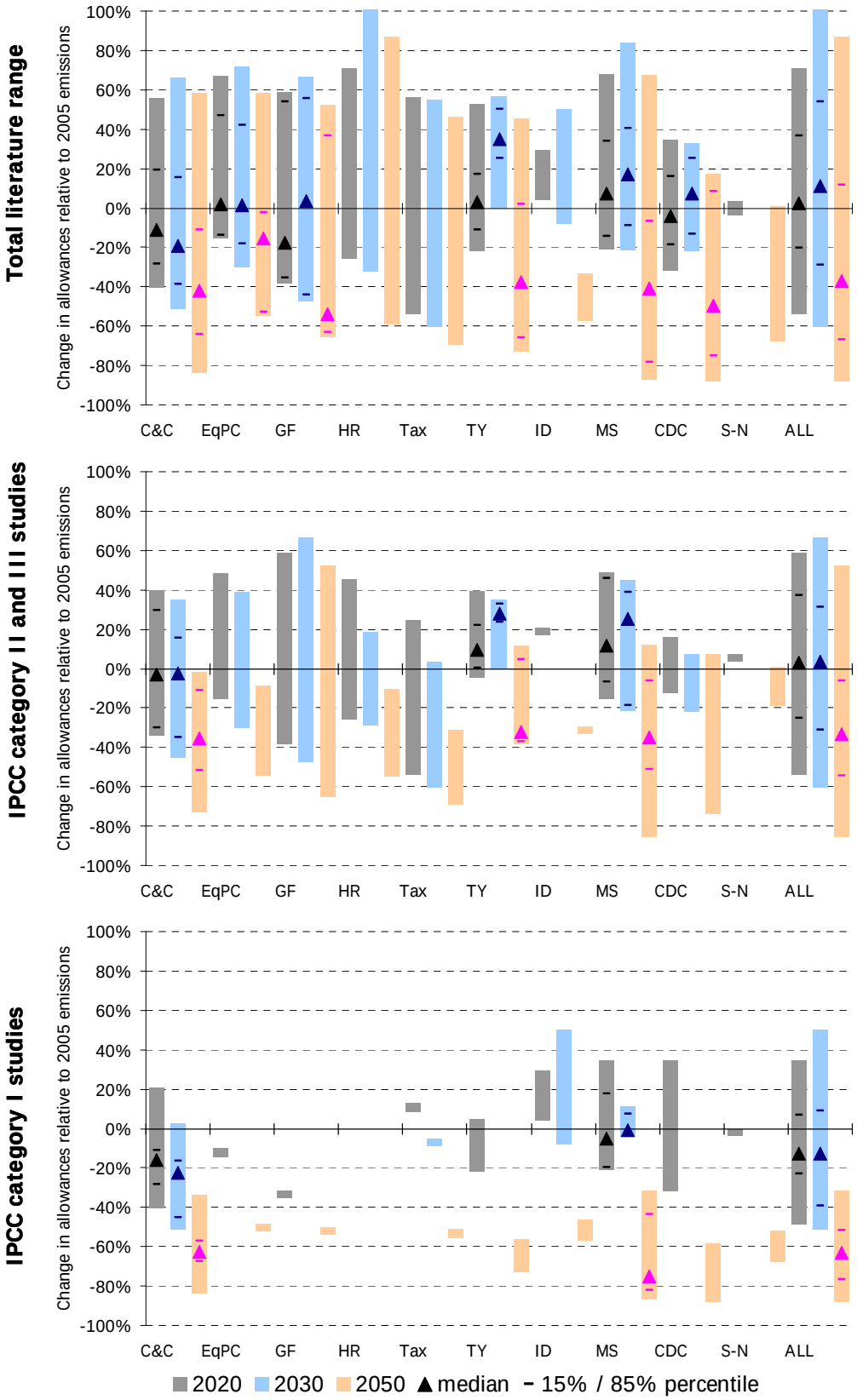

Figure 5: Emission allowances relative to observed 2005 emissions for China for several regimes for the total range of reviewed literature, IPCC category I and II&III studies. Statistical indicators are only shown if more than eight studies were involved. Note that we related allowances to historically observed 2005 emissions. The individual studies (may) use different levels of 2005 emissions, and hence, lead to different results.

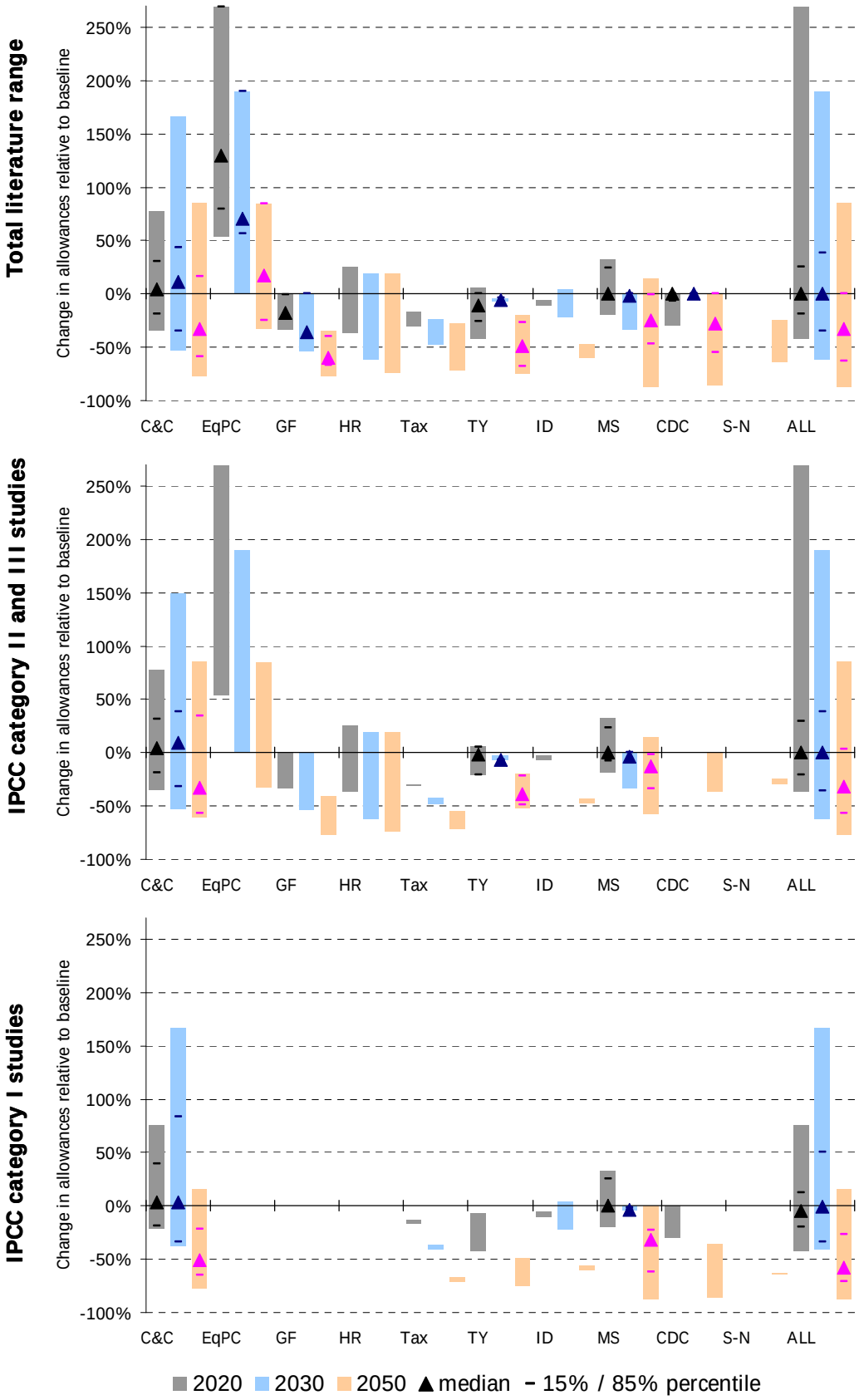

Figure 6: Emission allowances relative to baseline for India for several regimes for the total range of reviewed literature, IPCC category I and II&III studies. Statistical indicators are only shown if more than eight studies were involved.

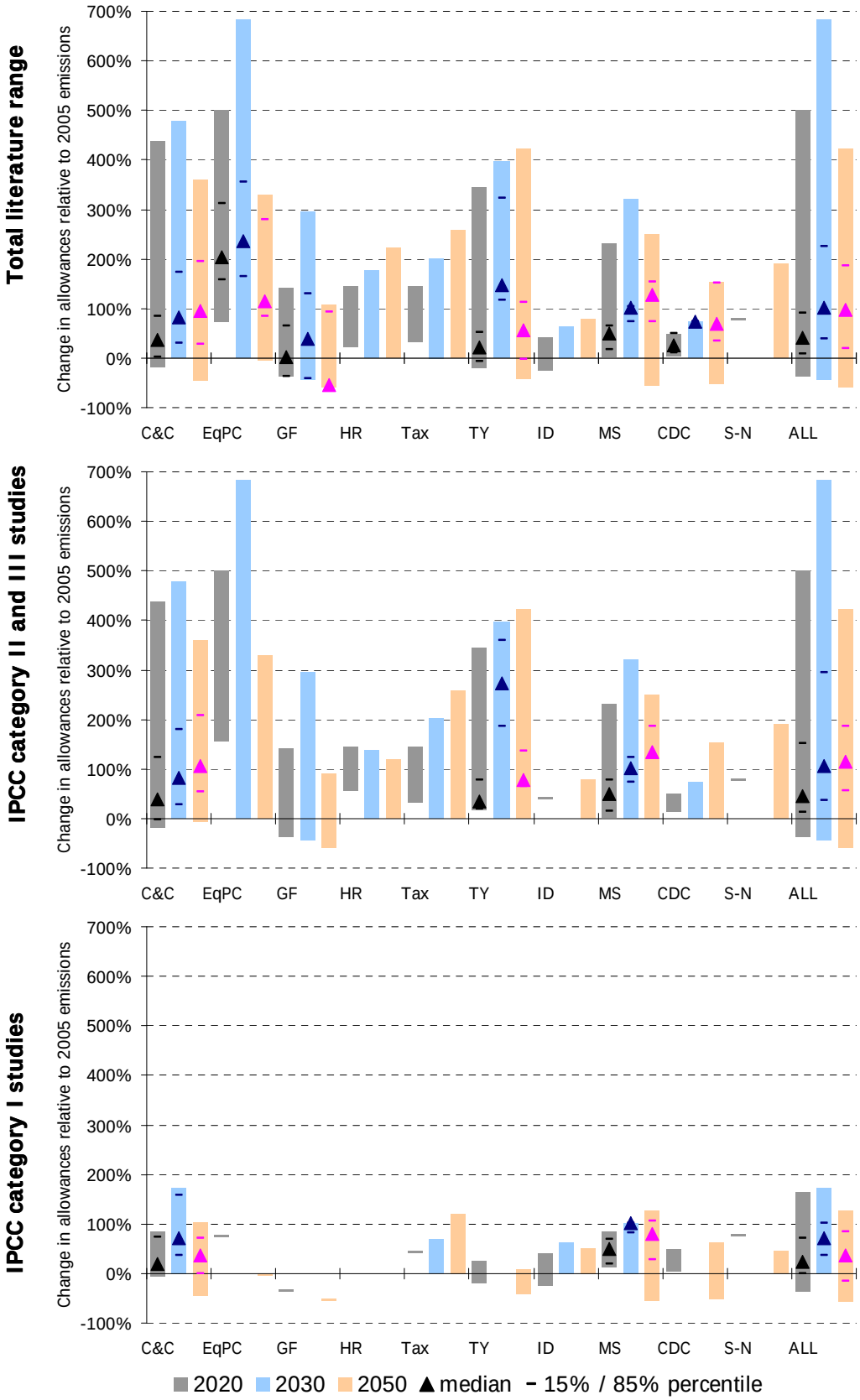

Figure 7: Emission allowances relative to 2005 emission levels for India for several regimes for the total range of reviewed literature, IPCC category I and II&III studies. Statistical indicators are only shown if more than eight studies were involved. Note that we related allowances to historically observed 2005 emissions. The individual studies (may) use different levels of 2005 emissions, and hence, lead to different results.

6.2 Emission and allowance peaking

Closely connected to the issue of the emission reduction requirements for China and India is the question on when emissions should peak in these countries. This issue has been discussed for the global emissions path in order to reach low carbon goals or when the need for emission reduction in developing and developed countries is compared (see e.g. IPCC 2007, Chapter 3 of WGIII).[17] On a country level, this discussion is less present. However, since India and China make up a large part of developing countries' emissions, considerations about emission peak timing might be relevant.

In the run-up to COP 15 in Copenhagen, Chinese officials announced that its emissions could peak in 2050, making this figure subject to political discussion.[18] In the follow-up, several Chinese think tanks have presented studies indicating that an earlier peak between 2020 and 2040 would be feasible with the necessary policies (CAS, 2009; ERI, 2009). India has yet refused to discuss peaking of emissions.

Depending on the allocation mechanism, allocated emission rights and actual emissions might differ from each other quite substantially due to emissions trading. Hence, there might be two different peaks: a peak in allowances and a peak in actual emissions.

6.2.1 Peak in emissions

The peak in emissions is the most relevant indicator to show the reduction efforts that are expected to take place within India and China, irrespective of who is paying for it. However, since most studies focus on the distribution of allowances and allow for trading permits, this information is very hard to obtain.

National studies can indicate peak years, however. The *2009 China Sustainable Development Report* suggests that Chinese emissions could peak between 2030 and 2040 when restrictive measures and policies, including CCS, are adopted to reduce carbon emissions (CAS, 2009). The Energy Research Institute envisions an "enhanced low carbon" scenario leading to a peak in emissions between 2020 and 2030 at a level of about 8.1 $GtCO_2$. When there is high economic growth, however, only broad application of CCS is able to induce a peak in emissions before 2030 and bring them to 2005 levels in 2050 (ERI, 2009). In comparing Chinese emission pathways for the 21st century, Wang and Watson (2010) use peak years of 2020 or 2030 for the different scenarios. They conclude that peaks before 2020 would not be technically feasible; peaks later than 2040 however would exceed the cumulative emission budget of 257 to 407 $GtCO_2$ for the 21st century.[19] Such reductions would require substantial changes to the economic structure and energy generation in particular. Most studies assert that there is a need to avoid a "carbon lock-in" and to implement new technologies already at early stages.

For India, the question when emissions could peak was less in the (public) focus than for China. Since India is still at an earlier stage of development than China, Indian emissions would probably peak

[17] Much of this discussion comes from the timing of emission reductions and the tradeoff between an early start with lower abatement costs in the near future and delayed action which would call for more mitigation effort at a later phase. The parameter of the peak year could hence be seen as a simple indicator on when emission reductions should take place.

[18] See e.g. http://www.reuters.com/article/idUSTRE57E0BA20090815.

[19] This corresponds to an equal per-capita allocation (257 GtCO2) or a equal intensity, i.e. GDP based (407 GtCO2) allocation leading to 450 ppm CO2 without international carbon trading.

later than China's. The Indian peak in emission intensities occurred about 20 years later in comparison to China (Halsnæs and Shukla, 2008), which could be an on orientation also for the time difference in peaking in absolute emissions. Shukla et al. (2008) show that a carbon tax regime could induce Indian emissions to peak in 2030 mainly through the use of CCS and fuel switch. They also show that a broader mix of sustainable policies could also lead to similar reductions until 2050 with lower carbon taxes and with reduced social costs and higher ancillary benefits. In this "sustainable society scenario", Indian CO_2 emissions would peak around 2045.

Comparing the different studies of this review, it can be concluded that there are large variation in the level and form of the emission pathways, as is the case for baselines. For China, many modelling studies find an early peak in emissions.

6.2.2 Peak in allowances

A second issue is a peak in emission allowances. This depends strongly on the regime. Some regimes lead by construction to a reduction in allocations for all (participating) countries from the very beginning (such as an Equal per capita allocation). A C&C regime could lead to immediate declining emission allowances for China, but initially rising emission allocations for India, as India is still below the global average of per capita emissions. This would lead to an allocation peak for India in the convergence year and for China in the first year of the regime if the per capita target is chosen sufficiently low. Because both economies are growing with a fast pace but have contributed relatively little to global emissions in the past, HR regimes would start with high allocations initially but these would decline over time. A regime that could have a peak in allowances that is similar to the peak in actual emissions could be the Multi-stage regime (apart from a global carbon tax regime, of course), where emissions are first be allowed to grow, then need to be stabilized at a peak and subsequently need to decline. This would reduce the need for transfer payments compared to scenarios with large surplus allowances that generates substantial financial flows from developed countries to developing countries. However, it might just be these payments that make a regime attractive for developing countries.

Another important issue is when mitigation measures would be needed (i.e., when emission allocations are lower than baseline emissions in regimes that allow for surplus emissions). Until then there would theoretically be no need for climate policy, but with an international carbon price, measures would be economically reasonable as long as the carbon price is higher than marginal abatement costs (under the assumption that emissions trading is allowed). While some allocation mechanisms with a strong focus on per capita emissions would leave India surplus emissions above its baseline for the entire period until 2050, other regimes such as Grandfathering would induce allowances below baseline from the very start of the regime.

Figure 9 and Figure 10 show an overview of the peaking years for allowances in the studies that are included in this report.[20] The results for China show that most studies assume a peak around 2020, while in low stabilisation scenarios this is even around 2015. For India, there is much more variation between the studies, with peaking years from 2010 to later than 2050. For low stabilisation scenarios the average peak in allowances is around 2030-2040, for less ambitious climate goals, this is even later. As discussed above, however, the peaking year for allowances might differ from the peaking year in real emissions. This is clearly the case for Equal PC regimes, where allowances peak directly at the beginning of the regime, though at levels far above baseline emissions. In any case, it seems a

[20] Not all studies report the peak year, thus limiting the number of studies that could be included for this part of the analysis.

robust result that peaking years need to occur earlier than currently assumed in Chinese policy discussions – if China is willing to support a 2°C target.

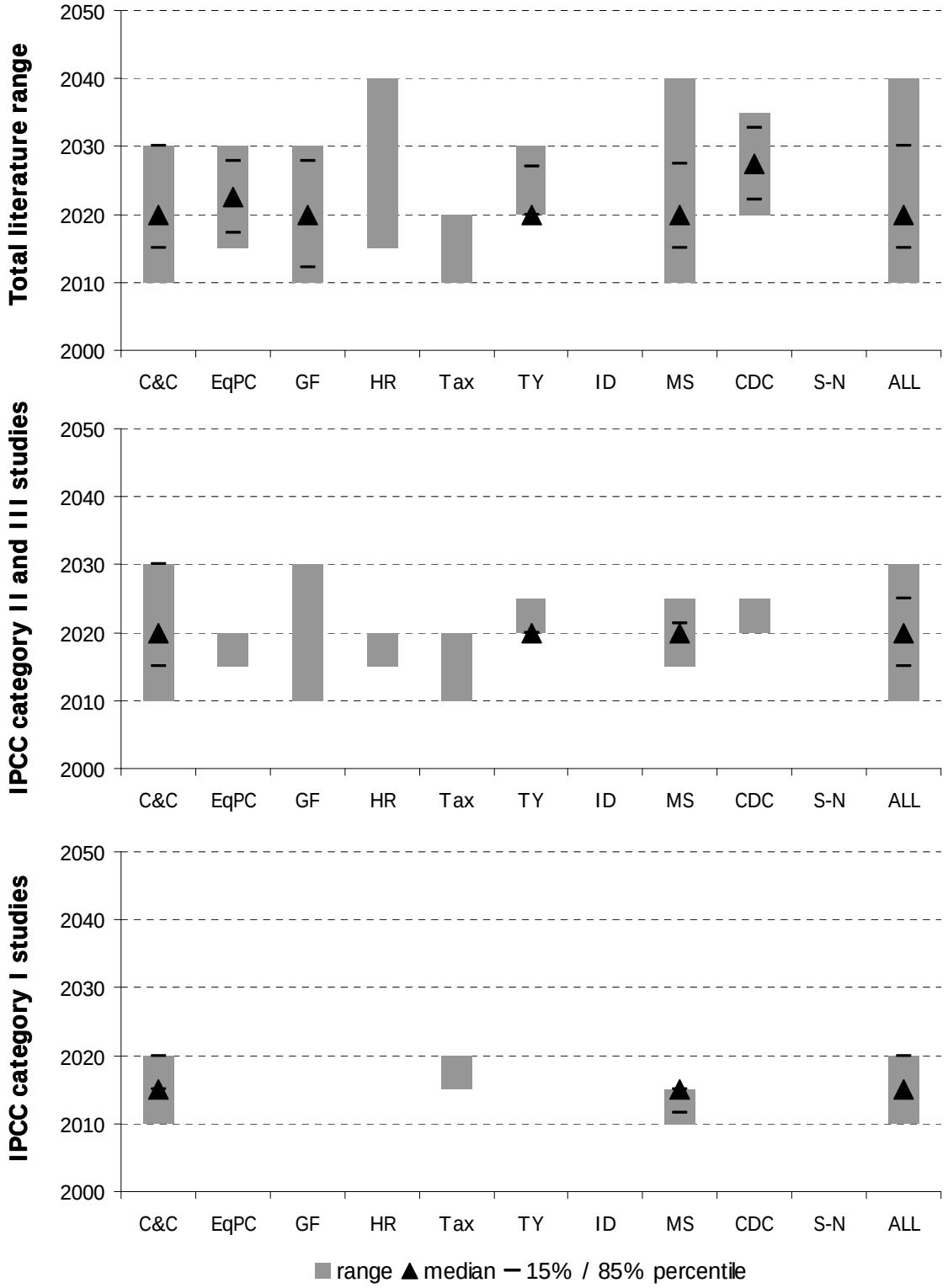

Figure 8: Overview of allowance peaking years for China in several regimes for the total range of reviewed literature, IPCC category I and II&III studies. Statistical indicators are only shown if more than eight studies were involved.

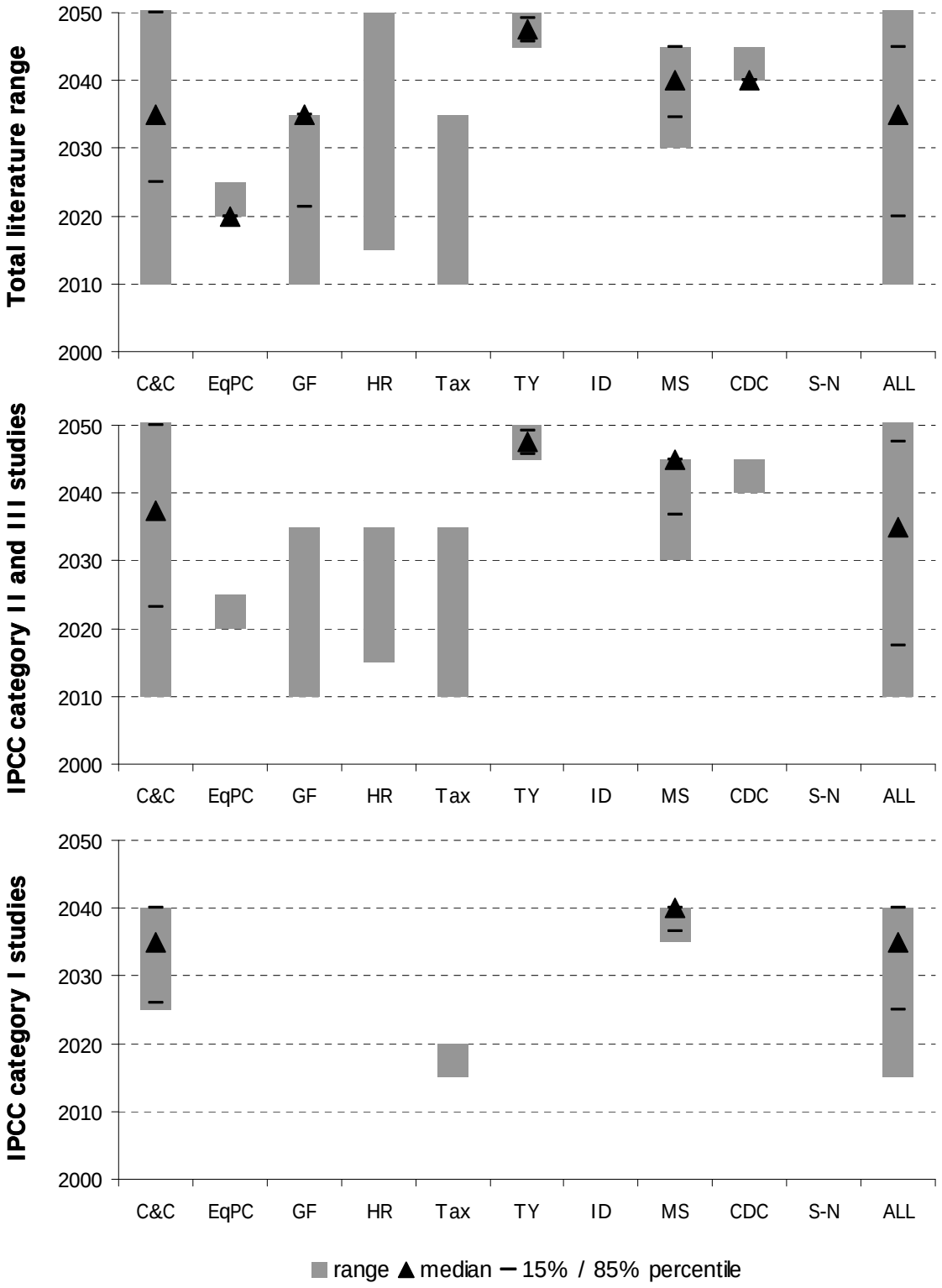

Figure 9: Overview of allowance peaking years for India in several regimes for the total range of reviewed literature, IPCC category I and II&III studies. Statistical indicators are only shown if more than eight studies were involved.

6.3 Economic impact & costs

Because the metrics of economic impacts and costs differ across the different studies and models, it is hard to compare the costs of different regimes across literature. The best way would be to consistently compare a series of burden-sharing regimes using several models. However, since this report reviews existing literature we made an attempt to compare the different costs measures. Figure 11 and Figure 12 show the economic impact and cost of climate policy in the different regimes for China and India in the metrics as used in the studies. Macro economic impacts are expressed in different ways, as change in consumption, GDP or welfare. Direct abatement costs are expressed as percentage of GDP. These different cost measurements are not mutually comparable, but the same measure across different regimes could yield useful insights. Comparing across the different cost measurement, it appears that cost estimates from general equilibrium models based on welfare measures yield rather extreme results (probably due to their logarithmic shape), whereas changes in GDP or direct costs are more moderate.

From Figure 11 it is clear that economic impacts and costs for China vary widely between different regimes, but also between studies and measurements. As discussed in Section 3, the economic impact or cost is closely related to the amount of allowances that can be traded internationally. Regimes with a (temporary) surplus of allowances show gains (e.g. Equal PC or Multi-stage) whereas others require domestic mitigation effort on the short term (e.g. C&C and Grandfathering). This can be explained by the fact that China is allocated relatively few allowances in C&C and Grandfathering schemes while it has a surplus allowances or allowances equal to baseline emissions in the initial period for Equal PC or Multi-stage schemes. A similar pattern can be found in the sub-graphs for low stabilisation scenarios and category II&III scenarios. GDP reductions for China in the order of 10% for low stabilisation scenarios, as expected by UNDP (2010) are not confirmed by the modelling studies in this review.

For India, almost all studies and regimes show economic gains (Figure 12). Only Grandfathering and a global carbon tax are relatively costly regimes for India. All other regimes lead to surpluses or zero costs, even towards 2050. It is thus important for India that future climate policy is based on a *grand scheme* with global emission trading, in which potential gains can be realised. If future climate policy continues along the line of voluntary pledges, as happened in Copenhagen, it is hard to generate and monetise surplus emission allowances.

Representing the costs in relative terms, i.e. setting the costs for India and China in relation to the global average costs, the cost differences stemming from different cost types can be reduced. Tables 28 and 29 present relative costs in categories, following Hof et al. (2009a). They show the percentages of studies that find:

- No cost or gains (0)
- Costs lower than half of global average (1)
- Costs below global average (2)
- Costs above global average (3).

The characteristics about the distribution of relative costs provide further information on the median of spread of different studies. The numerical values reported for the median and the 15% and 85% percentiles are the ratio of regional to average global costs, a value of 1 represents a regional burden of the same magnitude as the international average, while a value smaller than zero indicates gains.[21] Since the data is not available for many studies, all IPCC scenarios are put together; a differentiation is only carried out by regimes.

[21] This is helpful for the comparison of different regimes for India as most regimes indicate gains and are grouped in the same category.

For China, Table 32 mainly confirms the conclusions from Figure 11, regimes based on taxes of Grandfathering would be costly; furthermore, the cost China faces in these regimes often exceeds the global cost average. The cost of C&C are about the global average, the cost for MS regimes would increase over time with economic development and would approach global average over time.[22]

For India, a considerable number of studies find gains could already be seen from Figure 12, which is confirmed by Table 33. Grandfathering and taxes lead to a net burden, for many other regimes the majority is in the category indicating gains. Comparing the regimes, Equal per capita would bring along highest gains; Multi-stage, C&C, and Historic responsibility would also be economically attractive for India, although the range of the gains in relation to international costs has a significant spread.

[22] From Figure 10 it is not obvious that a C&C regime would likely to be preferable to a tax system for China because of different cost types, this becomes clearer with relative costs.

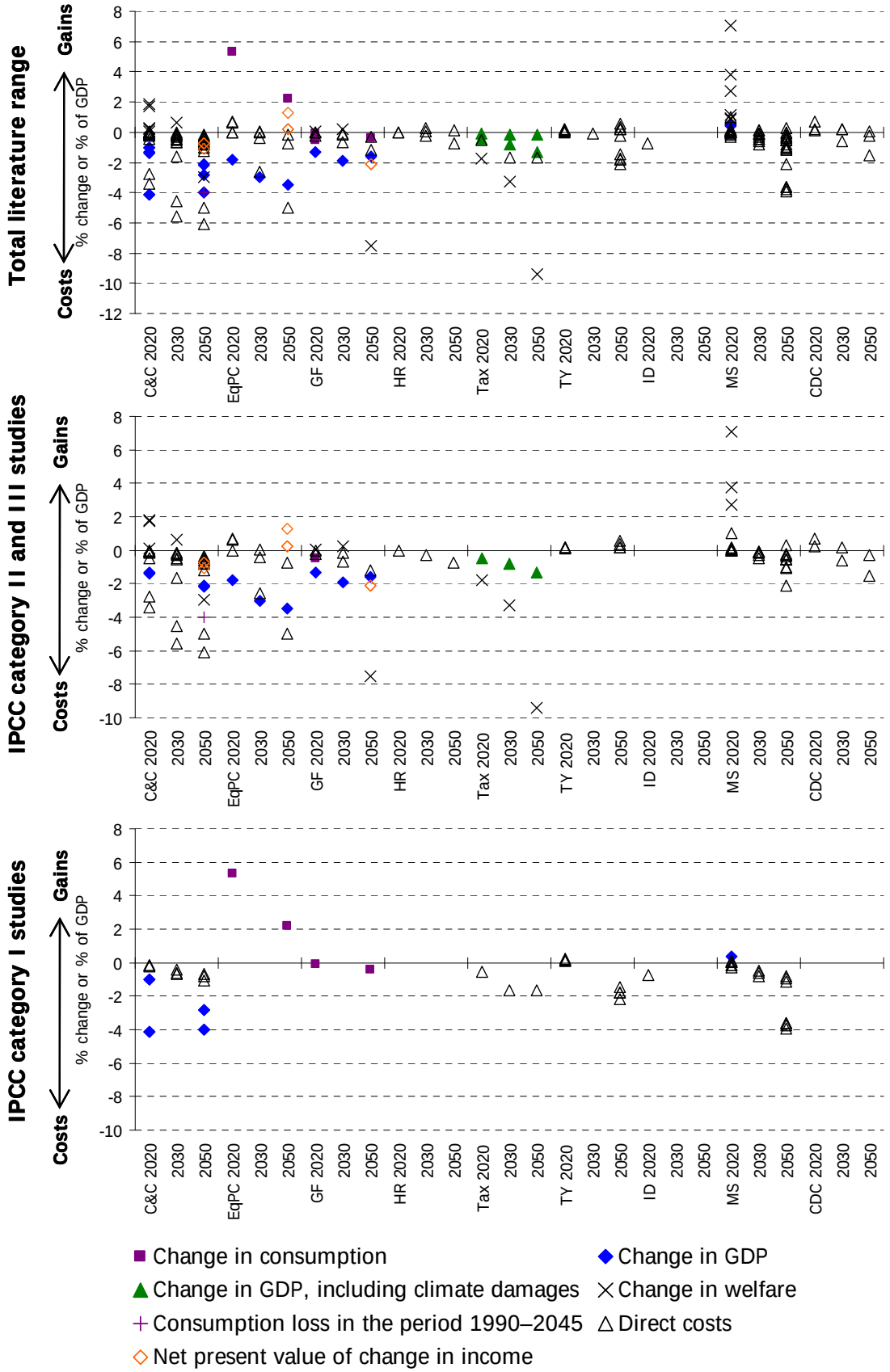

Figure 10: Economic impact or costs of climate policy for China for the total range of reviewed literature and IPCC categories I and II&III studies. Values of direct costs are expressed as percentage of GDP, all other values are in percentage change.

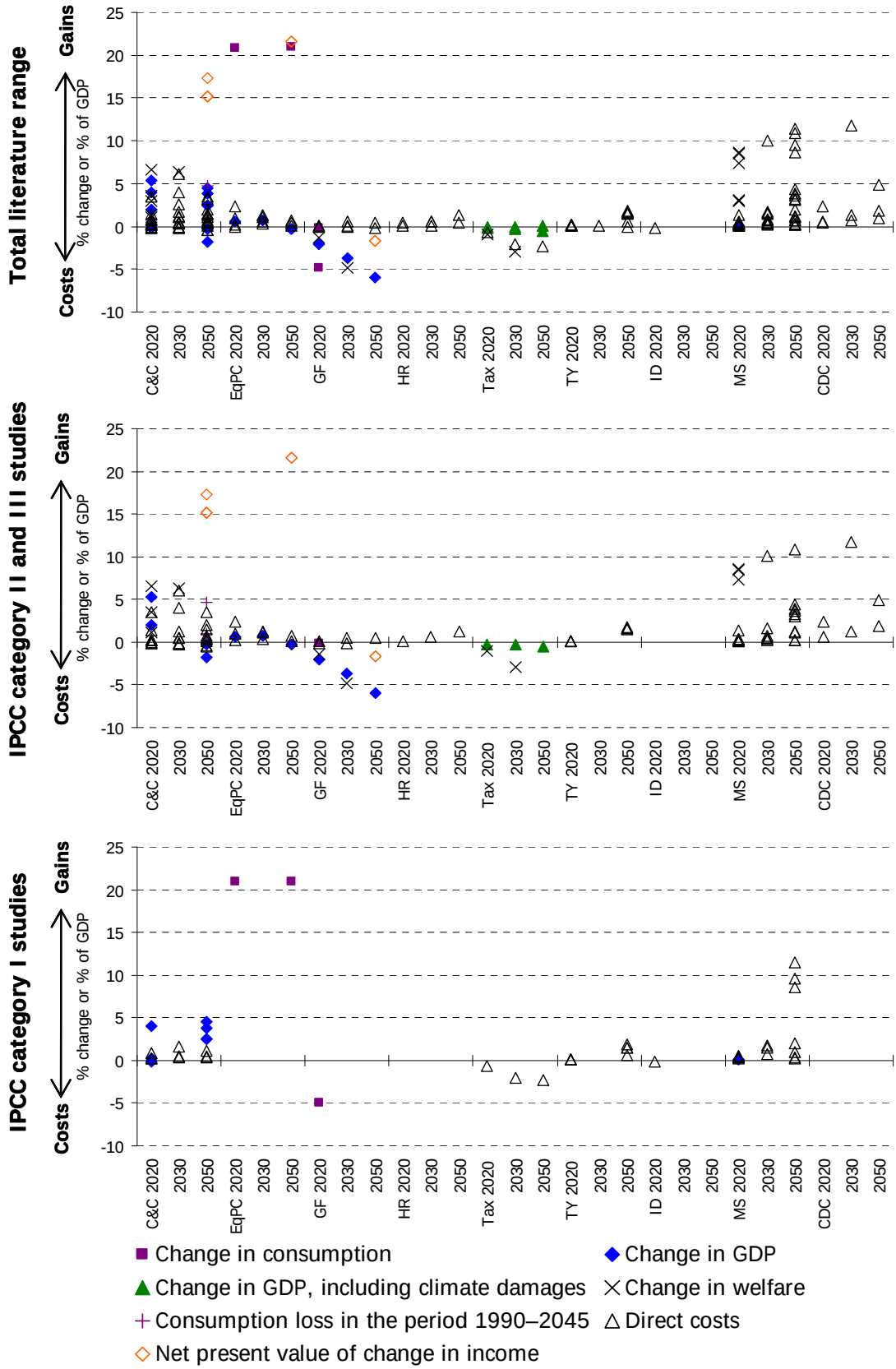

Figure 11: Economic impact or costs of climate policy for India for the total range of reviewed literature and IPCC categories I and II&III studies. Values of direct costs are expressed as percentage of GDP, all other values are in percentage change. Note that we left out three extreme cases for change in welfare: 43% gains in C&C, 25% loss for GF and 17% loss for Tax.

Table 32: Chinese costs relative to global average costs. The cost categories are no costs or gains (0), costs lower than half of global average (1), costs below global average (2), costs above global average (3). Statistical indicators are only shown if more than eight studies were involved.

2020	relative cost category				number of			
Regimes	0	1	2	3	studies	15%	Median	85%
C&C	11%	5%	32%	53%	19	0.39	1.02	4.12
Equal PC	50%	25%	0%	25%	4			
GF	33%	33%	0%	33%	6			
HR	0%	50%	50%	0%	2			
ID	0%	0%	100%	0%	1			
MS	74%	13%	13%	0%	23	-2.73	-1.50	0.34
Tax	0%	0%	0%	100%	4			
TY	89%	0%	0%	11%	9	-7.56	-2.69	-0.76
All	46%	12%	16%	26%	68	-2.58	0.12	1.77

2030	relative cost category				number of			
Regimes	0	1	2	3	studies	15%	Median	85%
C&C	8%	0%	83%	8%	12	0.73	0.83	0.95
Equal PC	33%	33%	33%	0%	3			
GF	25%	0%	0%	75%	4			
HR	67%	33%	0%	0%	3			
ID					0			
MS	33%	33%	33%	0%	12	-1.10	0.29	0.65
Tax	0%	0%	0%	100%	4			
TY	0%	0%	0%	100%	1			
All	23%	15%	38%	23%	39	-0.50	0.73	1.19

2050	relative cost category				number of			
Regimes	0	1	2	3	studies	15%	Median	85%
C&C	0%	16%	52%	32%	25	0.50	0.85	1.27
Equal PC	67%	0%	33%	0%	6			
GF	0%	33%	0%	67%	6			
HR	50%	0%	50%	0%	2			
ID					0			
MS	9%	32%	55%	5%	22	0.15	0.69	0.90
Tax	0%	0%	25%	75%	4			
TY	44%	33%	11%	11%	9	-0.30	0.28	0.52
All	15%	22%	41%	23%	74	0.12	0.73	1.20

Table 33: Indian costs relative to global average costs. The cost categories are no costs or gains (0), costs lower than half of global average (1), costs below global average (2), costs above global average (3). Statistical indicators are only shown if more than eight studies were involved.

2020	relative cost category				number of			
Regimes	0	1	2	3	studies	15%	Median	85%
C&C	89%	11%	0%	0%	18	17.43	-3.07	-0.66
Equal PC	75%	0%	25%	0%	4			
GF	33%	0%	0%	67%	6			
HR	100%	0%	0%	0%	2			
ID	0%	100%	0%	0%	1			
MS	100%	0%	0%	0%	23	-7.22	-2.68	-1.58
Tax	0%	0%	50%	50%	4			
TY	100%	0%	0%	0%	9	-6.03	-1.08	-0.74
All	82%	4%	4%	9%	67	-10.07	-2.14	0.21

2030	relative cost category				number of			
Regimes	0	1	2	3	studies	15%	Median	85%
C&C	92%	8%	0%	0%	12	-13.04	-2.34	-0.72
Equal PC	100%	0%	0%	0%	3			
GF	50%	0%	0%	50%	4			
HR	100%	0%	0%	0%	3			
ID					0			
MS	100%	0%	0%	0%	12	-5.48	-3.46	-1.43
Tax	0%	25%	25%	50%	4			
TY	100%	0%	0%	0%	1			
All	82%	5%	3%	10%	39	-5.82	-1.45	0.42

2050	relative cost category				number of			
Regimes	0	1	2	3	studies	15%	Median	85%
C&C	88%	8%	0%	4%	25	-11.57	-1.39	-0.40
Equal PC	100%	0%	0%	0%	6			
GF	17%	0%	17%	67%	6			
HR	100%	0%	0%	0%	2			
ID					0			
MS	100%	0%	0%	0%	22	-2.97	-2.11	-0.44
Tax	25%	0%	0%	75%	4			
TY	89%	11%	0%	0%	9	-1.43	-0.46	-0.18
All	84%	4%	1%	11%	74	-3.35	-1.12	0.32

6.4 China's recent emission growth and timing of reductions

The huge uncertainty in baseline scenario leads to a large variation in the emission reduction requirements. Especially for China, the growth of emissions in recent years was faster than anticipated (see also Section 2.4). The baseline projections of many studies for 2020 are actually below or only slightly above emission data from recent years. Therefore, we performed an extra experiment, analysing a subset of studies with high baselines for China. High baselines were defined

as those with emissions in 2020 being at least 30% higher than the observed 2005 values. This is roughly the baseline projection from Chinese national studies (ERI, 2009; UNDP, 2010).
Figure 13 and Figure 14 show the comparison emission reduction of the high baseline studies with the total range of studies, expressed relative to 2005 or compared to baseline. In absolute terms, not surprisingly, the high baseline studies generally involve only the higher side of the total range. This is in line with the observation that Chinese growth has led to lower emission projections for Annex I countries, and hence, a larger share of future emissions can be allocated to China. Compared to baseline, mitigation efforts in the high-baseline group are slightly higher than the total literature. This is most clearly shown for the regimes with many studies (C&C and MS) and the overall range.

Generally, one can conclude that analysis of regimes on the basis of higher baselines of China, allow for more emissions in absolute terms, but involve similar efforts compared to the baseline, than the total range of studies.

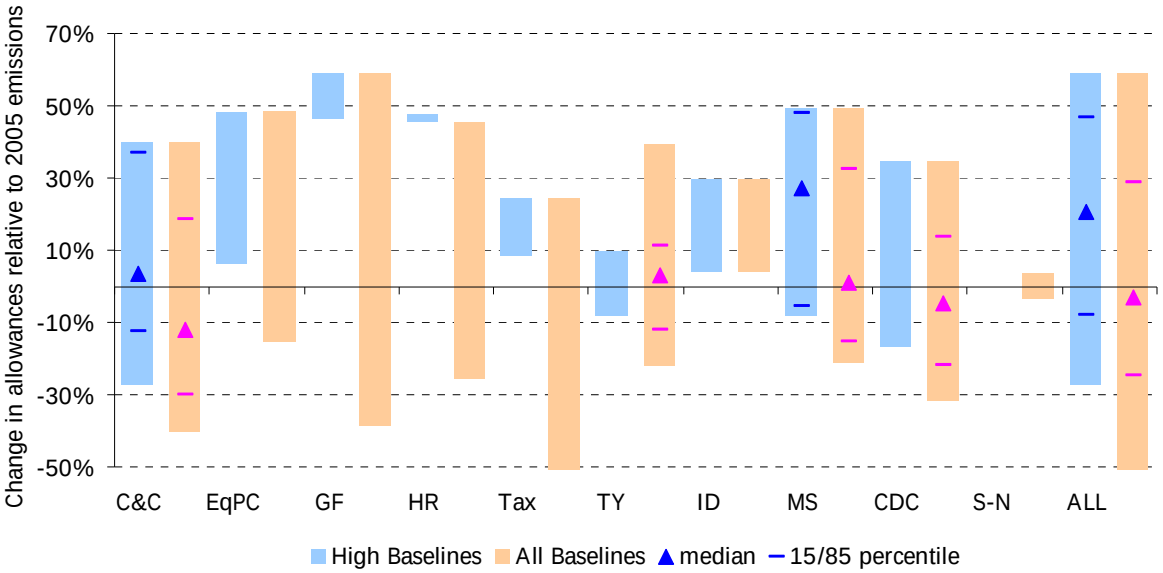

Figure 12: Emission allowances compared to 2005 levels for 2020 under different reduction regimes in IPCC cat. I, II and III scenarios, for all studies and a selection of studies with high baselines (emissions in 2020 at least 30% above observed 2005 levels). Statistical indicators are only shown if more than eight studies were involved.

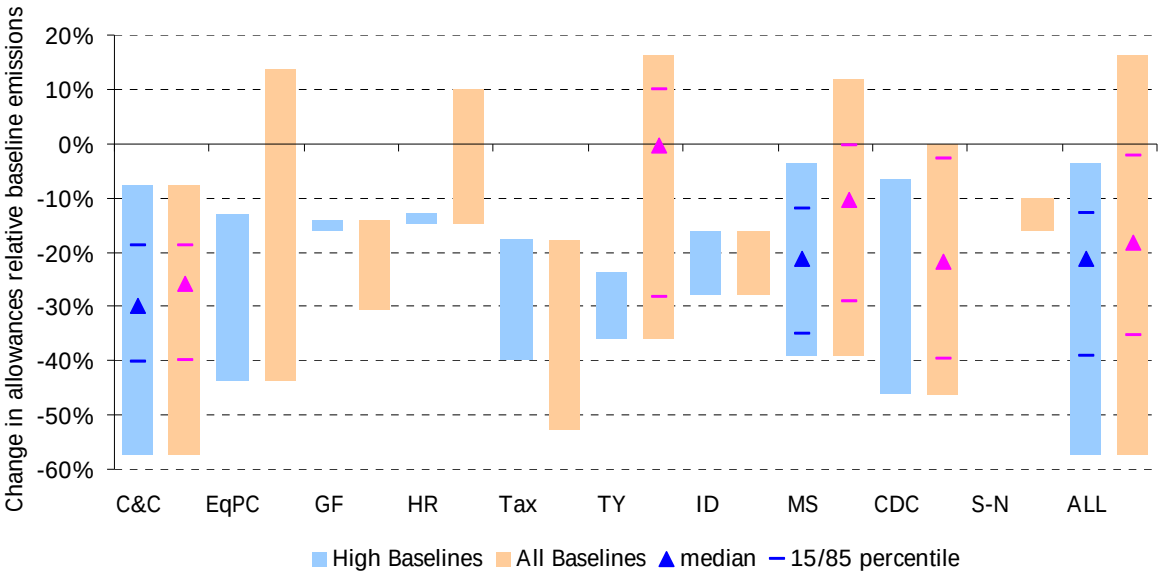

Figure 13: Emission allowances compared to baseline for 2020 under different reduction regimes in IPCC cat. I, II and III scenarios, for all studies and a selection of studies with high baselines (emissions in 2020 at least 30% above observed 2005 levels). Statistical indicators are only shown if more than eight studies were involved.

6.5 Ways forward and the POEM project

In the POEM project, the task of this working package is to identify post-Kyoto regimes that are useful to analyse in the next phases of the project. We defined useful regimes for further analyses on the basis of three main arguments: 1) regimes that allow for maximum development (i.e. large emission space, late peaking year) for India and China, 2) regimes with moderate economic consequences for India and China (i.e. no extreme gains or costs), and 3) regimes that do not involve instantaneous divergence of efforts between world regions, because they are based on normative approaches.

Table 34: Scoring the regimes along several selection criteria.

Criterion	C&C	EqPC	GF	HR	Tax	TY	ID	MS	CDC	S-N
Reductions below average of all regimes in 2020, China		+		+		+	+	+	+	+
Reductions below average of all regimes in 2030, China		+		+		+	+	+	+	
Reductions below average of all regimes in 2050, China				+		+		+	+	+
Reductions below average of all regimes in 2020, India	+	+						+	+	+
Reductions below average of all regimes in 2030, India	+	+						+	+	+
Reductions below average of all regimes in 2050, India		+						+	+	+
Peaking later than average of all regimes, China						+			+	
Peaking later than average of all regimes, India	+					+		+	+	
Economic gains higher than 5% of GDP, India		-						-	-	
Costs above global average in majority of studies, India										
Economic gains higher than 5% of GDP, China		-						-		
Costs above global average in majority of studies, China	-		-		-	-				
Divergence of efforts between world regions, due to normative approach		-	-	-						
Total (excluding economic criteria)	3	4	-1	2	0	5	2	7	8	5
Total (all criteria)	2	2	-2	2	-1	4	2	5	7	5
China	-1	1	-1	3	-1	3	2	2	4	2
India	3	2	0	0	0	1	0	3	3	3

Table 34 aims to operationalise these arguments, by scoring the regimes on several indicators. Regimes with relatively low reduction efforts gain advantages (+) over regimes that have reduction efforts above the average. Also, a peaking year later than the average is considered positive. On the other hand, extreme economic gains (either in direct abatement costs or in macro-economic impact) reduce the realism of a regime, and regimes with cost above the global average have a disadvantage (-). Finally, three regimes obtained a negative score on diverging efforts due to their strongly normative approach.

We currently weighted all indicators equally, and the results show a ranking of regimes. CDC has clearly a high score, but S-N, MS and TY score rather high as well. C&C, EqPC, HR and ID have lower scores, whereas GF and Tax are clearly unattractive.

This method has some caveats, for instance that not all information is available for all regimes (i.e. no cost information for CDC or S-N) and that all arguments have equal weight. Also, other arguments would lead to different results. Nevertheless, we regard this as a transparent way to select regimes to use in the subsequent phases of the project.

7. Conclusion

Based on a comparison of the scientific literature on burden sharing regimes, with respect to allowances, peaking year and economic impact or costs, we conclude that:

- **The emission allowances for both China and India differ greatly between studies, hence, not only across regimes, but also within regimes.** This can largely be explained by methodological issues such as model structure differences, assumptions on baseline developments and parameter assumptions within the regimes. Studies show especially a wide variation in baseline developments for China, leading to large uncertainties in the results.

- **For China, literature shows considerable differences between regimes on the short term, but literature on low stabilisation scenarios shows deep cuts in allowances on the long-term.** Towards 2020 and 2030, studies to Multi-stage, CDC, Triptych and Historic Responsibility regimes show the highest emission allowances and lowest costs or economic impact. Studies to Grandfathering and C&C show large reductions in allowances for China. For 2050, however, studies to low stabilisation scenarios (IPCC cat. I) show that Chinese emission allowances reduce to 50-80% below 2005 levels, irrespective of the regime and that China becomes a buyer of emission rights by that time.

- **The direct costs or macro-economic impact for China remains below the global average in most analysed studies and regimes.** While literature shows that China is likely to face mitigation costs in many regimes, it also shows that there are initial revenues from selling allowances in several regimes and that domestic mitigation costs can be dampened by buying emission allowances on the long run. Therefore, the upper range of literature projects costs to increase maximally to about the global average.

- **In the literature on burden sharing regimes, Chinese emission allowances peak relatively early**. Especially in low stabilisation scenarios, the median of the studies is observed around 2020, which is soon, given the currently high growth rates of the Chinese economy and emissions.

- **The literature shows that emission allowances for India increase considerably relative to 2005 – although allowances are below baseline emissions in a number of studies and regimes.** Equal PC and Multi-stage allow for small surpluses of allowances, whereas CDC and S-N require minor reductions compared to baseline. Grandfathering and a global carbon tax (without trade) show the largest reduction of allowances (or emissions, in case of global carbon tax).

- **Studies show that India can expect to have gains, or low costs from climate policy.** Due to revenues from excess allowances, climate policy seems beneficial for India, except in regimes that lead to a reduction in allowances (or emissions), like Grandfathering and tax (without trade).

- **In the literature on low stabilisation scenarios, Indian emission allowances peak towards mid-century**. In most low stabilisation scenarios, emission allowances for India peak around 2030-2040.

It should be noted that there are many uncertainties in this analysis. First, there is technical uncertainty in the underlying analysed studies, for instance with respect to baseline assumptions and methodology. However, also the methodology that was applied in this report involves uncertainty, of which we want to stress several sources explicitly:

- **Bias in literature towards certain regimes**. While some regimes are analysed in many studies (such as Contraction and Convergence or Multi-stage), analysis of other regimes is scarce (e.g. Ability to Pay, or global carbon tax). This bias in literature towards certain regimes complicates the comparison of different regimes: what seems a difference between regimes might well be a difference between studies or models.

- **Different regional definitions between studies**. Not all studies report regional emissions and reduction targets for India and China explicitly. If results are reported for regions where China or India is the dominant country (e.g., East Asia and South Asia), we did include results of these studies in our assessment. In these cases, it should be noted that the absolute figures for baseline emissions and allowances are probably biased upward.

- **Geographical bias of underlying analyses.** Most studies that were reviewed in this report contain global analyses of climate policy and burden sharing. Unfortunately, these studies are mainly carried out by scholars and institutes from Industrialised countries and global analyses from Indian and Chinese sources (that are published in English) are rare. There might be a (perceived) bias in the literature to under-represent the values of developing countries with respect to "common but differentiated responsibility".

- **Different measurements for costs**. Studies report very different cost measurements, ranging from direct costs to changes in GDP and welfare. All these different cost measurements are not directly comparable in absolute values. When comparing the regimes, we have focussed on the relative costs of regions compared to the global average costs as presented by the studies.

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