Energy Policy 46 (2012) 116–134

Contents lists available at SciVerse ScienceDirect

Energy Policy

journal homepage: www.elsevier.com/locate/enpol

Emission allowances and mitigation costs of China and India resulting from different effort-sharing approaches

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ARTICLE INFO

Article history:
Received 14 May 2011
Accepted 15 March 2012
Available online 10 April 2012

Keywords:
Climate policy
China
India

ABSTRACT

To meet ambitious global climate targets, mitigation effort in China and India is necessary. This paper presents an analysis of the scientific literature on how effort-sharing approaches affect emission allowances and abatement costs of China and India. We find that reductions for both China and India differ greatly in time, across- and within approaches and between concentration stabilisation targets. For China, allocated emission allowances in 2020 are substantially below baseline projections. Moreover, they may be below 2005 emission levels, particularly for low concentration targets (below 490 ppm CO_2-eq). Effort-sharing approaches based on allocating reduction targets lead to relatively lower reductions for China than approaches that are based on allocating emission allowances. For 2050, emission allowances for China are 50–80% below 2005 levels for low concentration targets with minor differences between approaches. Still, mitigation costs of China (including emissions trading) remain mostly below global average. According to literature, Chinese emission allowances peak before 2025–2030 for low concentration targets. India's emission allowances show high increases compared to 2005 levels. If emission trading is allowed, financial revenues from selling credits might compensate mitigation costs in most approaches, even for low concentration targets. India's emission allowances peak around 2030–2040 for all concentration targets.

1. Introduction

With the approaching expiration of the first commitment period of the Kyoto protocol in 2012, there is a need for a new international climate policy regime for allocating future commitments across all countries. The contours of such a regime are still very uncertain, but the United Nations (UN) climate negotiations in Durban (2011) made a first start by the established a new body to negotiate a global agreement that would cover all countries by 2015.

Following the Copenhagen (2009) climate negotiations, forty-two industrialised countries submitted quantified economy-wide emission targets for 2020. In addition, forty-three developing countries submitted so-called nationally appropriate mitigation actions (NAMAs) for inclusion in the Appendices to the 2009 Copenhagen Accord. All these reduction proposals were later "anchored" in the Cancún (2010) Agreements. Several studies assessed these national greenhouse gas emission reduction proposals for 2020 (den Elzen et al., 2010, 2011; Rogelj et al., 2010; UNEP, 2011), and concluded that they are not sufficient to meet the ambitious target to limit global mean temperature increase to less than 2° above pre-industrial levels, a climate target that is also mentioned in the Copenhagen Accord (UNFCCC, 2009) and Cancún Agreements (UNFCCC, 2010).

The mitigation effort of China and India are increasingly important for meeting ambitious climate targets, as their rapid economic growth leads to an increasing share in the world's greenhouse gas emissions. Substantial delay in the mitigation of their emissions would make such targets out of reach. In fact, emissions from developing countries alone will soon exceed the global emission trajectory for reaching a low concentration target (Blanford et al., 2009; Clarke et al., 2009; Metz et al., 2002). However, as income levels in both China and India are still much lower than that of industrialised countries and both countries have historically contributed less to current greenhouse gas concentrations, they are not eager to take on (ambitious) emission reduction targets. This position is consistent with Article 3.1 of the UNFCCC (1992) that

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http://dx.doi.org/10.1016/j.enpol.2012.03.042

indicates that countries have a "common but differentiated responsibility" to contribute to future reductions.

There are many different views possible on which allocation of emission reduction targets reflects a fair "common but differentiated responsibility" (den Elzen and Höhne, 2008; den Elzen and Höhne, 2010; Rose et al., 1998). Consistent with these views, there are many different post-Kyoto effort-sharing approaches or post-2012 regimes to allocate future reductions to the various regions, such as contraction and convergence, each with different participation levels, timing of reductions, as well as stringency and type of commitments, varying from voluntary action to absolute reduction commitments (see an overview of proposals in e.g. Bodansky, 2004; Gupta et al., 2007; Kameyama, 2004; Philibert, 2005). The IPCC's Fourth Assessment Report (AR4) (Gupta et al., 2007) summarised how emission reductions would be allocated to developed and developing countries according to various proposals by assessing model studies on this subject. It indicated that for meeting low stabilisation targets, developed countries as a group would need to reduce their emissions within a range of 25–40% below 1990 levels by 2020, as long as emissions in developing countries deviate substantially from their baseline emission levels. Den Elzen and Höhne (2008, 2010) elaborated further on this issue and concluded that 25–40% reduction below 1990 levels in 2020 for developed countries, combined with a 15–30% reduction below baseline for the developing countries, is needed to meet a 450 ppm (ppm) CO_2-eq stabilisation target. The reduction percentages for individual countries vary among different regimes and parameter settings and may be outside this range. For higher stabilisation levels, reductions would have to occur only at a later date. These differences in reductions have obviously major consequences for the economic impacts for developing countries in joining a regime (Gupta et al., 2007). Hof et al. (2009) have evaluated the impact of different regimes on regional mitigation targets and costs for large world regions.

The aim of this paper is to present a detailed overview of how different regimes may affect China and India. The focus is on emission allowances over time, the peaking year before which emission allowances start declining, and the costs or economic impact. Compared to the above-mentioned studies, this paper includes more studies and discusses the results vis-à-vis current policy initiatives and scientific literature in India and China. The information might be important to assess how different view points on different policy regimes might be combined with the observation that an early contribution of China and India is necessary to meet ambitious climate targets.

The paper is structured as follows. Section 2 describes the regimes and Section 3 the methodological aspects related to comparing the results of different studies. Section 4 discusses the findings and plausibility of regimes with respect to reductions, peaking of allowances and mitigation costs. Recently published literature from Indian and Chinese authors is discussed in Section 5. Finally, Section 6 concludes and discusses some of the caveats of this study.

2. Description of regimes

2.1. Definition of climate regime

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 greenhouse gas emissions. A regime can be characterised by a *certain goal*, a set of rules that determine *participation* and a *defined form of action* (Gupta et al., 2007).

For many climate regimes, the *goal* is to avoid dangerous climate change, most often specified top-down as a long-term greenhouse gas concentration target or corresponding global emission target, after which certain rules for allocating emission allowances or reduction requirements are applied. By contrast, in a bottom-up approach the emission allowances are put forward by regions without a predefined global reduction effort or global emission cap. The climate change problem can be defined as a property-sharing issue, in which case emission rights are allocated (*resource sharing*). In a *burden sharing* approach, the differentiation of commitments focuses on allocating reduction efforts. An important difference between these approaches is that with resource sharing surpluses in emission allowances (i.e. emission allowances are projected above baseline emission levels) are possible, while with burden sharing this is not the case.

The *participation level* relates to the number of countries that actively participate in the prescribed actions. A distinction can be made between immediate, full participation regimes and gradual participation regimes. In the first group, all countries join a grand scheme of emission allocation, while in the second group participation of a country depends on certain participation thresholds. These thresholds can be indicators for equity principles, like responsibility and capability. Immediate, full participation ensures that global abatement costs are minimised as marginal abatement costs are equalised (if emissions trading is allowed). 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 less economic burden for poorer countries, but also that participating countries have sufficient institutional capacity to ensure a functioning international carbon market.

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.

2.2. Classification of climate regimes

Regimes can be classified according to the equity principle on which they are based. These principles refer to general concepts of distributive justice or fairness. Clearly, 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 (see for example, Ringius et al., 2002; Rose et al., 1998). Den Elzen et al. (2003) distinguish four main 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.

Classifying the different regimes for comparison can also be done by their characteristics: the ambition level, the participation level or the form of prescribed actions. We here build upon the categorisation of climate regimes put forward in Hof et al. (2009), grouping regimes 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 (immediate, full 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. Within each of these groups, one can distinguish regimes that use a global emission gap and those that do not use such a cap.

2.3. Description of included regimes

This paper focuses on regimes that play a major role in scientific literature, and regimes that are oriented at developing countries. We therefore excluded regimes of which only very few studies were available, like Multicriteria (MCC) (Vaillancourt et al., 2008; Vaillancourt and Waaub, 2006), Global Compromise (GC) (Müller et al., 2009), Horizontal/Vertical Equity (Rose et al., 1998), Emission Intensity (EI) (Blanchard, 2002) and Ability to Pay (AtP) (Böhringer and Löschel, 2005; Jacoby et al., 2008). Table 1 shows an overview of the regimes that are included in this paper, as well as the abbreviations that will be used throughout this study. A more elaborate selection of regimes is analysed in van Ruijven et al. (2010). We did not include regimes on cumulative per capita approaches (such as Ding et al., 2010; Messner et al., 2010) in the comparison of regimes, due to a lack of comparable information in these studies. However, we discuss these approaches in Section 5.1 on Chinese literature.

2.3.1. Immediate, full participation regimes

In the 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. This regime is based on both the sovereignty and egalitarian equity principles, as first allowances are based on current emission levels but in time, equal emissions per capita is the dominant factor on which allowances are based. As the problem definition is based on resource sharing, some developing countries could be allocated more (surplus) emission allowances than their expected baseline emissions.

In a Grandfathering regime (GF), emission allowances are allocated on the basis of present day emissions and the relative share of allocations between countries remains constant. This regime is a direct outcome of the sovereignty principle. In theory, allocation of surpluses is possible, in particular for developed countries with declining baseline emission levels.

Equal per capita allocation of emission allowances (EqPC) is based solely on the egalitarian equity principle. An immediate start of allocating emission rights according to this approach implies that countries currently below global average emissions per capita would gain large excess emission rights. For countries with relatively high per capita emissions, on the other hand, very stringent targets would result. This allocation would therefore result in emission allowances being traded from developing to developed countries on a very large scale.

Historical responsibility (HR) regimes are based on the equity principle of responsibility and the polluter pays principle. Historical 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 (developed) 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. This could be estimated based on their contribution to the increase of average global 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 historical 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

Table 1
Overview and brief description of regimes included in this study.

Name	Abbreviation	Short description
Immediate, full participation		
Regimes with a global emission cap		
Contraction & convergence	C&C	Emission targets based on a convergence of per capita emission levels under a contraction of the global emission level
Grandfathering	GF	Distribute emission allowances in proportion to current emissions
Equal per capita allocation	EqPC	Distribute emission allowances in proportion to population
Historical responsibility[a]	HR	Distribute emission allowances in proportion to the contribution of global temperature increase over a certain period of time
Regimes without a global emission cap		
Triptych	TY	National emission targets based on sectoral considerations
Carbon tax	Tax	All countries agree to a common, international carbon tax
Gradual participation		
Regimes with a global emission cap		
Common but differentiated convergence	CDC	All countries' per capita emissions converge, but the convergence is differentiated in time
Income distribution	ID	Distribute emission allowances in proportion to the share of rich or poor people in a country, with a participation threshold
Multi-stage	MS	Countries participate at different stages and with stage-specific types of targets
Regimes without a global emission cap		
South–North Dialogue proposal	S–N	Countries participate in the system at different stages and with stage-specific types of targets

[a] The Historical responsibility approach is placed under full participation, but there are also some applications of this approach with a participation threshold that could be placed under gradual participation.

some developing countries would have a high responsibility (see, e.g. Baumert et al., 2005; den Elzen et al., 2005a; Höhne et al., 2010; UNFCCC, 1997). This regime differs from the previous ones in that the problem definition is based on burden sharing instead of resource sharing.

The Triptych (TY) approach (Groenenberg et al., 2004) is a bottom-up sectoral approach to distribute emission reductions among countries. It 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. Emissions of the sectors are treated differently: For the power and industry sector, a growth in the physical production is assumed together with an improvement in production efficiency. For the domestic sector, convergence of per-capita emissions is assumed. 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).

Finally, one of the most straightforward proposals for future climate policy is a global uniform carbon tax (Nordhaus, 2006; Nordhaus, 2010) (Tax). This approach leads to the global equalisation of marginal abatement costs. Hence, a cost efficient reduction of emissions is ensured even without emissions trading. Most proposed taxes increase progressively over time, in order to reduce emissions in a cost-effective way. A carbon tax regime has the advantage of a relatively high certainty on costs, but has relatively low certainty on the amount of emission reduction. An important disadvantage is that given the relative importance of the energy sector at low levels of development costs might be higher in developing countries. There are methods to deal with this, but at the costs of the simplicity of the approach.

2.3.2. Gradual participation regimes

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. In this approach, developed 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 developing 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. Developing countries that do not pass this percentage threshold do not have binding emission reduction requirements. Either they take part in the clean development mechanism (CDM) or they voluntarily take on "positively binding" emission reduction targets. The CDC approach aims at equal per capita allowances in the long run. However, many developing countries have more time to develop without emission reduction requirements. Developing country participation is conditional to reductions made in developed countries through the gradually declining world average threshold.

Two proposed regimes allocate emission allowances on the basis of income distribution within countries (ID) (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.

In the Multi-stage regime (Berk and den Elzen, 2001; den Elzen et al., 2006) (MS), 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 income levels (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 studies. Model outcomes critically depend on the time when large countries such as China and India enter the system.

The South North Dialogue proposal (den Elzen et al., 2007; Ott et al., 2004) (S–N) 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, developing countries are divided in newly industrialised countries, rapidly industrialising developing countries, least developed countries and "other" developing countries. All these groups have different emission reduction objectives. Least developed countries and other developing countries have no reduction targets, rapidly industrialising developing countries have absolute emission limitations if funding is provided by developed countries and newly industrialised countries have absolute emission limitation or reduction targets.

3. Methodology

3.1. Studies included in the assessment

We collected data from many different studies to assess the different regimes (see Table 2). We assessed 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: (i) there is a bias in literature towards certain regimes, (ii) studies use different regional definitions, (iii) different timescales are used in studies, (iv) different measurements for reduction are used to assess emission allowances and (v) different measurements for costs are used.

3.1.1. Literature bias

While some regimes are analysed in many studies (such as C&C or MS), analysis of other regimes is scarce (e.g. S–N or 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).[1]

[1] In general, much of the literature comes from the European research institutes. This also has a historical reason, as the EU adopted in 1996 the 2 degree climate target. This led to many burden-sharing studies from the EU, to analyse the countries' emission implications to meet this climate target. In addition, the issue of internal burden-sharing to allocate the overall EU reduction target across

Table 2
Overview of the studies that are analysed in this report, the allocation schemes included in these studies (see Table 1 for abbreviations) and the concentration stabilisation targets (including only CO_2 or all greenhouse gases as CO_2-equivalent).

Studies	Allocation schemes	Concentration stabilisation target
Baer et al. (2008)	ID	400 ppm CO_2e
Berk and den Elzen (2001)	C&C, HR, MS	450 ppm CO_2
Blanchard (2002)	C&C, EI, HR	550 ppm CO_2
Bode (2004)	HR	450 ppm CO_2
Boeters et al. (2007)	MS	450 ppm CO_2e
Böhringer and Helm (2008)	C&C, EqPC	550 ppm CO_2e
Böhringer and Löschel (2005)	AtP, GF	550 ppm CO_2e
Böhringer and Welsch (2004)	C&C	550 ppm CO_2e
Böhringer and Welsch (2006)	C&C, EqPC, GF	550 ppm CO_2e
Chakravarty et al. (2009)	ID	400 ppm CO_2
Criqui et al. (2003)	C&C, MS	550, 650 ppm CO_2e
den Elzen and Lucas (2005)	AtP, C&C, EI, GF, HR, MS, TY, CSE, MC, GC	550, 650 ppm CO_2e
den Elzen and Meinshausen (2006)	C&C, MS	400, 450, 500, 550 ppm CO_2e
den Elzen et al. (2005b)	C&C, HR, MS	550, 650 ppm CO_2e
den Elzen et al. (2007)	S–N	400, 450, 500, 550 ppm CO_2e
den Elzen et al. (2008a)	TY	450 ppm CO_2e
den Elzen et al. (2008b)	C&C, MS	450, 550 ppm CO_2e
Ekholm et al. (2010)	C&C, MS, TY	450, 550 ppm CO_2e
Groenenberg et al. (2004)	TY	450 ppm CO_2
Hof et al. (2010)	C&C, MS, CDC	550, 620 ppm CO_2e
Hof and Den Elzen (2010)	TY	500 ppm CO_2e
Höhne and Moltmann (2008)	C&C, ID, MS, CDC	450, 550 ppm CO_2e
Höhne and Moltmann (2009)	ID, MS, CDC	80% below 1990 levels by 2050
Höhne et al. (2005)	C&C, MS, CDC, TY	400, 450, 550 ppm CO_2e
Höhne et al. (2006)	C&C, CDC	550, 650 ppm CO_2e
Höhne et al. (2007)	C&C, EI, MS, CDC, TY	450, 550 ppm CO_2e
Jacoby et al. (2008)	AtP, EqPC, GF	450 ppm CO_2e
Knopf et al. (2009)	C&C, HR	450 ppm CO_2e
Kuntsi-Reunanen and Luukkanen (2006)	C&C	400 ppm CO_2
Leimbach et al. (2010)	C&C, EI, MS	415 ppm CO_2
Leimbach (2003)	C&C	450 ppm CO_2
McKibbin and Wilcoxen (2009)	EqPC, GF	550 ppm CO_2e
Nordhaus (2006, 2010)	Tax	430, 500 ppm CO_2
Persson et al. (2006)	C&C, EqPC	450 ppm CO_2
Peterson and Klepper (2007)	C&C, GF, Tax	550 ppm CO_2e
Rose et al. (1998)	EqPC, GF, MC, Hor, Vert	20% below 1990 from 2010 onwards
van Vuuren et al. (2009)	Tax	450 ppm CO_2e
WBGU (2003)	C&C	400, 450 ppm CO_2

3.1.2. 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 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 included 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.

3.1.3. 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.

3.1.4. Emission measurement

Emissions are reported as either CO_2 only or as CO_2-equivalent (Kyoto gases), and studies report different sources (energy, industry, land-use). For comparison, we therefore expressed all emission (allowance) reductions relative to baseline and to the 2005 emission level, corrected for the regional definition and greenhouse gases included in the study. It should be noted that the observed 2005 emission level that we used might deviate considerably from the numbers actually used in the study (in case 2005 emissions were still unknown). In these cases, the results may be inconsistent with the reductions compared to baseline of the study. For example, older studies tend to have lower baseline projections for China, and their 2020 projection might actually be equal to the observed 2005 values. Such studies could have 2020 allowances equal to 2005 emissions, but with no reduction below baseline. This would probably not have been the result if they used a more recent, higher, baseline projection. There is, however, no way how this can be solved.

3.1.5. Cost measurement

Studies report very different cost measurements. 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 losses 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).

(*footnote continued*)
the EU Member states, already before the Kyoto Protocol, has triggered many burden-sharing studies as well.

Other differences in cost measurement are cumulative costs vs. costs in a particular year and discounted costs or not. Finally, for some studies numbers had to be estimated by reading graphs, which obviously leads to some imprecision. Obviously, the absolute values of these different metrics cannot be directly compared. Therefore, 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. (2009) as: (1) 'no cost or gains', (2) 'costs lower than half of global average', (3) 'costs between half global average and global average', (4) 'costs above global average'. Earlier, van Vuuren et al. (2009) showed that the relative costs of different metrics reasonably correlate.

3.2. 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 a 20% and 17% share 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 2% of global GDP in MER (4% in PPP). GDP per capita is well below the global average in both countries, with the Indian per capita GDP in fact being 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, these numbers are 36.3% and 15.9% of population below 2 and 1.25 $\$_{ppp}$/day, respectively. China's economy is also more important globally in terms of energy use and CO_2 emissions, with resp. 15% and 19% of the global energy use and CO_2 emissions. In fact, per capita emissions of China approach the global average. The Indian economy has a share of nearly 5% in both energy use and CO_2 emissions.

3.3. 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 effort sharing only provide data on emissions, not on the other factors. Interestingly, many studies have baseline estimates for 2020 for China and India that are below their 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 period of high income and emissions growth. This unexpected growth is also reflected in the IEA forecasts for 2020 of different years. In 2004, the IEA projected the Chinese emissions for 2020 to be 5700 $MtCO_2$; the latest projection is in fact 9990 $MtCO_2$ (see also Blanford et al., 2009 for the need to update emission projections for China). The rapid Chinese growth does have implications for emission reduction projections. While Chinese emissions have been growing rapidly, this has been partly on the basis of exports (Pan et al., 2008). In other regions other trends can be noticed, the implications of these changes for mitigation regimes are discussed in Section 4.

India's emissions are at a 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, and also population projections are very different.[2] For India, the difference between CO_2 and total greenhouse gas emissions is an important one as the contribution of non-CO_2 greenhouse gases 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).

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	36,610
GDP per capita, MER (US $\$_{2000}$/yr)	1452	589	5665
GDP, PPP (billion int $\$_{2005}$/yr)	5314	2445	56,667
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[a]/yr)	1700	538	11,253
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

[a] MTOE—million tons of oil equivalent.

4. Results

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 in emission allowances and the economic impacts and costs. Finally, we discuss some other relevant issues, like baseline uncertainty and timing of emission reduction.

4.1. Emission (allowance) reduction targets

The ranges of emission reduction targets (in terms of allowances) for China and India for the climate policy regimes are shown in Figs. 1–4. Figs. 1 and 3 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. Figs. 2 and 4 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.

In each figure, the coloured areas reflect the total range, within which we have indicated the median value and the 15th and 85th percentile of the results of the studies. The latter is mainly to indicate whether wide ranges are caused by outliers, or whether there is wide variation across the total literature. We only applied the statistical analysis (median, 15th–85th percentile range) if at least eight analyses 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

[2] Interestingly, older studies such as Berk and den Elzen (2001), Blanchard 2002) and Rose et al. (1998) 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.

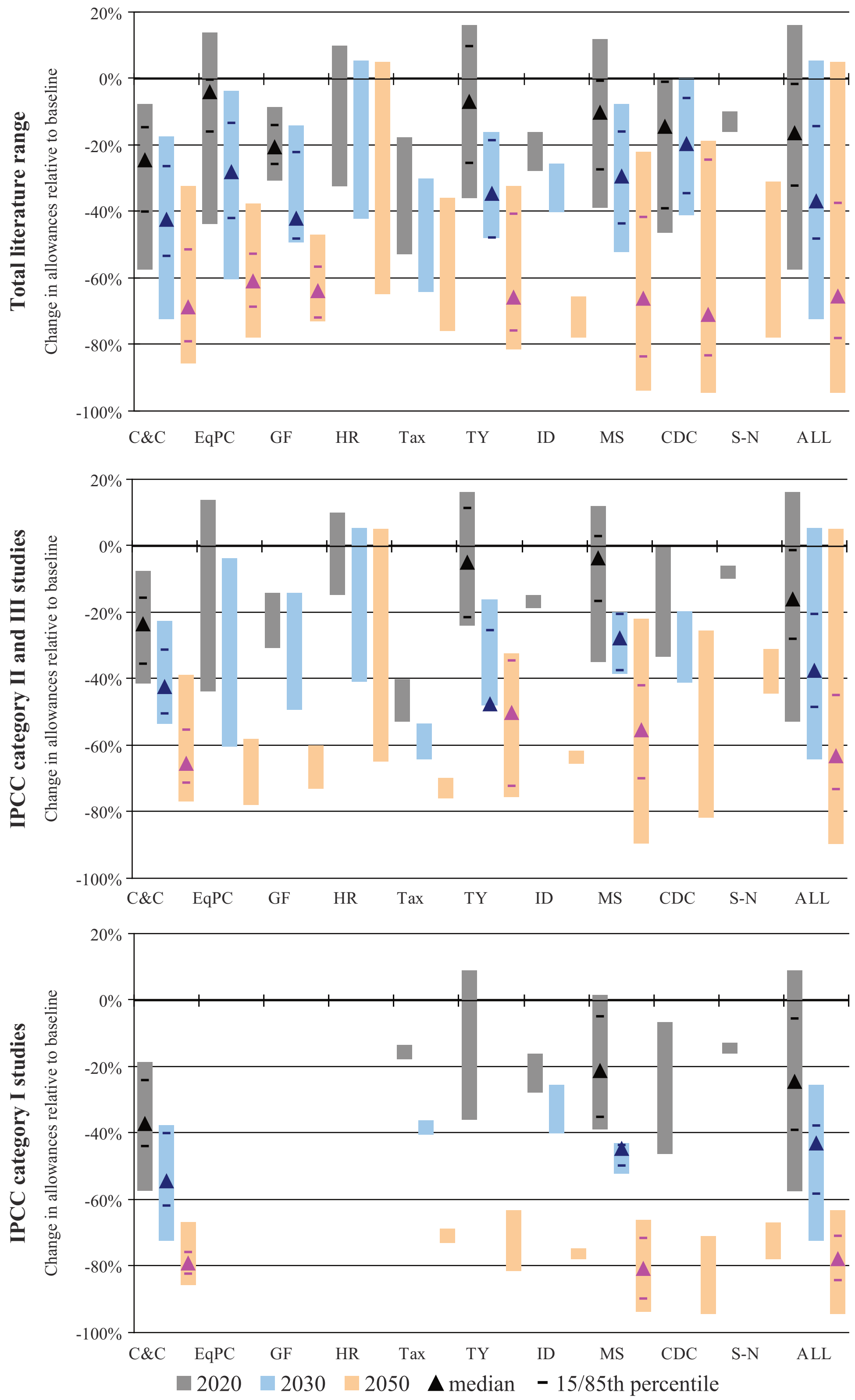

Fig. 1. Emission allowances relative to baseline for China for several regimes for the total range of reviewed literature, IPCC category I and II & III studies (as explained in the text). Statistical indicators are only shown if more than eight studies were involved.

aiming for radiative forcing of less than 3 W/m^2, or a CO_2-equivalent concentration below 490 ppm CO_2-eq and categories II and III aim for 3–4 W/m^2 or 490–590 ppm CO_2-eq. We clustered categories II and III because very few studies contain category II targets.

4.1.1. Results for China

Generally, across all regimes and stabilisation levels, the figures show a fairly diverse picture for China. In 2020, allowances of the 15th and 85th percentile of all literature are between 0%

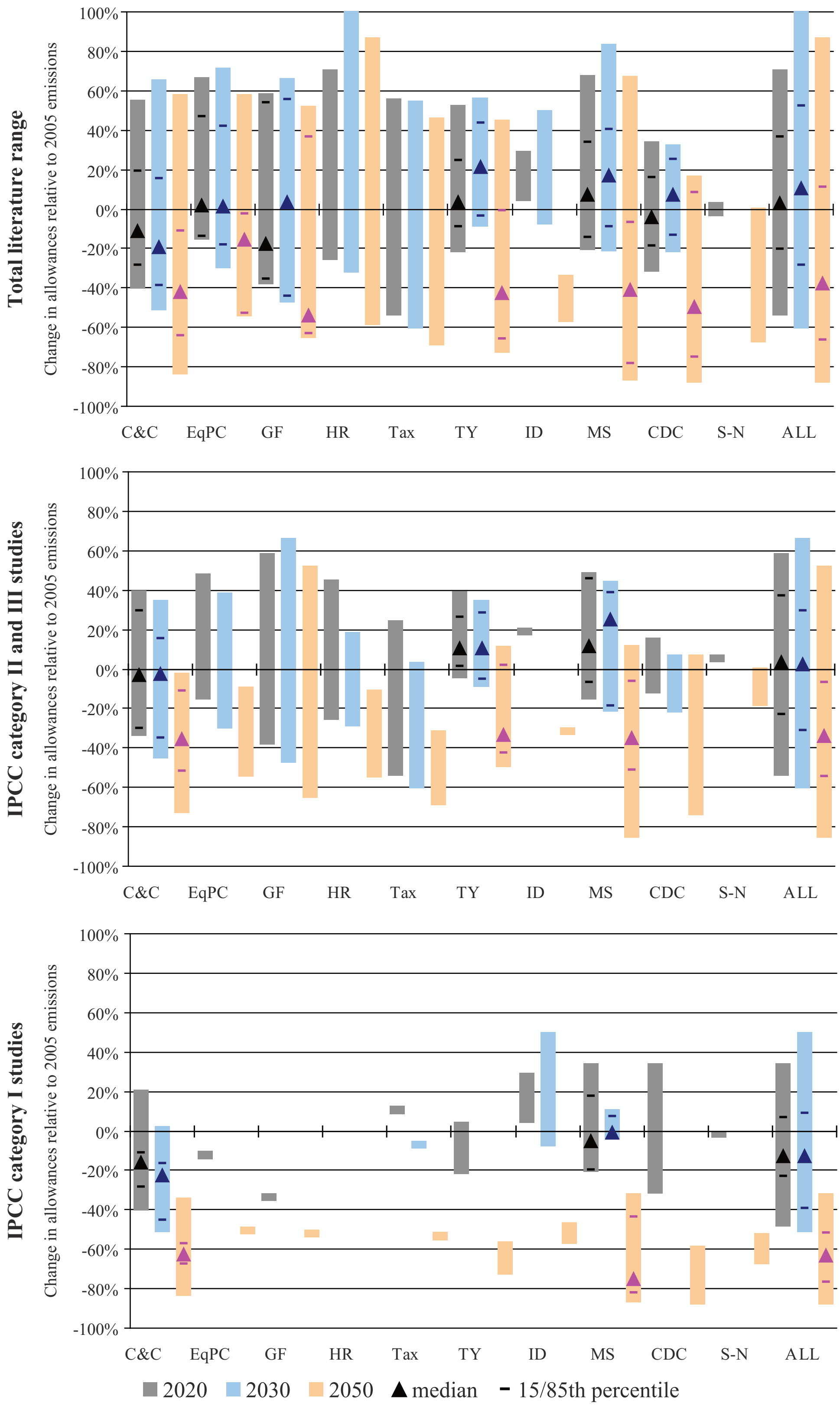

Fig. 2. Emission allowances relative to observed 2005 emissions for China for several regimes for the total range of reviewed literature, IPCC category I and II & III studies (as explained in the text). Statistical indicators are only shown if more than eight studies were involved. Note that we related allowances to historically observed 2005 emissions. The individual studies (may) use different levels of 2005 emissions, and hence, lead to different results.

and 35% below baseline, or +40% to −20% compared to the observed 2005 level. For IPCC category II and III scenarios, the reduction over all regimes is 0–30% below baseline (or +40% to −20% on 2005 levels), and for IPCC category I scenarios it is 5–40% below baseline (or +5 to −20% compared to 2005). For 2050, the 15th and 85th percentile of all literature is

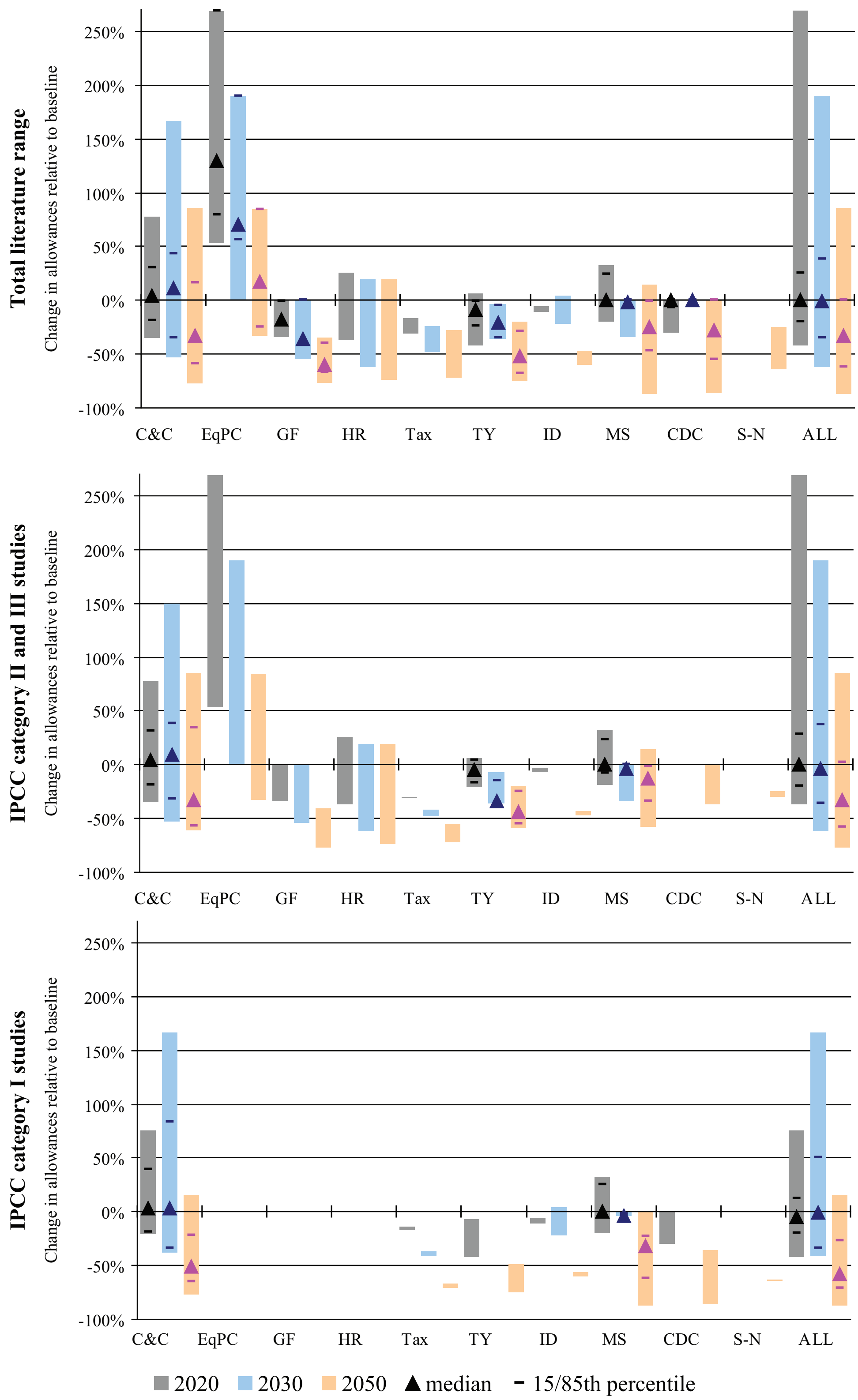

Fig. 3. Emission allowances relative to baseline for India for several regimes for the total range of reviewed literature, IPCC category I and II & III studies (as explained in the text). Statistical indicators are only shown if more than eight studies were involved.

between about 40% and 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 should be noted that here our earlier remark on the impact of fast emission growth in China in the early 2000s may play a role; current studies might yield different results (see Section 4.4).

It is important to note that low stabilisation scenarios have only been evaluated in the literature for a small selection of studies and regimes. Still, all regimes show for 2050 a reduction

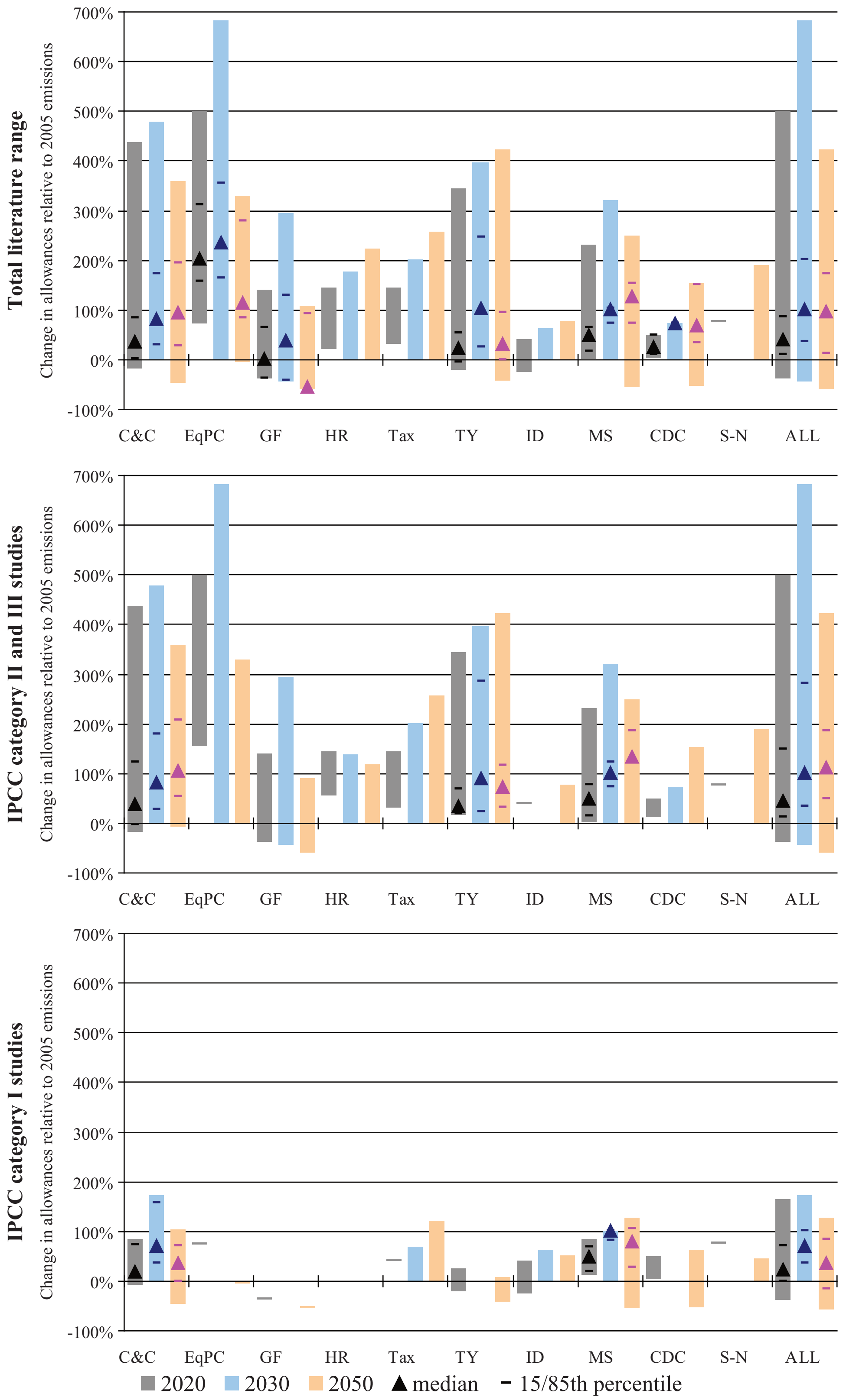

Fig. 4. Emission allowances relative to 2005 emission levels for India for several regimes for the total range of reviewed literature, IPCC category I and II & III studies (as explained in the text). Statistical indicators are only shown if more than eight studies were involved. Note that we related allowances to historically observed 2005 emissions. The individual studies (may) use different levels of 2005 emissions, and hence, lead to different results.

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 resource sharing approaches (i.e. C&C, Grandfathering, or Equal PC) would involve significant reductions for China—while the burden sharing approaches (i.e. Multi-stage, income distribution and a global carbon tax) would require lower reductions. This is because

China's per capita emissions are very close to the world average (see Section 3.2), leaving little flexibility in resource sharing approaches. Burden sharing approaches have generally more flexibility to account for China's particular situation.

As can be expected, category II and III climate targets require less stringent targets for China. The broader ranges for these targets can be explained by the fact that more studies have evaluated regimes for these targets. Nevertheless, also here, the difference between the regimes is mainly relevant for the shorter term. By 2050, reductions vary between 40% and 80% below baseline in all regimes. Regimes with the lowest reduction effort for China in the short term seem to be HR, MS, CDC, S–N and TY. GF, C&C and Tax require generally high emission reductions in the short term. The suggestion in Figs. 1 and 2 that a Tax regime leads to less emission reduction for China under low stabilisation scenarios, than under the IPCC category II and III studies seems not to be robust (and is a consequence of the limited amount of studies in this category).

4.1.2. Results for India

For India, in 2020, emission reduction requirements of the 15th and 85th percentile of all literature are between +25% and −20% of the baseline, or between +10% and +90% compared to 2005. For IPCC category II and III scenarios, the reduction over all regimes is +30% to −20% of the baseline (or 30–150% above 2005 levels), and for IPCC category I scenarios it is +13% to −20% of the baseline (or 0–70% above 2005 levels). For 2050, the 15th and 85th percentile of all literature is between 0% and 60% below baseline or 18–185% above 2005 emissions. The range for the stringent climate target scenarios is 30–70% reduction below baseline (or +84 to −15% on 2005 levels).

The results also show that many regimes lead to 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 range of results across regimes and even within regimes. For instance, for C&C allowances range from a surplus of 50% to 50% reduction below baseline in 2050. For the low stabilisation scenarios, C&C also shows surpluses in 2020. The CDC, S–N, income distribution and Triptych approaches instead show small reductions. Grandfathering requires clearly most reductions for India (see category I), as it is the only regime with allowances below the 2005 level in 2020. In category II and III 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.

4.2. Emission 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. Fisher et al., 2007).[3] On country level, less information has been published, but still the issue plays an important role in discussions. In the run-up to COP 15 in Copenhagen, Chinese officials announced that its domestic emissions could peak in 2050, making this figure subject to political discussion.[4] 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 not (yet) discussed peaking of emissions.

It should be noted that we focus here on emission allowance peaking, rather than emissions peaking. Most regimes allow emission trading, differentiating emissions from allowances.

The peaking year of emission allowances depends strongly on the regime. As shown in Section 3, a C&C regime generally leads to emission allowances below baseline levels for China, but could lead to emission allowances higher than projected baseline emissions for India. This could lead to a peak in emission allowances for India in the convergence year and for China soon after their participation in 2020, if the convergence level in per capita emissions is chosen sufficiently low. Because both economies are growing fast but have contributed relatively little to global emissions in the past, HR regimes would start with high emissions allocations but these would decline over time, as their share in global emissions increase fast after 2005 (also due to declining shares of the developed countries).

Figs. 5 and 6 show an overview of the peaking years for allowances in the studies that are included in this report.[5] Most studies find that in China, allowances peak before 2025, while in low stabilisation scenarios this is even before 2020. For India, in low stabilisation scenarios the average peak in allowances is around 2030–2045 and for higher concentration targets even later. Again, it should be noted that the peaking year for allowances might differ from the peaking year in domestic 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.

4.3. Economic impact and costs

Table 4 shows the costs for China for several regimes relative to the global average costs as share of GDP. It shows the percentages of studies that find (1) 'no cost or gains', (2) 'costs lower than half of global average', (3) 'costs between half global average and global average', (4) 'costs above global average'.

It is clear that economic impacts and costs for China vary widely among different regimes, but also across studies and measurements. The costs strongly depend on the amount of allowances that can be traded internationally. Regimes with a (temporary) surplus of allowances obviously lead to gains (e.g. Equal PC or Multi-stage) whereas others require domestic mitigation effort in the short term (e.g. C&C and Grandfathering). A similar pattern can be found in the sub-graphs for low stabilisation scenarios and categories II and III scenarios, although the amount of studies for individual regimes is too limited for valid conclusions. Overall, economic impacts and costs for China are far below the global average in the short term, but approach the global average towards 2050. This pattern holds for the lower stabilisation scenarios as well. Other analyses, that looked towards the whole period 2000–2100, report higher costs for China, which can probably be explained from increasing costs in the second half of the century (Edenhofer et al., 2010).

For India, almost all studies and regimes show economic gains (Table 5). However, Grandfathering and a global carbon tax are

[3] Much of this discussion comes from the timing of emission reductions and the trade off between an early start with higher 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.

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

[5] The peaking year cannot be derived for all studies, which is clearly limiting the number of studies included in this part of the analysis.

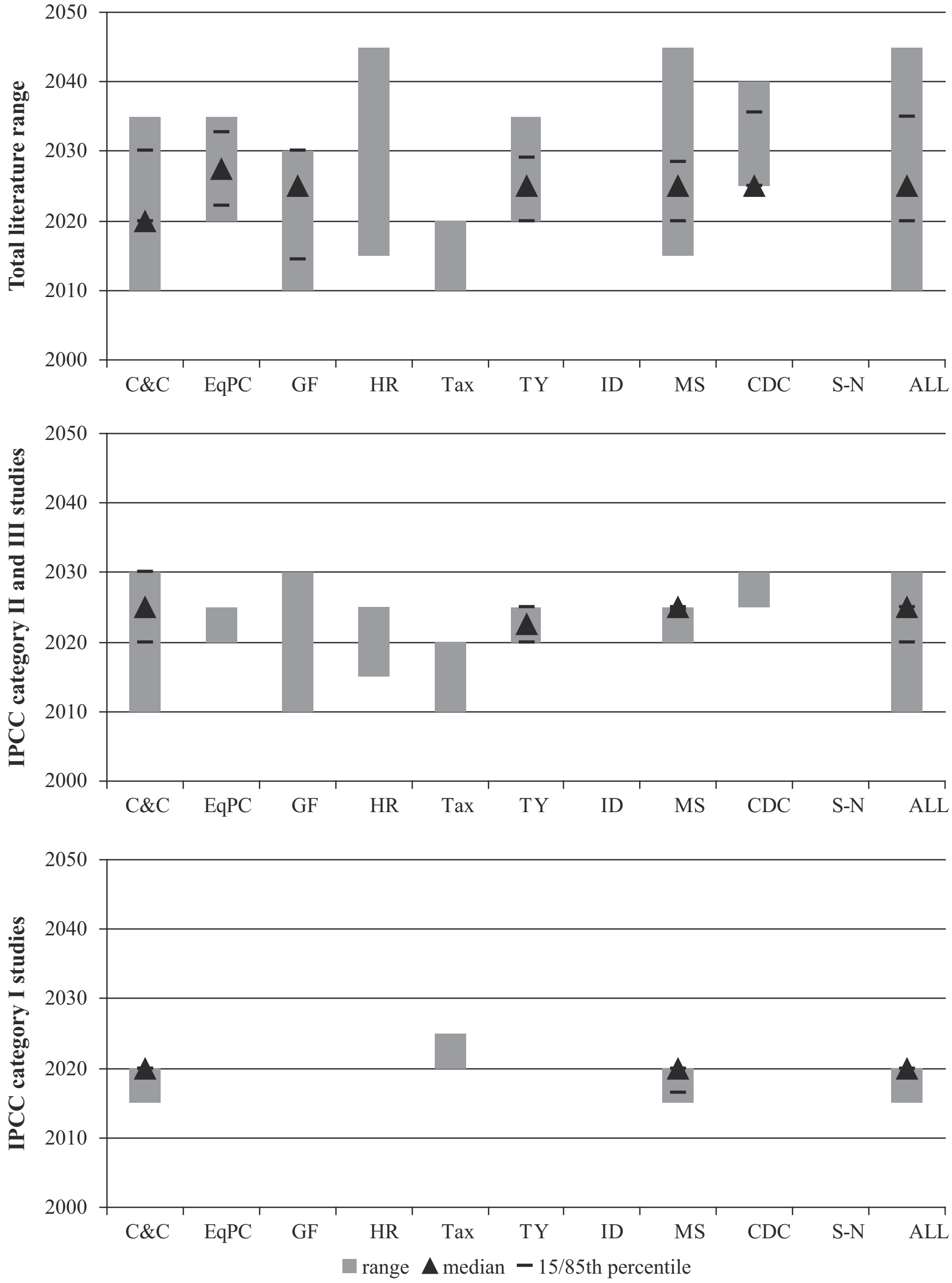

Fig. 5. Overview of allowance peaking years for China in several regimes for the total range of reviewed literature, IPCC category I and II & III studies (as explained in the text). Statistical indicators are only shown if more than eight studies were involved.

relatively costly regimes for India. Equal per capita would bring along the highest gains; Multi-stage, C&C and Historical responsibility would also be economically attractive for India, although the range of the gains in relation to international costs has a significant spread. 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.

4.4. *China's recent emission growth and timing of reductions*

The huge uncertainty in the 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. The baseline projections of many studies for 2020 published before 2005 are actually below or only slightly above emission data from recent years. Therefore, we analyse 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 recent Chinese national studies (ERI, 2009; UNDP, 2010).

Fig. 7 compares the emission reductions of the high baseline studies with the total range of studies, expressed relative to 2005 or compared to baseline. Not surprisingly, in absolute terms 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 developed countries, and hence, a larger share of future emissions can be

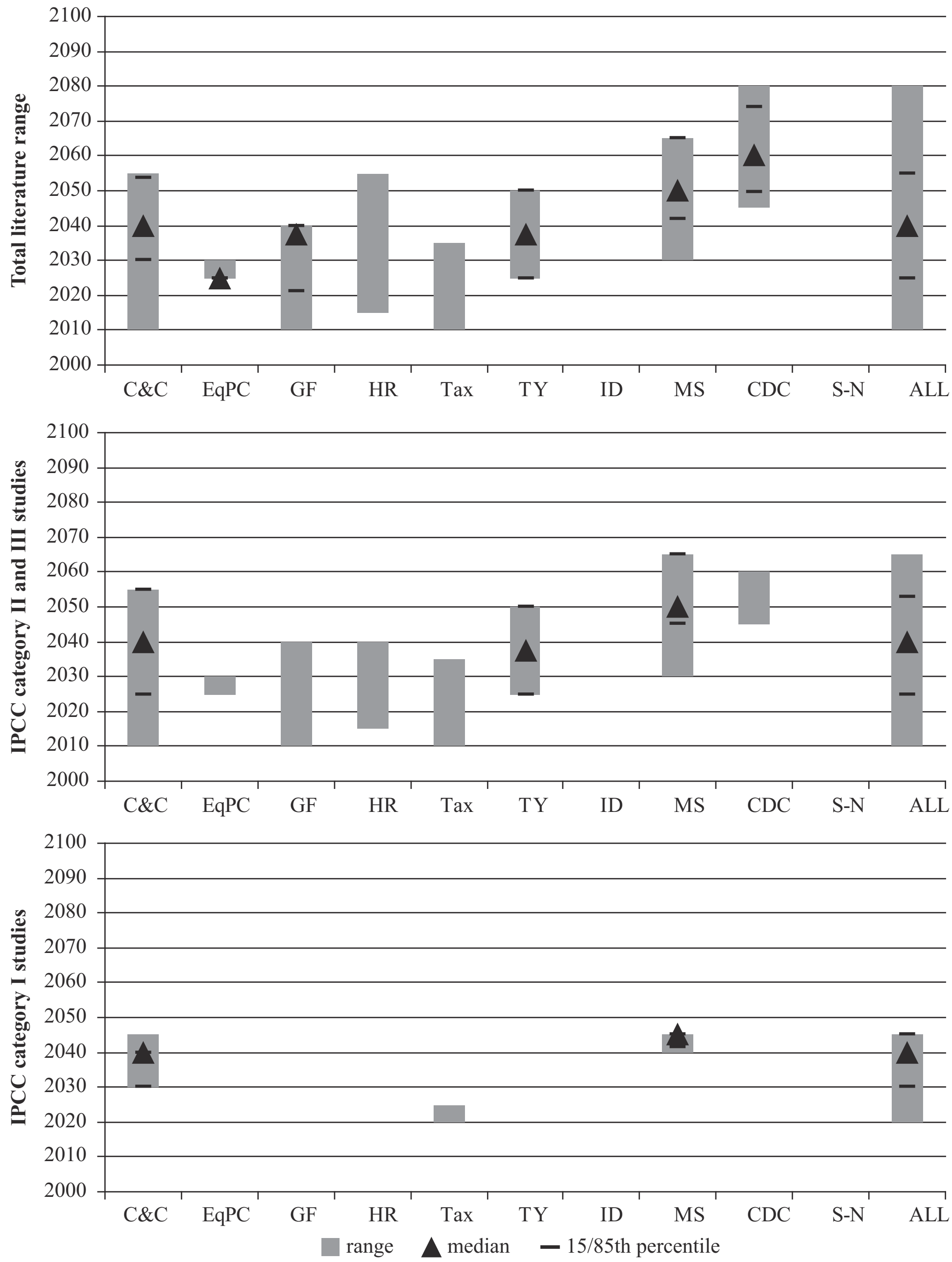

Fig. 6. Overview of allowance peaking years for India in several regimes for the total range of reviewed literature, IPCC category I and II & III studies (as explained in the text). Statistical indicators are only shown if more than eight studies were involved.

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).

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, as the total range of studies.

5. Recent literature from China and India

5.1. Chinese proposals and considerations

As part of the Copenhagen accord, China submitted a mitigation action plan to the UNFCCC. This plan consists of reducing CO_2 emissions per unit of GDP by 40–45% by 2020 compared to 2005, increasing non-fossil fuels in primary energy consumption to around 15% and increasing forest coverage by 40 million ha and forest stock volume by 1.3 billion m^3 relative to 2005 levels (as analysed by e.g., den Elzen et al., 2011; Rogelj et al., 2010; UNEP, 2011; Zhang, 2011a).

Recently, two climate policy scenarios for China have been published. ERI (2009) explored the possibilities for low-carbon development in China under two scenarios: low-carbon and enhanced low carbon development. Both scenarios include a reduction of about 20% 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 28% reduction below baseline in 2020 and resp. 41% and 66% in 2050. In the latter case, the underlying modelling study from Renmin University, foresees

Table 4
Distribution of Chinese costs, relative to global average costs and the number of studies included. 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).

Regimes	**Total literature range** Relative cost category					**IPCC category II+III studies** Relative cost category					**IPCC category I studies** Relative cost category				
	0	1	2	3	Studies	0	1	2	3	Studies	0	1	2	3	Studies
2020															
C&C	11%	5%	32%	53%	19	10%	10%	30%	50%	10	0%	0%	29%	71%	7
Equal PC	50%	25%	0%	25%	4	50%	50%	0%	0%	2	100%	0%	0%	0%	1
GF	33%	33%	0%	33%	6	25%	25%	0%	50%	4	0%	100%	0%	0%	1
HR	0%	50%	50%	0%	2	0%	100%	0%	0%	1					
ID	0%	0%	0%	100%	4	0%	0%	0%	100%	2	0%	0%	0%	100%	1
MS	89%	0%	0%	11%	9	100%	0%	0%	0%	4	100%	0%	0%	0%	4
Tax	0%	0%	100%	0%	1						0%	0%	100%	0%	1
TY	70%	15%	15%	0%	20	70%	30%	0%	0%	10	63%	0%	38%	0%	8
All	43%	12%	17%	28%	65	42%	21%	9%	27%	33	43%	4%	26%	26%	23
2030															
C&C	8%	0%	83%	8%	12	14%	0%	86%	0%	7	0%	0%	100%	0%	2
Equal PC	33%	33%	33%	0%	3	50%	0%	50%	0%	2					
GF	25%	0%	0%	75%	4	33%	0%	0%	67%	3					
HR	67%	33%	0%	0%	3	0%	100%	0%	0%	1					
ID	0%	0%	0%	100%	4	0%	0%	0%	100%	2	0%	0%	0%	100%	1
MS	0%	0%	0%	100%	1										
Tax															
TY	22%	33%	44%	0%	9	0%	60%	40%	0%	5	0%	0%	100%	0%	2
All	19%	14%	42%	25%	36	15%	20%	45%	20%	20	0%	0%	80%	20%	5
2050															
C&C	0%	16%	52%	32%	25	0%	19%	56%	25%	16	0%	14%	29%	57%	7
Equal PC	67%	0%	33%	0%	6	75%	0%	25%	0%	4	100%	0%	0%	0%	1
GF	0%	33%	0%	67%	6	0%	25%	0%	75%	4	0%	100%	0%	0%	1
HR	50%	0%	50%	0%	2	0%	0%	100%	0%	1					
ID	0%	0%	25%	75%	4	0%	0%	50%	50%	2	0%	0%	0%	100%	1
MS	44%	33%	11%	11%	9	100%	0%	0%	0%	4	0%	75%	25%	0%	4
Tax															
TY	5%	32%	58%	5%	19	10%	40%	40%	10%	10	0%	0%	100%	0%	7
All	14%	21%	41%	24%	71	20%	20%	39%	22%	41	5%	24%	48%	24%	21

rather fierce macro economic impacts, reaching up to 10% reduction of GDP compared to baseline.

Recent literature on effort-sharing regimes from Chinese authors focuses mainly on Historical responsibility. While the Brazilian proposal is based on Historical responsibility of countries, Chinese considerations focus on the concept of cumulative emissions per capita. Hu et al. (2009) determined the historical 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 Historical 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 Development Research Centre of the State Council (2009) developed a theoretical framework for National Emission Accounts that distinguishes between historical emissions and future emissions under a future climate regime. Ding et al. (2009, 2010) published an analysis for China under a cumulative per capita regime using multiple emission scenarios, which are all considerably higher than the allowances in the studies with low stabilisation levels analysed above. They conclude that regimes that aim at convergence of annual per capita emissions are more attractive for industrialised countries than cumulative per capita regimes. The publications on cumulative per capita approaches did not contain enough information to include them quantitatively in this analysis.

He et al. (2009) propose an allocation scheme, in which developing countries gain room for development by allowing the per capita emission allowances of non-Annex 1 countries to exceed per capita allowances of industrialised countries for some time, after which both levels converge to a sustainable emission level. The peaking level of per capita allowances decreases over time, argued for by technology development and global emission cap that becomes more stringent over time. This regime is comparable to the Common but Differentiated Convergence approach (Höhne et al., 2006).

Other authors discuss the current position of China in the climate debate and propose ways forward. Zhang (2010) highlights several reasons for China's currently fast growing CO_2 emissions and why these cannot be reduced in the short term. For instance, there is a large difference between central and local governments, and local governments have to be convinced of the urgency of GHG emission mitigation. As a 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 (2011b) 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.

Recently, two studies on climate policy scenarios for India have been published. Shukla et al. (2008) explored a low-carbon

Table 5
Distribution of Indian costs, relative to global average costs and the number of studies included. 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).

Regimes	**Total literature range**					**IPCC category II+III studies**					**IPCC category I studies**				
	Relative cost category					Relative cost category					Relative cost category				
	0	1	2	3	Studies	0	1	2	3	Studies	0	1	2	3	Studies
2020															
C&C	89%	11%	0%	0%	18	90%	10%	0%	0%	10	83%	17%	0%	0%	6
Equal PC	75%	0%	25%	0%	4	100%	0%	0%	0%	2	100%	0%	0%	0%	1
GF	33%	0%	0%	67%	6	25%	0%	0%	75%	4	0%	0%	0%	100%	1
HR	100%	0%	0%	0%	2	100%	0%	0%	0%	1					
ID	0%	0%	50%	50%	4	0%	0%	50%	50%	2	0%	0%	0%	100%	1
MS	100%	0%	0%	0%	9	100%	0%	0%	0%	4	100%	0%	0%	0%	4
Tax	0%	100%	0%	0%	1						0%	100%	0%	0%	1
TY	100%	0%	0%	0%	20	100%	0%	0%	0%	10	100%	0%	0%	0%	8
All	81%	5%	5%	9%	64	82%	3%	3%	12%	33	82%	9%	0%	9%	22
2030															
C&C	92%	8%	0%	0%	12	86%	14%	0%	0%	7	100%	0%	0%	0%	2
Equal PC	100%	0%	0%	0%	3	100%	0%	0%	0%	2					
GF	50%	0%	0%	50%	4	33%	0%	0%	67%	3					
HR	100%	0%	0%	0%	3	100%	0%	0%	0%	1					
ID	0%	25%	25%	50%	4	0%	0%	50%	50%	2	0%	0%	0%	100%	1
MS	100%	0%	0%	0%	1										
Tax															
TY	100%	0%	0%	0%	9	100%	0%	0%	0%	5	100%	0%	0%	0%	2
All	81%	6%	3%	11%	36	75%	5%	5%	15%	20	80%	0%	0%	20%	5
2050															
C&C	88%	8%	0%	4%	25	81%	13%	0%	6%	16	100%	0%	0%	0%	7
Equal PC	100%	0%	0%	0%	6	100%	0%	0%	0%	4	100%	0%	0%	0%	1
GF	17%	0%	17%	67%	6	25%	0%	0%	75%	4	0%	0%	0%	100%	1
HR	100%	0%	0%	0%	2	100%	0%	0%	0%	1					
ID	25%	0%	0%	75%	4	0%	0%	0%	100%	2	0%	0%	0%	100%	1
MS	89%	11%	0%	0%	9	100%	0%	0%	0%	4	100%	0%	0%	0%	4
Tax															
TY	100%	0%	0%	0%	19	100%	0%	0%	0%	10	100%	0%	0%	0%	7
All	83%	4%	1%	11%	71	80%	5%	0%	15%	41	90%	0%	0%	10%	21

scenario and a sustainable society scenario for India. The low-carbon scenario reduces 8% below baseline in 2020 and 80% in 2050. The sustainable society scenario outlines an early shift to broader sustainable development policies, leading to 20% reduction below baseline in 2020 and 62% in 2050. TERI (2008) present a set of three mitigation scenarios: the Evolution, Resolution and Ambition scenarios. This study includes a particularly high baseline scenario, projecting a doubling of CO_2 emissions in 2021, compared to 2011, and a fivefold increase in 2031. The mitigation scenarios show reductions of 13–27% below baseline in 2020 and resp. 36%, 63% and 75% below baseline in 2050.

Recent Indian literature on climate policy is rather broadly and qualitatively oriented. 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 Historical 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 (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 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 pre-requirements for successful implementation of SD-PAMS. Finally, Sudhakara Reddy and Assenza (2009a,b) argue that

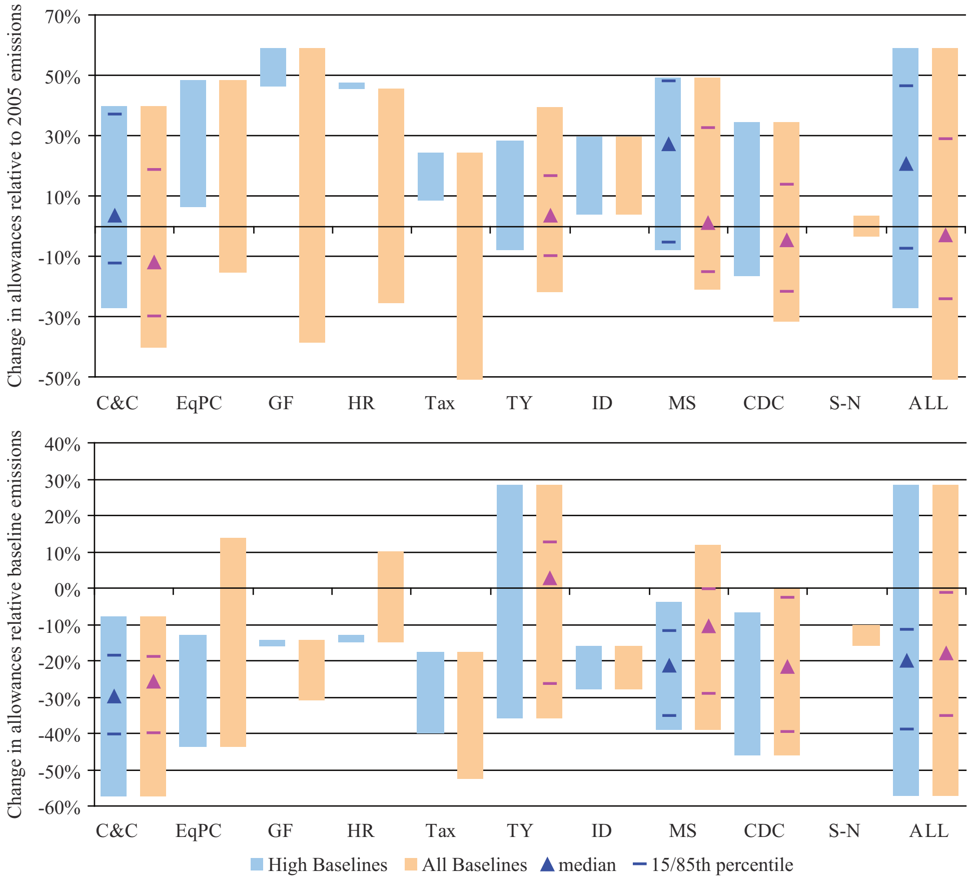

Fig. 7. Emission allowances of China compared to 2005 levels and compared to baseline for 2020 under different reduction regimes in IPCC category I, II and III studies (as explained in the text) for all studies and a selection of studies with high baselines (emissions in 2020 at least 30% above observed 2005 levels). Statistical indicators are only shown if more than eight studies were involved.

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.

5.3. *Main differences between the Chinese/Indian position and international studies*

We first compare the national studies on climate policy scenarios for China and India with international studies with respect to mitigation levels. For China, expressed in terms of reductions below baseline, the national scenarios are on the short term comparable to low-stabilisation scenarios of regimes with relatively high allowances for China (Multi-stage or CDC). However, as reductions do not carry on towards 2050, the national literature is in total most comparable to international literature on less stringent scenarios (IPCC II/III category) with contraction and convergence approaches. Expressed in absolute terms (on observed 2005 emission levels), the national studies are roughly comparable to international less stringent scenarios with Multi-stage or Triptych approaches, though with a much higher emission level on the short term.

The national scenarios for India are comparable to international low-stabilisation scenarios, in terms of reductions below baseline. However, expressed in absolute emission levels, only the lowest national scenarios would match with IPCC category I studies, the others would be in line with less stringent stabilisation scenarios. Given the wide ranges in results for India, it is hardly possible to compare the national scenarios to different effort-sharing approaches.

When comparing the national literature on effort-sharing approaches with international studies, it can be seen that the Historical responsibility approaches, as interpreted by Chinese researchers in terms of historical emissions per capita, are hardly analysed in an international context. Other approaches that appear in the Indian and Chinese literature do often have an international equivalent, like common-but-differentiated convergence or Multi-stage approaches. The approaches that are based on sustainable development measures are less-committal, and therefore appear hard to quantify in an international context.

6. Conclusion and discussion

Based on a comparison of the scientific literature on climate policy regimes, with respect to allowances, peaking year and economic impact or costs, we conclude that the allocation of emission allowances to both China and India are more sensitive to the global emission target than to the allocation regime, especially for low concentration targets. As both countries have expressed their support for the 2°C target, this implies that ambitious emission reductions will have to be achieved in both China and India.

Furthermore, the allocation of emission allowances to both China and India differs greatly, not only across regimes, but also within regimes, especially in the short term. 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 emission developments for China, leading to large uncertainties in the results.

Notwithstanding the large differences between and within regimes, all studies show deep cuts in allowances for China in the long term. Towards 2020 and 2030, studies of Multi-stage, Common but differentiated convergence, Triptych and Historical responsibility show the highest emission allowances and lowest costs or economic impact. Studies of Grandfathering and Contraction & convergence show large reductions in allowances for China. By 2050, however, studies of low stabilisation scenarios (IPCC category I) show that Chinese emission allowances reduce to 50–80% below 2005 levels, irrespective of the regime.

The economic impact or costs for China remain below the global average in most analysed studies and regimes. While literature shows that China is likely to face 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 in the long run. Therefore, the upper range of literature projects costs to increase to about the global average at maximum.

In the literature on climate policy regimes, Chinese emission allowances peak relatively early, before 2025–2030. Especially in low stabilisation scenarios, the median of the studies is observed around 2020–2025, 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—and are even above baseline emissions in a number of studies and regimes. Equal per capita and Multi-stage allow for small surpluses of allowances, whereas Common but differentiated convergence and the South-North Dialogue proposal 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 gain, or to incur only low costs, from climate policy. Net revenues can be explained by revenues from selling carbon credits being larger than mitigation costs. Therefore, climate mitigation seems beneficial for India, except in regimes that lead to a reduction in allowances in the short-term, like Grandfathering and a global carbon tax.

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 2030–2045.

These results imply that the inclusion of the 2° climate target in the Cancún Agreements (UNFCCC, 2010) has consequences for emission peaking and allowances in the short term, especially for China. Another implication is that policy regimes in which emissions are allocated to countries based on meeting the 2° climate target may be more attractive to both China (at least on the short term) and India, compared to the current muddling through approach since the Copenhagen Accord—provided that these countries are allowed to sell emission credits to developed countries.

It should be noted that there are many uncertainties in this analysis. These firstly relate to technical uncertainties in the underlying studies, for instance, with respect to baseline assumptions and methodology. Secondly, the methodology that was applied in this report involves uncertainties, of which the most important are the following. First, there is a bias in literature towards certain regimes, which complicates the comparison of different regimes: what seems a difference between regimes might well be a difference between studies or models. Second, there is a geographical bias of underlying analyses. Most studies that were reviewed in this report contain global analyses of climate policy regimes. Unfortunately, these studies are mainly carried out by scholars and institutes from industrialised countries; 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". Third, and more methodological, are the different measurements for costs. Studies report very different cost measurements, ranging from direct costs to changes in GDP and welfare. When comparing the regimes, we have focussed on the relative costs of regions compared to the global average costs as presented by the studies. A final issue is the recent high growth of economy and emissions in China. Observed emissions and baseline emission projections for China have been growing rapidly over the last few years. Therefore, the conclusions with respect to reduction targets and allowance peaking in this paper might deviate from studies that would be performed with present day information and current future projections. In general, it might be assumed that such studies would allow more emission space for China and later peaking of allowances.

Acknowledgements

This article has been written as part of the POEM project (Policy Options to engage Emerging Asian economies in a post-Kyoto regime), co-funded by the European Commission DG Research and Innovation within the Seventh Framework Programme. The authors wish to thank the other partners of the POEM project for their contributions.

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