POEM –

Policy Options to engage Emerging Asian economies in a post-Kyoto regime

Final project report

Grant Agreement nr: 226282

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Part I - Executive summary

Mitigation efforts in China and India are necessary in order to meet ambitious global climate targets. In the POEM project, various aspects of carbon mitigation in India and China have been addressed. The main aim was to analyse how a 2-degree climate target could affect economic and energy systems development in China and India.

In an analysis of the scientific literature on how effort-sharing approaches affect emission allowances and abatement costs of China and India it was shown 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, while India's emission allowances show high increases compared to 2005 levels and, if emission trading is allowed, financial revenues from selling credits might compensate mitigation costs in most approaches.

In a modeling framework seven national (India and China) and global models (economy wide, computable general equilibrium - CGE, and energy system models) were soft-linked with harmonized baseline developments. Utilising the modelling framework, analyses were carried out based on a global greenhouse gas emission pathway aiming at a radiative forcing of 2.9 W/m^2 in 2100, compatible with the 2-degree target, and with a policy regime based on convergence of per capita CO_2 emissions with emissions trading.

The multi-model analysis concludes that significant reductions are required in both China and India, implying huge changes in their energy systems. Today, there are large differences in the size of the energy system and the related CO_2 emissions between China and India. The current situation and the assumed future developments imply that there are differences as well as similarities in how India and China may be affected by climate policies.

In the climate policy case, Indian emissions are allowed to grow more than the Chinese emissions and still stay below their assigned amount, due to the per capita convergence rule and the higher population growth in India. Clear differences and similarities with respect to the actual consequences for the energy system due to the climate policy can be observed, not only among the two countries, but also among the two model types - CGE vs. energy system model. Energy efficiency improvements are important in the CGE models, while improvements in the carbon intensity are more important for the energy system models. With respect to the carbon intensity improvements, renewable energy (including biomass) together with nuclear power are important in both countries while the role of CCS is larger in China.

The economic impacts of international climate policy – measured as direct mitigation costs in the energy system models or as welfare losses relative to baseline GDP in the CGE models - are generally larger in China than in India, while India can even gain primarily due to benefits from international emissions trading. In general, China is a seller on the short term, but becomes a buyer on the long-term, while India is a seller over the whole 2010-2050 period. Dependent on the model, costs are also affected by decreasing global fossil fuel prices, currency depreciation resulting from a net capital inflow from international carbon trading and timing of emission reductions.

Part II - Summary descriptions of project context and objectives

II.1 The Challenge

In order to restrict global warming to 2 ^{o}C, major greenhouse gas (GHG) emission reductions are needed by 2050. While most of the accumulated anthropogenic atmospheric carbon dioxide can be attributed to industrialized countries, the greater share of future emissions will come from the developing world, and India and China will contribute to a substantial part of this. Thus, participation by India and China in climate change abatement is essential. However, the countries are reluctant to enter into any binding commitment due to development objectives. Are there policy options being able to combine both the development and climate perspectives?

II.2 The Project Objectives

Any climate policy has spill-over effects across several societal sectors and, thus, carefully chosen national policies coupled with international cooperation may offset some of the possibly negative effects. The primary objective of the study was to develop a portfolio of policy options including both international and national policies as well as institutional frameworks for international cooperation for India and China in order to facilitate their engagement in post-2012 climate change abatement regime. By applying an integrated modeling framework, the project will explore possible multiple pathways which may exist for India and China to contribute into international climate initiatives while not compromising national development priorities.

II.3 The Methodology

The project built upon two hypothesis: that there are options for engagement of India and China in climate commitments combining climate and development objectives; and that an integrated modelling framework can assist in techno-economic assessments of such options.

The project modelling framework comprised a number of global and national models:

- the global climate model FAIR-connected to the global energy model TIMER,
- the global CGE model DART,
- a national macro-economic model for India and China, respectively,
- a national energy system model MARKAL for India and China, respectively.

Originally, applications of the global population and health model PHOENIX/integrated sustainability model GISMO were also planned for but they came to play a less prominent role in the project than anticipated.

The models were first compared in a number of rounds of comparison concerning basic macro parameters (population assumptions and GDP assumptions (output in some models)), fuel price parameters (global fossil fuel prices (exogenous assumptions in some models while endogenous in other)), marginal abatement cost curves, and responses to simple carbon tax models. Then the models were harmonized to a certain extent. The harmonisation was only carried out as far as to enable meaningful model integration while leaving most assumptions unharmonised.

II.4 Project structure

The research activities of the project, distributed over 36 months were divided into five work packages (WP):

- WP 1: Review of national socio-economic, energy and environment conditions and policies,
- WP 2: Identification/design of international climate policies in a post-Kyoto regime,
- WP 3: Modelling and policy analyses,
- WP 4: Design of national policies and institutional frameworks for international cooperation,
- WP 5: Dissemination.

Workpackages 1 to 4 were further divided into a number of tasks of different character.

Review of national socio-economic, energy and environment conditions and policies:

- Task 1.1: Review of macro-economic development and policies and setting related modelling parameters and indicators;
- Task 1.2: Review of energy and environment development and policies.

Identification/design of international climate policies in a post-Kyoto regime:

- Task 2.1: Review of the available international climate policies and framework;
- Task 2.2: Identifying/designing plausible post-2012 regimes and instruments for future commitments and participations of emerging economies.

Modelling and policy analyses:

- Task 3.1: Developing integrated modelling framework;
- Task 3.2: Policy and scenario analyses.

Design of national policies and institutional frameworks for international cooperation:

- Task 4.1: Identifying/designing macro-socio-economic, energy and environment related domestic policies;
- Task 4.2: Designing institutional frameworks for international cooperation.

Part III - Main results

The main results of the project will be described following the sequence of the work packages of the project. They were of rather different character. WP1 provided an overview and background on energy, economy, environment and policies in India and China. WP 2 analysed the literature on burden sharing regimes and their possible impact on India and China and, in particular, the different impacts on the two countries. In WP 3 a modeling framework utilising soft-linking of a number of economy and energy systems models was developed and applied for policy and scenario analysis. In WP4, possibilities and barriers of integrating international climate regimes with national policies were assessed.

In addition to the results presented in the work package reports, the project is going to result in a number of scientific publications of which one already is published (based on the WP2 report and mentioned in the WP2 section below). Brief accounts of the results presented in these scientific publications are presented at the end of the chapter.

In addition to this, the project has also contributed to a number of other scientific works and publications, and some of these are listed at the very end of the chapter.

III.1 Work package 1

The objectives of work package 1 were the

- Understanding of national macro-socio-economic, energy and environment development, policy issues and their interactions across different sectors; and
- Preparation of macro-economic and socio-economic parameters and indicators for modelling and policy simulations.

The work package had the following two tasks:

- Task 1.1: Review of macro-economic development and policies and setting related modelling parameters and indicators;
- Task 1.2: Review of energy and environment development and policies.

The work package deliverable is a report describing macro-socio-economic trends, policies and future projections for important macro-economic and socio-economic development parameters and indicators in India and China, and overview of the energy sector and environment, policies and future projections and goals in the two countries.

In the framework of the overall project, the primary objective of WP1 was to collect background information of importance for the subsequent parts of the project, primarily for the modelling activities performed in WP3. The work package report is divided into the following chapters:

- Ch 1: The role of Asian countries in climate debate
- Ch 2: Development and climate change linkages
- Ch 3: Development trends and drivers for China and India
- Ch4: Development indicators for China and India

- Ch 5: Energy and environment policies in China and India
- References

Thus, it was meant as a background collection of useful information for the rest of the project, and as such it has been utilized. The data gathered and collected in the report was used as background but not only as input for the national macro-economic modelling in the modelling work package 3 but also as a common ground of knowledge and understanding for the entire project. There is no explicit results or conclusion from this part of the project but the large differences in terms of energy system, GDP, and policies between India and China are highlighted in the WP1 report.

III.2 Work package 2

The objective of the work package was to:

- Identify and/or design plausible post-2012 regimes for future commitments for emerging economies and instruments for their participation to achieve targets

The work package was divided into two tasks:

- Task 2.1: Review of available international climate policies and framework,
- Task 2.2: Identifying/designing plausible post-2012 regimes and instruments for future commitments and participations of emerging economies.

The work package report contains a thorough review of international climate regimes. The first part of the report, corresponding to task 2.1, covers different proposed regimes, an overview of studies and regimes, and a comparative analysis of these with particular emphasis of the difference in terms of outcome of the different regimes for India and China, respectively. Due to the different GDP levels of the countries combined with energy structure differences the regime outcome differs considerably between India and China.

Based on the background analysis carried out within task 2.1, in task 2.2 a selection of plausible post-2012 regimes, i.e., a set of targets, allocations procedures and instruments that was considered for the further analysis in the following work packages, was made. The report and conclusion therein were not only essential for the project but also highly valuable for external use as a review of climate regimes with particular focus on the outcome for China and India, respectively.

In table 1 an overview and brief description of the regimes included in the study are presented.

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.

The work package 2 report concludes 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:

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.

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.

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”.

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.

The work has resulted in one published scientific paper (Ruijven et al 2012a).

III.3 Work package 3

The overall objective of the work package was the development of an integrated modelling framework for policy and scenario analyses; and to carry of a number of policy and scenario analyses in order to quantify the impacts of national and international policies through the application of the modeling framework.

The work package was divided into two tasks, task 3.1. and task 3.2, where task 3.1 concerned the development of an integrated modelling framework while task 3.2 concerned the actual policy and scenario analyses applying the developed modelling framework.

The development of an integrated modelling framework was one of the core activities of the project, and the task with most manmonths related to it. The objective of the modelling framework was to enable quantifications of selected policy designs developed based on the work within primarily work package 2 but to some extent also work package 4.

In order to analyse the impacts of international climate policies at national socio-economic and sectoral levels, and cost-benefits of several policies, the project had to its disposal a number of different types of models at global and national scales:

- the global climate model FAIR-connected to the global energy model TIMER,
- the global CGE model DART,
- a national macro-economic model for India,
- a national macro-economic model for China,
- a national energy system model India-MARKAL
- a national energy system model China-MARKAL, and
- the global population and health model PHOENIX/integrated sustainability model GISMO, which eventually was not extensively utilized.

These models are described in detail in an appendix to the Workpackage 3 report and here just a summarizing description is provided.

The **FAIR** model, developed and maintained by PBL, calculates through its emissions allocation module the regional or countries’ emission targets for different climate regimes for future commitments within the context of meeting long-term climate targets such as stabilising atmospheric GHG concentrations. It consists of: 1) a climate model for calculation of the climate impacts of global emission pathways; 2) an emission allocation model to calculate the emission allowances for countries and regions for more than ten regimes for the differentiation of future commitments; and 3) a costs model to calculate the abatement costs and abatements on the basis of the emission allowances, the use of the flexible Kyoto mechanisms such as international emissions trading and substitution of reductions between the different gases and sources following a least-cost approach.

The FAIR model was connected to the world energy model TIMER, which represents a consistent description of the world energy system. It allowed, in the context of the project, analysis of climate mitigation costs for China and India in a global context.

The Dynamic Applied Regional Trade (**DART**) model, developed and maintained by IfW, is a global applied general equilibrium model, with a coverage of several global regions including India and China. DART was developed especially for the analysis of international climate policies. The model, distinguishing various sectors, is sufficiently detailed to monitor the development of energy-related CO2 emissions.

Within the Global Integrated Sustainability Model (**GISMO**), PHOENIX, DART and TIMER are integrated and coupled to take into account feedbacks, and thereby insights in the interactions between the energy system, the economic system and the human system (including health issues), resulting in plausible and consistent scenarios.

A SAM (Social Accounting Matrix) based Computable General Equilibrium (**CGE**) model for India and China, respectively, is used to analyse the macro-economic and social impacts of energy and climate parameters due to climate abatement measures. A Social Accounting Matrix (SAM) can be defined as an organized matrix representation of all transactions and transfers between different production activities, factors of production and institutions (like households, corporate sector and government) within the economy and with respect to the rest of the world. A SAM is thus a comprehensive accounting framework within which the full circular flow of income from production to factor incomes, household income to household consumption and back to production is captured. Households are classified into different income classes and as urban and rural. SAM provides the database for many multi-sector models including the CGE models. Compared to DART the national SAM-based CGE models can provide better national and sectoral disaggregations. The China national CGE model is denoted **CEEPA** and the India national CGE model is denoted **IEG-CGE**.

MARKAL is a bottom-up technology-driven modelling framework based on a linear optimisation approach and thus a modelling framework useful for the understanding of complex interactions between energy and environment and the role of energy technologies for energy sector development. Inputs to MARKAL include energy demand by sectors/end-uses, energy resource availability, and energy technologies used for energy production, conversion and end-uses (represented by technical, economic and environmental characteristics). Model outputs include optimal energy technology choice, energy related emissions, energy system costs, marginal cost of energy supply, import/export strategies, and investment requirement for the energy sector. In the project, both **MARKAL-China** and **MARKAL-India** models were employed.

The above described models have not been run together in any structured way previously. It was one of the project objectives to investigate how a modelling framework like the one applied could contribute to improved knowledge creation. However, since the models utilised in the project are of very different kinds; global vs national; economic vs engineering; it was a delicate task to construct a modelling framework being able to contribute to improved decision support knowledge. In order to construct the modelling framework, harmonisation of the models to some extent was necessary. Further, the harmonisation process was designed in order for the project partners to improve their understanding of the other models during the harmonisation process. Thus, models were compared in a structured way using a template developed for these comparisons. This comparison was followed by decisions of harmonisation in a step-wise fashion; a new round of comparisons was carried out, followed by further harmonisation, and so further. Below, this process is described in some detail and in the WP 3 report further details are provided.

<u>Comparison and harmonisation process:</u>

- Comparison of global and national population and GDP figures to 2050, followed by harmonisation.
- Fossil fuel price comparison followed by harmonisation of international prices but not national (for national fossil fuel prices endogeneous supply curves were used).
- Comparison of marginal abatement cost (MAC) curves using block taxes. Large differences found in particular between engineering type models and computational general equilibrium (CGE) type models. This led to the introduction of new technology representation in the CGE models based on TIMER and MARKAL model data (back-stop technologies).
- Further, carbon abatement comparisons were carried out.

In table 2 an overview of the model characterisitics is presented.

In addition to the harmonisation, model-linking schemes have been developed as presented in the WP3 report.

The respective owner of each model have been responsible for the model updating and, and Chalmers has been coordinating the activities and the process of model comparison, harmonisation and linking. All steps have been decided upon during the biannual project meetings.

In the original work plan, the possibility of establishing a hard link between two of the models is mentioned. This would have been an interesting exercise but since the major objective of the entire project is not model development as such but policy support and tools for policy support it was decided not to further develop the hard link, which would have been a time and resource consuming option but instead to use soft links throughout the project. The modelling soft linking, which is graphically presented in Figure 1 and further discussed in the WP3 report, can be described in the following steps:

Table 2: Characteristics of the models

	FAIR	TIMER	DART	CEEPA	China MARKAL	IEG-CGE	MARKAL-India
Institute	Netherlands Environmental Assessment Agency (PBL)	Netherlands Environmental Assessment Agency (PBL)	Kiel Institute for the World Economy (IfW)	Beijing Institute of Technology (BIT)	Tsinghua University (TU)	Institute of Economic Growth (IEG)	Indian Institute of Management (IIM-A)
Model class	Climate policy model	Recursive dynamic energy system model	Recursive dynamic computable general equilibrium model (CGE)	Recursive dynamic computable general equilibrium model (CGE)	Energy system model with perfect foresight	Recursive dynamic computable general equilibrium model (CGE)	Energy system model with perfect foresight
Regional coverage	Global (26 regions)	Global (26 regions)	Global (13 regions)	China	China	India	India
Household groups	NA	10 (urban and rural quintiles)	1representative agent per region	2 (urban and rural)	2 (urban and rural)	9	1
Sectors	NA	5 sectors (industry, transport, residential, services and other)	12	24	5 sectors (agriculture, industry, commercial, residential and transport) and 32 sub-sectors	18	5 Sectors (agriculture, industry, commercial, residential and transport) 46 end-use sectors
Energy carriers	NA	Coal, oil, natural gas, modern biofuels, traditional biofuels, nuclear, solar, wind and hydro	Coal, natural gas, oil, bio-energy, wind and hydro	Coal, natural gas, oil, bio-energy, nuclear, wind and hydro	Coal, natural gas, oil, bio-energy, nuclear, wind and hydro	Coal, natural gas, oil, bio-energy, nuclear, wind/solar and hydro	Coal, natural gas, oil, bio-energy, nuclear, solar, wind and hydro, hydrogen
Technology dynamics	Based on marginal abatement cost curves from TIMER and other models	Capital stocks, Penetration rate constraints, Learning by Doing	Capital stocks, Learning by doing, Autonomous energy efficiency improvement	Capital stocks, Autonomous energy efficiency improvement	Capital stocks, penetration rate constraints	Capital stocks, Energy efficiency improvement, Total factor productivity growth, Efficiency improvement in renewables	Capital stocks, Penetration rate constraint, Energy Infrastructure
CCS	NA	Yes	Yes	No	Yes	Yes	Yes
Substitutes to petroleum as transport fuel	NA	Electricity, modern biomass, hydrogen	Not explicitly modeled	Not explicitly modeled	Yes	No	Electricity, modern biomass, hydrogen

- NA = not applicable

1. FAIR calculates the CO_2-equivalent emissions[1] pathway, a globally uniform carbon price and regional emission allowances based on the energy-related CO_2 part of the pathway and an effort-sharing approach
2. DART determines the globally uniform carbon price based on the global energy-related CO_2 pathway and the regional emission allowances from FAIR
3. The national CGE models use the emission allowance from FAIR and the carbon price from DART to determine changes to the energy system and total climate policy cost
4. The national MARKAL models use the emission allowances and carbon price from FAIR to determine changes to energy system and total climate policy cost
5. TIMER uses the emission allowances from FAIR to determine changes to energy system. Total climate policy cost is determined by FAIR.

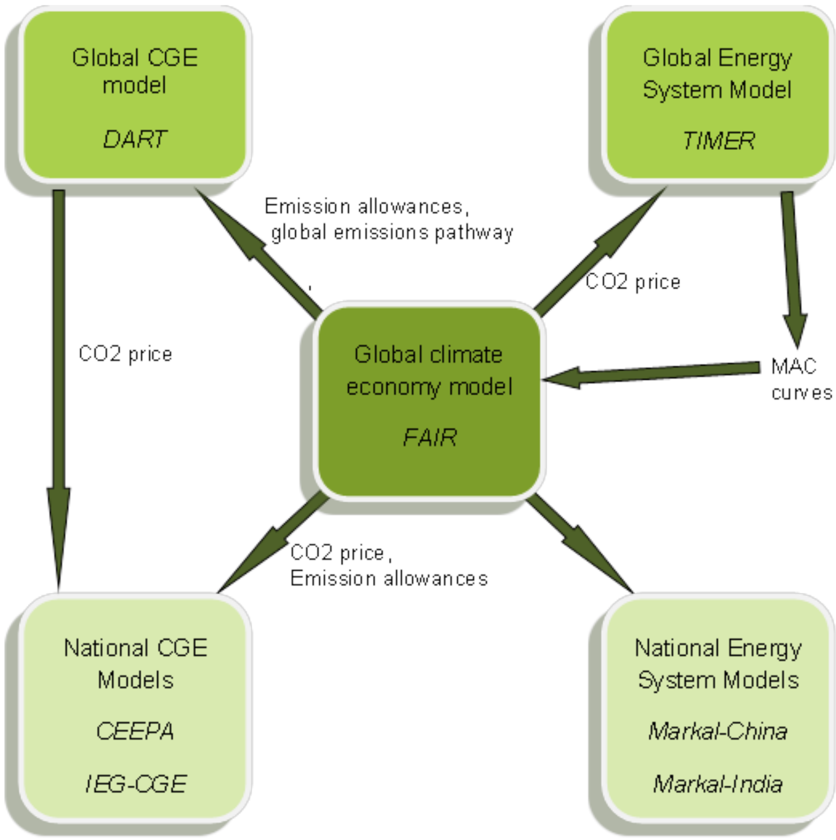


Figure 1 Modelling soft-linking structure.

<u>Emission pathway</u>

The analysis is based on a global greenhouse gas emission pathway that aims at a radiative forcing of 2.9 W/m^2 in 2100 and with a policy regime based on convergence of per capita CO_2 emissions with emissions trading.

[1]All greenhouse gas emissions refer to all emissions relevant under the Kyoto Protocol (Annex A) including the land-use related CO_2 emissions, i.e. the global warming potential-weighted sum of six Kyoto greenhouse gas emissions (CO_2 equivalent emissions).

Burden sharing approach

The so-called common-but-differentiated convergence (CDC) approach is a simple allocation scheme that takes into account "common but differentiated responsibilities" (see the WP2 report and Ruijven et al 2012a and references therein). It assumes that per capita emission allowances of all countries converge over time. Different from the more well-known Contraction and convergence (C&C), in the CDC approach developing countries have to start their convergence trajectory only after reaching a certain threshold of per capita emissions.

Important parameters for the CDC approach are the long-term per capita emissions convergence level and the threshold that requires countries to enter the regime and start converging. Instead of a threshold, different country groupings are defined according to their current income levels, i.e. developed countries, Advanced Developing Countries (ADCs) and Other Developing Countries (ODCs), that take on different reduction objectives in terms of start year for convergence, convergence level and convergence year.

The developing countries are divided according to 2009 GNI per capita, calculated using the World Bank Atlas method (World Bank, 2011). High and upper middle-income regions are classified as ADCs and low and lower middle income regions as ODCs. China and India are both categorized by the World Bank as lower middle-income regions and could therefore be classified as ODCs. However, China's per capita income in 2009 is almost reaching the threshold to become an ADC. Therefore, China starts reducing emissions earlier than the other ODCs, but later than the ADCs. Also India starts converging earlier than the other ODCs, but later than China.

We assume that all countries that made a reduction pledge under Cancún Agreements meet their conditional, more ambitious one in 2020. Here, only energy-related CO_2 emission pledges are considered. Pledges addressing land-use emissions or other non-energy related source are not taken into account given the scope of this analysis, although these reductions are included in the global 2.9 W/m^2 greenhouse gas emission pathway. After 2020, the developed countries and ADCs start instantly following the per capita emission convergence trajectories of the CDC approach; developed countries converging in 2040 and the ADC in 2050. China and India start in 2025 and 2030, respectively. The other ODCs start in 2035. Between 2020 and the start of convergence countries follow their baseline trend. Therefore, countries that made a 2020 pledge (including China and India) have similar reductions compared to their baseline emissions as in 2020 until they start converging. China, India and the other ODCs take 30 years to converge. All countries converge to a level of 1.7 tCO_2/capita in their respective convergence year.

Main results of the scenario and policy analysis

Emissions

The global greenhouse gas emissions, including all Kyoto gasses, and the corresponding energy related CO_2 emissions, are shown in Figure 2. Without any mitigation policies global greenhouse gas emissions and energy related CO_2 emissions continue to increase towards

2050, with more than 50% and 80% compared to 2010 levels, respectively. The dotted lines represent the 2.9W/m^{2}stabilization emissions pathway.

In DART and FAIR the transition from the baseline emissions to the 2.9 W/m^{2}pathway is achieved via a carbon tax on emissions (see Figure 3). These taxes are very similar up to 2045, beyond that the tax in DART rises further, as mitigation options in DART are limited after certain abatement levels, while FAIR allows for more radical technology changes that are especially available in the long run.

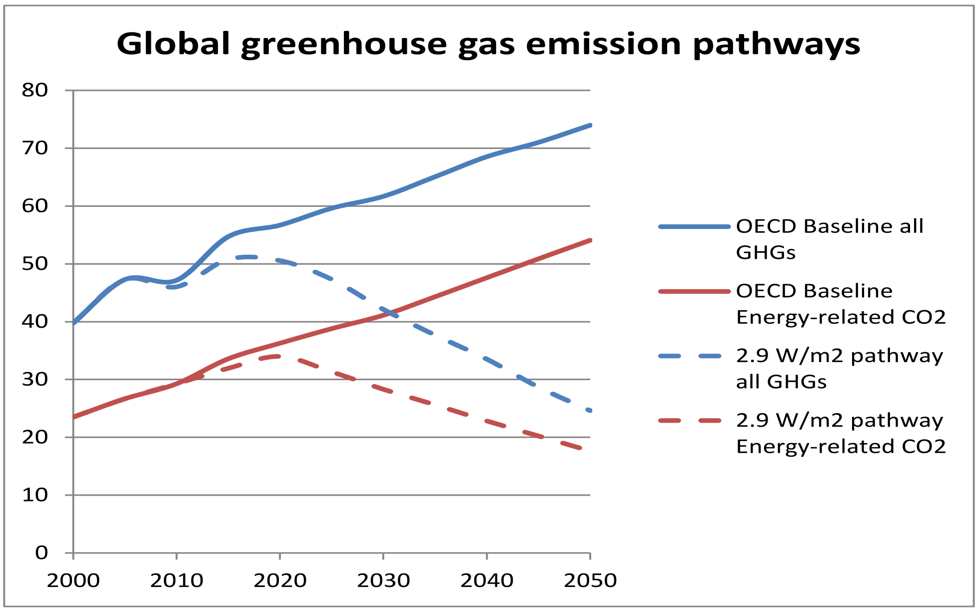


Figure 2. Global CO_2-equivalent emissions (Kyoto gases including land-use CO_2) and energy-related CO_2 emissions for the baseline and the 2.9 W/m^2 pathway generated by FAIR.

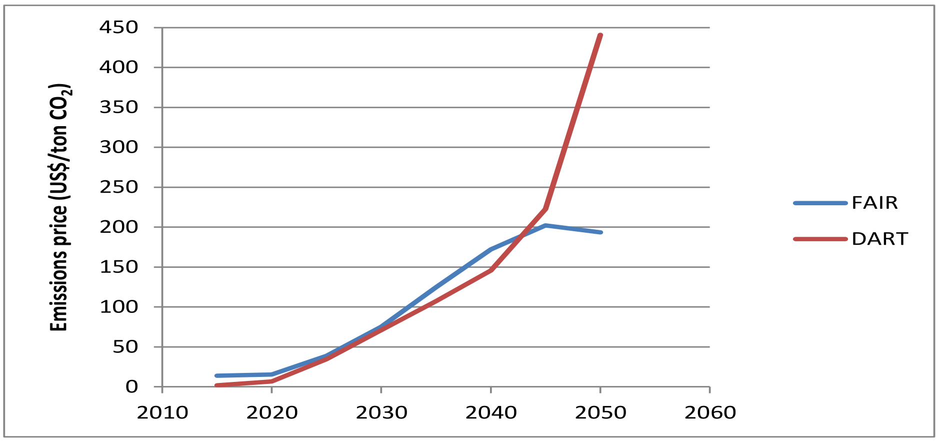


Figure 3. Carbon taxes compatible with the global emissions pathway leading to a stabilization of 2.9 W/m^2 in 2100 in FAIR and DART. These taxes consider only the energy-related CO_2 emissions.

In the baseline scenario (without any international climate policies) CO_2 emissions for China continue to increase in all models (Figure 4). After 2030, a decrease in the growth rate can be observed even leading to a small decrease in absolute emissions in the CEEPA model. Since emissions were not harmonized, there is a spread. Interestingly, national models show considerably higher emissions in 2030. This implies that the 2020 Copenhagen pledge is much more challenging under these assumptions than in the global models.

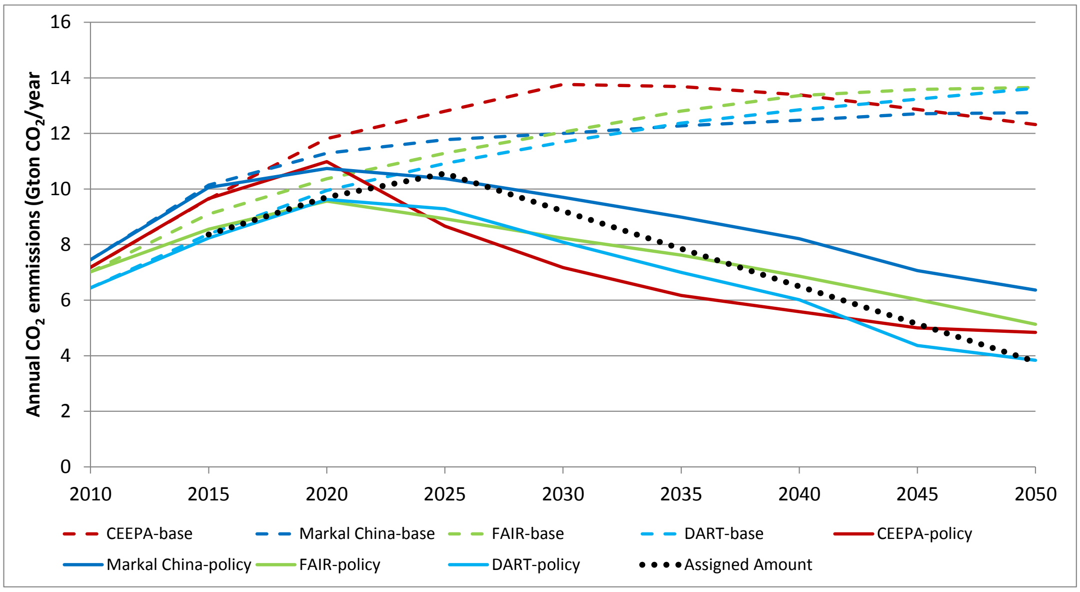


Figure 4. Baseline emissions, emission allowances and emissions (CO_2 only) in the policy scenario for China.

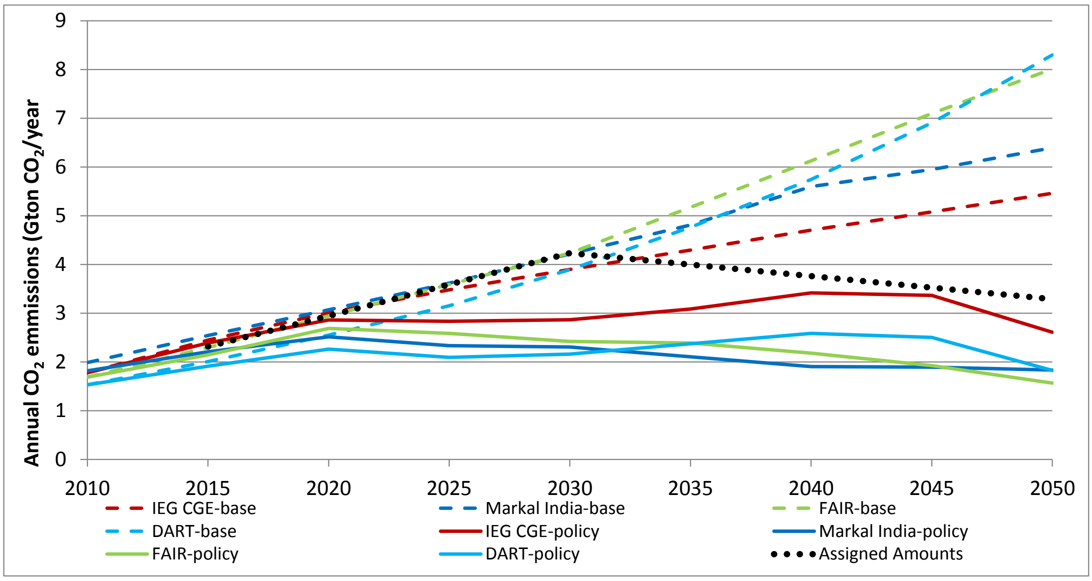


Figure 5. Baseline emissions, emission allowances and emissions (CO_2 only) in the policy scenario for India.

In the baseline scenario CO_2 emissions in India will continue to increase with almost a constant growth rate over the coming decades (Figure 5). The 2020 Copenhagen pledge is almost identical or even slightly higher than baseline emissions in the different models. It should also be noted that MARKAL India does consider some planned climate policies in the baseline scenario. The final emissions according to the CDC regime – taking into account international emission trading – remain considerably below the emission allowances in all models for the whole 2020-2050 period. This implies that India is a net seller of credits on the international carbon market.

Energy system change and climate policy costs

Currently, the Chinese energy system is dominated by coal followed by oil. Other fuels such as natural gas and biomass play a less important role. The primary energy supply grows rapidly between 2010 and 2020 while at a slower speed between 2020 and 2050. Notable is that CEEPA shows a peak in primary energy supply by 2030 in the baseline, while the other models show continued growth. In all models, coal remains the most important fuel in the baseline scenario.

In the climate policy scenario, a reduction of energy use stands out as the most central mitigation option. Reductions in primary energy use are stronger in the CGE models than in the energy system models. A large difference across models is the degree to which low carbon technologies are deployed. The energy system models show higher shares than the CGE models, especially in the policy scenarios. In these models, high carbon prices imply that the system starts investing mainly in low carbon technologies.

The primary energy supply scenarios for India diverge in the different models. It should be noted that quite a large range of different energy demand levels are projected already for 2020. Coal remains the most important fuel in the baseline scenario, followed by oil. In DART and TIMER, natural gas increases most rapidly. Again, the CGE models project a much larger role for the reduction in energy consumption in climate policy.

Direct and macro-economic costs of climate policy

The cost of climate policy is measured as abatement cost relative to baseline GDP levels in the energy system models (including FAIR) and as welfare changes (Hicks equivalent variation) relative to the baseline for the CGE models. The estimates for economic impacts between model classes are therefore not directly comparable. Furthermore, since the models include different technologies, sectors and energy sources it can be expected that abatement costs differ. Energy systems models focus on the competition between different technologies for meeting the demand for goods and services and derive cost estimates from detailed descriptions of the energy systems. In contrast, CGE models focus on the economy as a whole and include the interactions between the various sectors. They do not focus on direct costs, but on changes in economic production and consumption levels or welfare, which better captures the implications of overall structural changes and economy wide effects.

The economic impacts of the climate policy scenario for China and India are depicted in Figure 6 and 7, respectively. The figures also show the global average effects from FAIR and DART to put regional effects into perspective.

While in all models (except CEEPA), costs are increasing over time there are large differences between the models. While the CGE models show moderate costs for a longer period, in the case of DART for the whole model period, costs increase to 2.5 or even 5% relative to GDP in the energy system models by 2040.

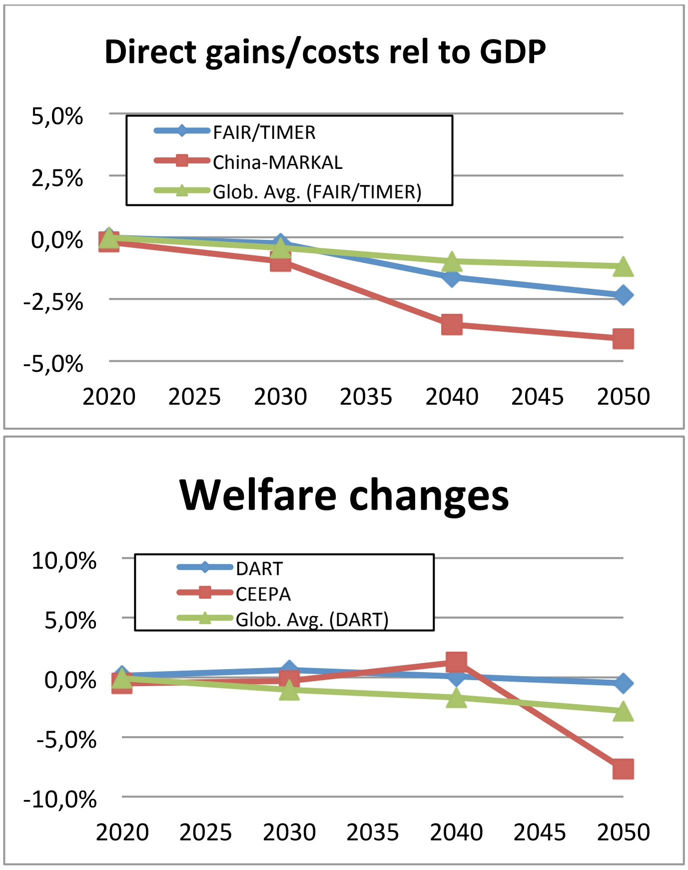


Figure 6. Economic impacts of climate policy in China for selected years. For FAIR and China-MARKAL gains or costs are reported as abatement cost relative to GDP (top) for the CGE models DART and CEEPA welfare changes (Hicks equivalent variation) are reported (bottom).

One explanation for the modest cost estimate in DART is that in DART the repercussions on the international fuel market are relatively large. The world (as a whole) consumes less fossil fuels in the climate policy scenario as compared to the baseline scenario, so that the (global) fossil fuel price declines. China, an importer of fossil fuels, can profit from this. The national models do not capture this effect.

As expected, the climate policy scenario also affects India differently in the different models. The global models, DART and FAIR, show an economic gain from international climate policies throughout the simulation period. The main explanation for the economic gain is that

Indian per capita emissions are lower than those in China. As a consequence, India can sell more allowances on the international allowance market than China (see Figures 4 and 5). In addition, the Indian economy is smaller than the Chinese and for this reason an equal net export of carbon allowances has a larger impact on India. For the DART results it is again important that international fuels prices decline considerably benefitting net importers of fossil fuels such as India.

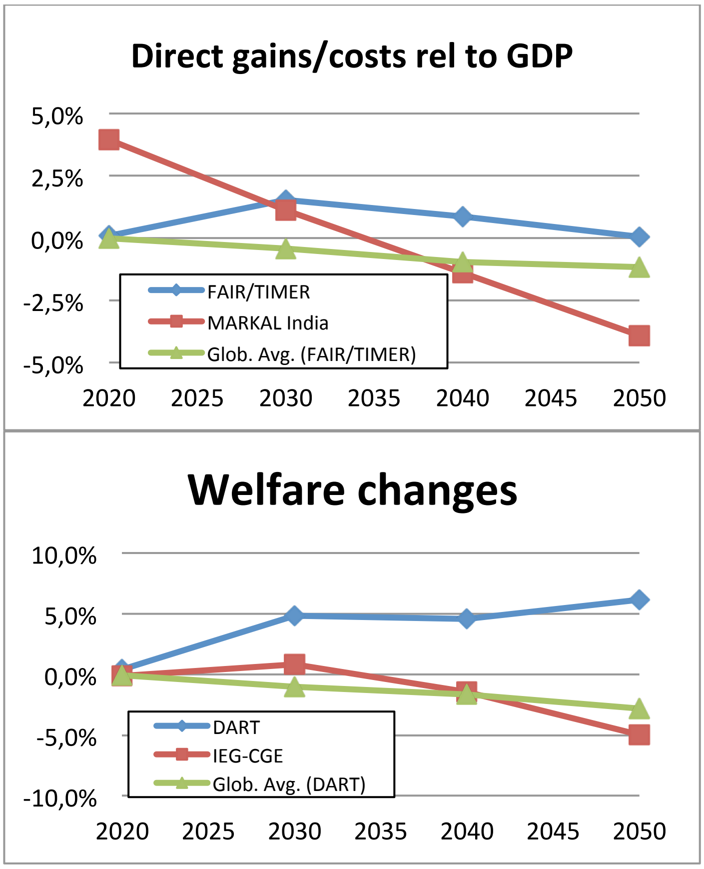


Figure 7. Economic impacts of climate policy in India for selected years. For FAIR and India-MARKAL gains or costs are reported as abatement cost relative to GDP (top) for the CGE models DART and CEEPA welfare changes (Hicks equivalent variation) are reported (bottom).

Sensitivity analysis

In the sensitivity analysis it is tested if the model results are sensitive to alternative assumptions in GDP growth, the timing of emissions reductions, and to choices in the effort-sharing approach. We focus on the economic implications, since the qualitative nature of the energy results turn out to be relatively robust to changes in these assumptions.

The higher GDP growth assumptions imply that the models with a higher GDP growth scenario for China and India, while the rest of the world still follows the OECD baseline scenario. In this case China's economy is projected to grow on average about 6.2% per year between 2010 and 2050 compared to about 5% per year in our base case, while India's economy to grow on average about 7.9 % per year instead of about 6.8% per year. The altered growth assumption also leads to increases in CO_2 emissions in the baseline.

In the climate policy case assumed throughout the main part of the analysis, countries implements their high Copenhagen Accord pledge for 2020, after which global emissions gradually decrease. Thus, resulting global 2020 emissions compared to 1990 are higher than in a cost-optimal pathway while the early action case represents a cost-optimal pathway. As a consequence while still aiming for the same 2.9 W/m^2radiative forcing target in 2100, the mid- and long-term emissions levels (2025-2050) can be slightly higher.

As alternatives to the CDC base case, we consider two alternative regimes: a global uniform carbon tax approach and an alternative CDC approach. One of the most straightforward proposals is a globally uniform carbon tax, i.e. carbon tax is the same across all regions. Through the global equalization of marginal abatement costs this approach would ensure cost-effectiveness. However, a uniform carbon tax does not distinguish between developed and developing countries, hence leading to no compensation to developing countries.

In the alternative CDC case, further referred to as CDC with delayed participation, China and India start converging 5 years later than in the base case. To stay within the global emission pathway, developed countries have thus to reduce more and converge to 0.6 tCO_2/cap - instead of 1.7 tCO_2/cap in the base case. This results in a 90% emission reduction for developed countries in 2050 compared to 1990 while developing countries still converge to 1.7 tCO_2/cap.

The results (Figure 8) show that overall climate policy costs for China are more sensitive to the assumptions on the effort-sharing approaches than to assumptions for economic growth and the global emission pathway. Higher economic growth increases the cost of climate policy compared to the base case for all models, although considerably more for China-MARKAL and CEEPA than for FAIR and DART. Early action has a mixed impact on climate policy costs in the different models.

Finally, an effort-sharing approach with a uniform carbon taxes tends to be most detrimental for China in most models, except China-MARKAL. Also, the magnitude of the economic impact of a tax policy is very different across models. In the CDC with delayed participation, China does not adopt an emission cap in the context of the international climate negotiations until 2030 and for this reason costs are lower in all models compared to the base case. Besides DART, now also CEEPA shows a net benefit from such an effort-sharing approach.

For India (Figure 9), overall economic impacts are more sensitive to assumptions on the effort-sharing approaches than to different economic growth and global emission pathways in all models except for MARKAL-INDIA in which the results are most sensitive to the GDP growth assumption.

Under higher economic growth the cost of climate policy (in relative terms) increases slightly as compared to the base case for IEG-CGE, the benefits in DART and FAIR are almost similar and the benefit found in MARKAL-India is turned to a substantial loss. With higher growth, global emissions are higher in the baseline. Because the policy target is unchanged, the effort-sharing approaches become relatively more ambitious and carbon prices rise. Since

India remains a net seller of credits it continues to benefits from higher carbon taxes. Early action – more global abatement in the short run - has a negative impact on India in all models, i.e. the benefits either drops or the costs increases. Concerning the effort-sharing approaches, a uniform carbon tax would on average be most detrimental for India.

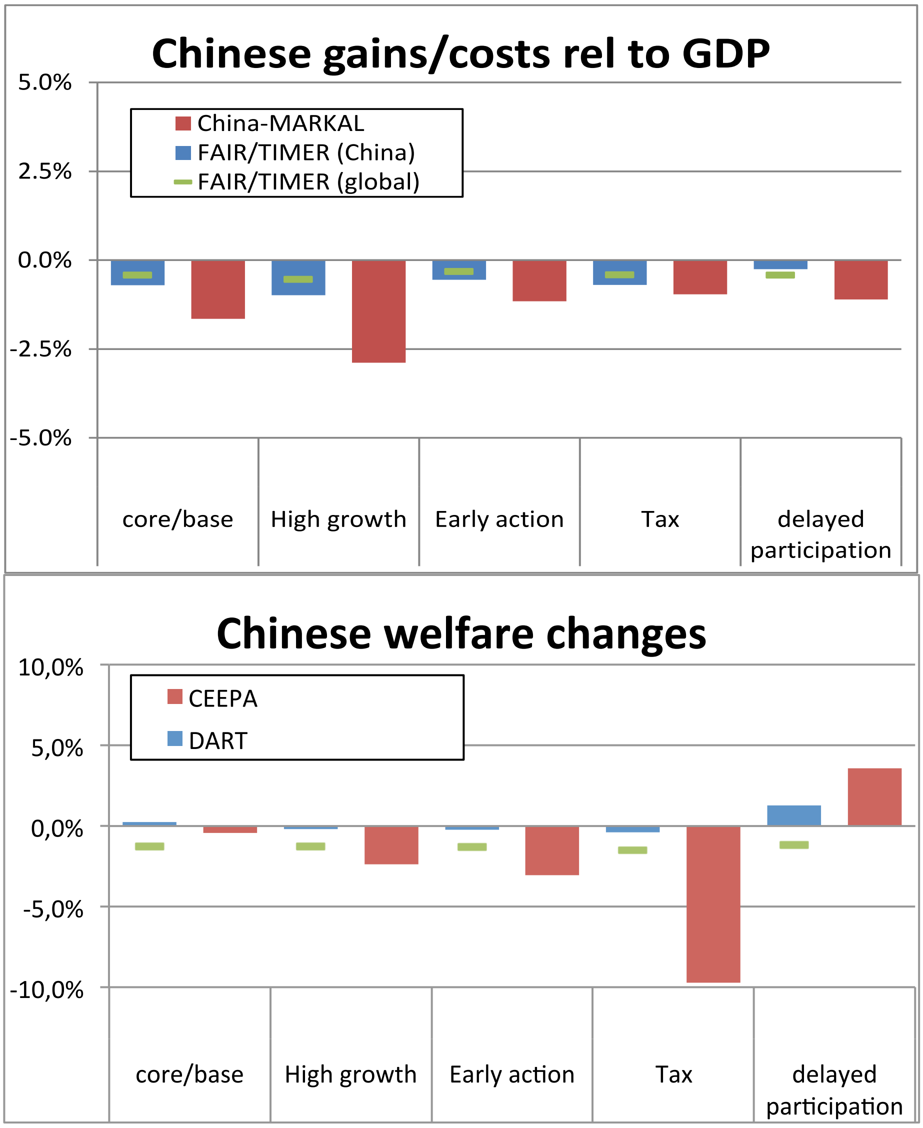
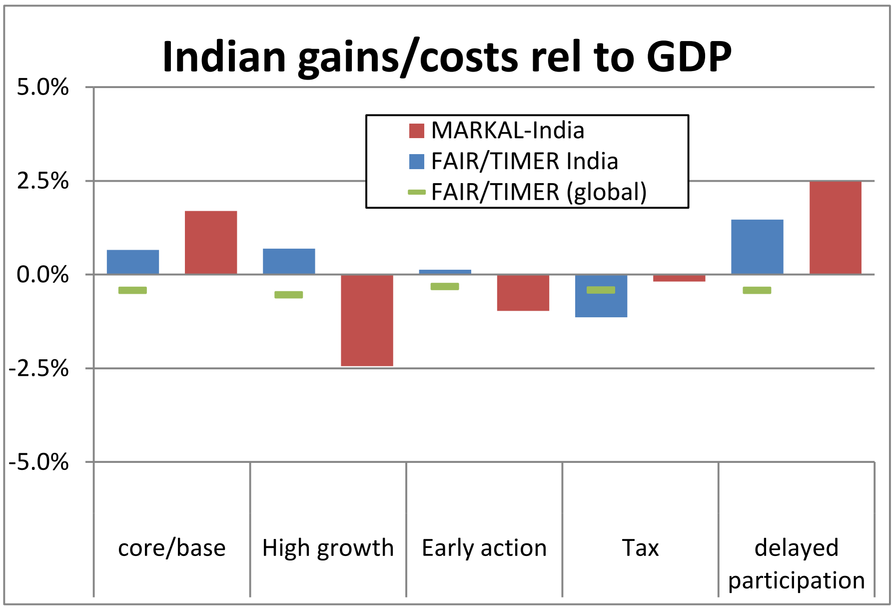


Figure 8. Impact of key assumptions on cumulative discounted costs of climate policy in China.

<u>Discussion and conclusion</u>

Energy system change and cost estimations of climate regimes in the literature are often not directly comparable and differences in result are not always easy to explain (Van Ruijven et al., 2012a). The harmonization of the baseline and policy scenarios in this study improves the ability to understand the substantial differences in cost estimations across different model types and individual models. The analysis shows in particular that models with a similar structure (CGE vs. Energy system) lead to comparable results. Differences in model results can thus be explained in part by the general underlying assumptions of CGE versus energy system models.

CGE models are top-down models based on the economic structure and technologies of a reference year. Deviating from this equilibrium is possible through substituting energy inputs by additional capital inputs (technique effect) or by shifting demand to less carbon intensive sectors (composition effect), causing that a drop in energy intensity is important for abatement in these models. Both effects are driven by changes in relative prices. Furthermore, while substitution possibilities in the vicinity of the initial equilibrium are easy to achieve and therefore relatively cheap, deviating further from the initial situation is increasingly costly.



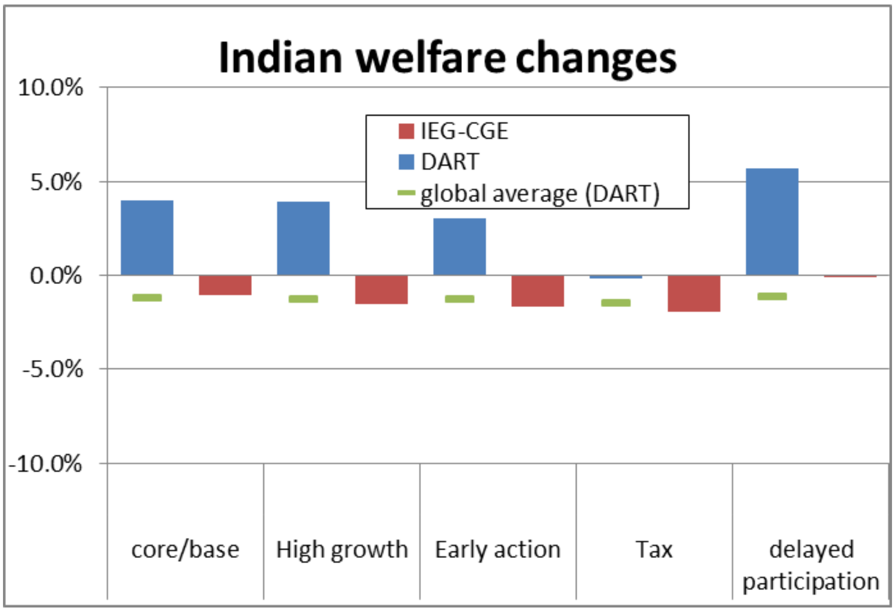


Figure 9. Impact of assumptions on cumulative discounted costs of climate policy in India.

Only explicit modeling of alternative technologies makes it possible to change specific sectors more fundamentally. In our analysis, not all CGE models include low carbon technologies to the same extent and thus react differently to climate policy. We identify in particular a lack of technology alternatives for oil consuming sectors, most important the transport sector. Concerning cost estimates, CGE models take into account different kind of repercussions on other markets. Differences between the national CGE models and the global CGE model include modeling differences in representing repercussion on international fossil fuel markets and the impact of capital transfers on the exchange rate. For details see Weitzel et al (2012).

Generally, energy system models have more options for meeting energy demand than CGE models and more abatement takes place via carbon intensity reductions, i.e., through changes in the energy supply mix. Also, the inertia in the capital stock imply that small carbon taxes lead to little change in the short run in the energy system models. The timing of emission reductions is therefore more important for energy system models and leads – compared to CGE models - to higher carbon taxes in the short run, see Figure 3. For a more detailed discussion of this issue see Lucas et al. (in prep.). In the longer run, carbon taxes are lower than in the CGE models due to learning and explicit modeling of more abatement options – a sharp increase would only be observable when the potential of relatively low cost abatement options is completely exhausted, which is not the case in our analysis. Concerning cost estimates energy system models are able to give only the direct cost of energy system changes.

For MARKAL models, the importance of energy efficiency improvements vis-à-vis carbon intensity improvements is about the same in relative terms for both countries. Also in TIMER, the carbon intensity improvement plays a major role – but here the contribution is even more important in India than in China. For the reduction in carbon intensity, CCS stands out as the most important options across models. In addition, solar energy and small hydro are important in MARKAL-India, CCS is important in China MARKAL and modern biomass in TIMER.

In the main climate policy case assuming a least-cost implementation of international climate policy, CO_2 emission levels for the different models in the year 2050 are in the range of -20% to +25% compared to 2005 emission levels in China and between +20 and +130% compared to 2005 emission levels in India. In 2010 China's CO_2 emissions are almost three times higher than the Indian emissions, while in the baseline and policy scenarios in 2050 the CO_2 emissions in China are about twice those in India. Demand for new capacity in India remains high towards 2050, while in China this demand levels off after 2030. As especially the energy-system models take account of the capital stock, this has a limiting effect on mitigation potential in China compared to India.

In our main policy case the costs of climate policy are larger for China than for India. In the energy system models the cumulative discounted costs as fraction of GDP are in the order of +0.4 to +1.8% for China and -0.7% to -1.7% for India, with positive numbers representing losses and negative numbers gains. In the CGE models, welfare losses range from +0.4% to -0.2% for China and from +1.1% to -4% for India. The main reason for these differences is that per capita emissions for China are already around the world average, while for India they are substantially lower. As the CDC approach implies a convergence of global per capita emissions, India is confronted with a lower reduction objective, and, as a result has a higher potential of selling reductions on the international carbon market generating revenues.

In general China is a seller on the short term, but becomes buyer on the long-term, while India is a seller over the whole 2010-2050 period, see figure 4 and 5. Only DART finds that China can benefit from international climate policy, mainly due to reduced costs of fossil fuels, although gains are small. For India, on the other hand, most models show an economic benefit of climate policies up to 2030/2040, mainly due to benefits from international emissions trading. For both India and China the models with a national focus tend to show more negative economic implications of climate policies than the global models. The reason for this is not trivial. For the CGE models, it can be explained in part by repercussions on international fuels market taken into account by the international DART model.

The sensitivity analyses reveal that both China and India benefit from delayed participation and both countries are more negatively affected by climate policies if a uniform carbon tax is assumed instead of a CDC approach. Although, China MARKAL is an exception here, showing that a uniform carbon tax approach results in the lowest costs. The reason behind this result is that in China MARKAL China is a net buyer of permits in the main CDC case. Finally, if higher economic growth rates for China and India are assumed, the model results point towards smaller benefits or larger costs (relative to GDP) of climate policies for both countries.

In conclusions, the results show that economic and energy implications for China and India vary across models. Decreased energy intensity is the most important abatement approach in the CGE models, while decreased carbon intensity is most important in the energy system models. Reliance on Coal without Carbon Capture and Storage (CCS) is significantly reduced in most models, while CCS is a central abatement technology in energy system models, as is renewable and nuclear energy. Concerning economic impacts China bears in general a higher cost than India, as China benefits less from emissions trading. Costs are also affected by changes in fossil fuel prices, currency depreciation from capital inflow from carbon trading and timing of emission reductions.

The multi-model analysis concludes that, compatible with the 2-degree target and global convergence of per-capita CO_2 emissions, significant reductions are required in both China and India, implying huge changes in their energy systems.

There are large differences in the size of the energy system and the related CO_2 emissions between China and India today, pertinent to the differences in economic activity. In the baseline scenario, the differences will decrease over time primarily due to higher economic growth in India. The current situation and the assumed future developments imply that there are differences as well as similarities in how India and China may be affected by climate policies on an aggregated national level.

In the main climate policy case Indian emissions are allowed to grow more than the Chinese emissions and still stay below their assigned amount, due to the per capita convergence rule and the higher population growth in India. Clear differences and similarities with respect to the actual consequences for the energy system of climate policy can be observed, not only among the two countries, but also among the two model types - CGE vs. energy system model. Energy efficiency improvements are important in the CGE models, while improvements in the carbon intensity, primarily through expansion of CCS and renewables, are more important for the energy system models. With respect to the carbon intensity improvements, CCS is more important in China, while renewables (including biomass) is more important in India.

The economic impacts of international climate policy – either measured as direct mitigation costs in the energy system models or as welfare losses relative to baseline GDP in the CGE models - are generally larger in China than in India, while India can even gain. This is primarily the result of India benefiting more from international emissions trading. In general China is a seller on the short term, but becomes a buyer on the long-term, while India is a seller over the whole 2010-2050 period. Dependent on the model, costs are also affected by decreasing global fossil fuel prices, currency depreciation resulting from a net capital inflow from international carbon trading and timing of emission reductions. Furthermore, China and India benefit from delayed participation and both countries are more negatively affected by climate policies if a uniform carbon tax is assumed (no international emissions trading) instead of a CDC approach.

III.4 Work package 4

The main goal of WP 4 of the POEM project was to identify policies that enable participation of the emerging economies in the global carbon mitigation process and simultaneously achieve development and climate goals. This WP has had two different tasks:

Task 4.1: Identifying/designing macro-socio-economic, energy and environment related domestic policies, and

Task 4.2: Designing institutional frameworks for international cooperation.

WP 4 built on the earlier POEM project work packages WP1 and WP2 and was also closely associated with WP3.

Following the review of macro-economic, energy and environment policies for the emerging economies that was carried out in WP1 and presented in the WP1 report, in this work package (WP4) different national policies (development, energy, environmental) in the emerging economies India and China were assessed from a climate perspective. Further, the alignment of national policies in the two countries was assessed in the perspective of international cooperation in a post-Kyoto regime.

In the project it was agreed that the basis of designing national policies and international co-operation framework would be based on the analysis of modeling results from WP3 for the 2 deg C global CO_2 stabilization scenario. Further, it was decided that the nature of international co-operation (institutional framework) would be assessed based on the agreed burden sharing regimes: (i) uniform carbon tax with full participation, and (ii) common but differentiated convergence.

A key focus of WP4 was policies having significant co-benefits vis-à-vis national development goals like energy security, energy access and air quality. Some possible areas for exploring co-benefits in this context are: i) Low Carbon Infrastructure, ii) Water-Energy Nexus, iii) Clean Energy, iv) Energy Conservation, v) Urban Planning and, vi) Sustainable Agriculture. The analysis of WP4 also stressed the immediate targets of 2020. As India and China have announced targets (emission intensities) for 2020 along with the policy road map to achieve those targets, it was useful to analyze domestic policies & international institutional cooperation keeping 2020 targets in mind. In a process building upon WP1, the WP4 report includes more detailed 5-year plan targets and its underlying relevance vis-à-vis the global climate targets and commitments.

There is some literature focusing on low carbon infrastructure and water-energy inter-linkages, but research work with regards to developing countries is scant. Quantifying the impacts of such a policy choice would help in making greater strides towards achieving global climate goals, particularly in the context of the 2 deg C stabilization target.

Primarily based on the model simulations carried out in WP3, Task 4.2 looked into the level of international cooperation needed to make India and China to comply with global climate combating efforts, without sacrificing the domestic priorities.

In the report, after a brief common introduction, India and China are treated in two different parts. Some key findings and conclusions are presented below, starting with India.

India

There has been a change in the structure of the Indian economy and in line with the nature of emerging economies; the share of service and industrial sector has been consistently growing over the past three decades with a corresponding decrease in the agriculture sector. Over the period, energy and environment policies in India have evolved; albeit slower compared to the challenges posed by rapidly growing economy. Environment policies have covered a wide-range of issues such as air and water pollution, waste management, and biodiversity conservation. However, the policies have traditionally been aimed at environmental protection and geared towards managing local issues.

The National Conservation Strategy and Policy Statement on Environment and Development, 1992, provided the basis for the integration of environmental considerations in the policies of various sectors. For example, the Policy Statement for Abatement of Pollution, 1992, stresses the prevention of pollution at the source based on the ‘polluter pays’ principle and The Forest Policy, 1988, highlights environmental protection through preservation and restoration of the ecological balance (a substantial increase of the forest cover in the country through afforestation programmes).

In 1991, liberalization of the economy triggered new policies such as focus on investment, deregulation and initiation of privatization. The energy sector was specifically targeted during the post-1991 period, with significant focus on expanding energy production opportunities (such as coal mining and oil exploration and production), use of alternative fuels (such as natural gas) and energy conversion capacities (such as power plants and oil refineries). Thus, energy policies in India started by laying emphasis on expanding energy production to match increasing demand. In the past decade, energy conservation and efficiency has received greater attention with the adoption of the Energy Conservation Act 2001 and Electricity Act 2003.

There are many supply-side oriented measures, in particular within the power sector, such as R&D in the area of ultra super critical boilers for coal-based thermal plants, use of integrated gasification combined-cycle (IGCC) technology to make coal-based power generation more efficient, the setting up of more combined cycle natural gas plants, promotion of nuclear energy through adoption of fast breeder & thorium based thermal reactor technology, adoption of high-voltage AC & DC transmission to reduce technical losses during transmission and distribution, setting up of small & large hydro power projects as a source of clean energy (apart from adaptation related benefits), promotion of renewable energy technologies such as biomass combustion & gasification based power generation, enhancement in the regulatory/tariff regimes to help mainstream renewable based sources in the national power system and promotion of renewable energy technologies for transportation (biofuels) and industrial fuels but also energy efficient technologies and appliances.

The Energy Conservation Act encompasses multitude of energy conservations measures and actions such as energy consumption standards for equipment and appliances; prohibited manufacture, sale, purchase and import of notified equipment and appliances not conforming to energy consumption standards; establishment and prescription of energy consumption norms and standards for designated consumers; and energy conservation building codes. Another major demand side measure is the Bachat Lamp Yojana (mass distribution of CFLs—to help in reducing peak load demand and reduce electricity demand by 6 GW).

These measures have enabled the Indian energy landscape to shift to a more sustainable path, with the ultimate goal of off-setting demand additions on the supply side.

India faces major development challenges such as better health services, clean energy and clean and safe drinking water for all. Meeting the development needs of its people is one dimension of this challenge and the other is to a fast and consistent growth of the economy. The Prime Minister of India has stressed the importance of growth to meet developmental needs of the country's people. Climate change adds an additional dimension to the existing challenge. Aligning developmental objectives with concerns for climate change has thus emerged as one of the key challenges for India.

The vital relationship between sustainable development and climate change was brought into sharper focus in the Delhi Declaration made at COP-8 in November 2002, and India has already embarked on an ambitious path in terms of aligning its development agenda with the global carbon architecture. The National Action Plan on Climate Change (NAPCC) was launched in June 2008 and has laid specific emphasis on a technology-driven transition to a sustainable future.

At COP-15 in Copenhagen, 2009; India pledged to move ahead on the road to cutting the emissions intensity of GDP by 20-25% by 2020. In line with India's emissions intensity targets and also to promote future low carbon energy transitions, India has already embarked on a eight missions that comprises numerous actions, particularly on the technology side; so as to secure a sustainable low carbon future transition. The adoption of low carbon growth is an essential pillar for India's 12th five-year plan (2012-2017) strategy. The specific measures such as diversifying the energy mix of the country through the solar mission, promotion of natural gas as a fuel and the plan to double the nuclear capacity in the next 10 years are aimed to achieve multiple simultaneous goals like energy security, air quality and carbon intensity of the economy.

<u>China</u>

China has taken intensive actions to phase out old production capacity. The main aim of this is to contribute to improved energy efficiency but there are both climate and environmental benefits coupled to these measures. Small and old units have been phased out and substituted by larger, more modern technology; e.g. during 2005-2010 a total capacity of 72 GW of small thermal power units were closed, and the proportion of large-sized furnace in the iron and steel industry increased from 21% to 39%.

Other types of project whose objective is increased energy efficiency also have major positive climate implications. In order to implement the Outline of the Eleventh Five-year Plan for National Economic and Social Development and attain the mandatory goal of reducing energy consumption per unit of GDP by around 20%, the National Development and Reform Commission (NDRC) together with other departments, on the basis of the Mid- and Long-term Special Plan for Energy Conservation, formulated and issued in July 2006 the Opinion on Implementing 10 Key Projects of Energy Conservation in the Eleventh Five-year Plan Period. These ten key projects of energy conservation includes e.g. district combined heat and power generation; utilization of waste heat; petroleum conservation and substitution projects; introduction of electrical motors, energy conservation of buildings and "green" lighting. The Implementation of the ten key projects has resulted in a total of 340 million TCEs saved.

The implementation of standards and labeling system for energy efficiency has improved the energy efficiency of terminal product, and up to date China has issued seven product lists subject to energy efficiency labeling management, covering 23 types of products in household electric appliance, industrial and lighting equipment etc.

The Chinese government attaches importance to the development of low-carbon energy, such as new and renewable energy, and has actively promoted a diversification of the Chinese energy mix e.g. through a number of financial, tax and price incentive policies in the area of renewable energy. Though the primary objective is rather energy security and diversification, the policies also have a strong climate impact.

From 2005 to 2010, the total installed capacity of hydropower plants was increased by 82 %, the total accumulative installed capacity of wind farms was increased by 30 times to 40 GW. The utilization level of solar resources was increased significantly and the total installed capacity of photovoltaic power generator sets was increased by 10 times and the total collector area of solar water heater was doubled. Biomass resources were developed, both as biomass power generation and production of transport biofuels. In addition to renewables, also the nuclear capacity has been expanding. From 2005 to 2010, the share of coal consumption was reduced from 71% to 68%, the share of natural gas consumption was increased from 2.6% to 4.4%, and the share of renewable and nuclear power increased from 6.8% to 8.6%.

The introduction of a carbon tax in China has been proposed by NDRC and the Ministry of Finance (MOF). One important aspect of the introduction of a carbon tax in China is the impact on GDP but also distribution effects are central. Therefore, the CEEPA model has been applied to simulate and compare different carbon tax schemes. The difference among the schemes lies in their different manners of levy, or different manners of revenue recycling.

The study concludes that, if no protections for households are considered, a carbon tax will reduce the living standard of both urban and rural households, and the negative impacts on rural households are greater than on urban households mainly because currently urban households obtain a much greater share in transfer payments.

Exemption of households from carbon tax has weak effects either on reducing the negative impacts on households, or on preventing the expansion of the urban-rural gap. Further, given the current social security system that obviously favors urban households, two measures can effectively reduce the extent of the urban-rural gap expansion caused by carbon taxation. These are a scheme using the carbon tax revenue to reduce the indirect tax and a scheme transferring the carbon tax revenues to households in proportion to their number. Given that the current social security system obviously favors urban households, the only scheme that can completely avoid the expansion of rural-urban gap is a scheme transferring carbon tax revenue to households in proportion to the population. But the long-term negative impacts on household living standard under this scheme are greater than with the no-protection scheme.

Given the current investment-driven economic growth pattern, the negative impacts on household income and welfare under each of the schemes will increase over time. In the long term, a scheme using the carbon tax revenue to reduce indirect tax has obviously smaller negative impacts on household living standard and economic growth than the other schemes. In addition, increasing the share that rural households obtain in government transfers helps to avoid the expansion of the urban-rural gap.

Based on this, some policy recommendations can be drawn. Given the current investment-driven economic growth pattern, it is necessary to introduce proper complementary measures for protecting economic growth and household life when designing a carbon tax scheme for China, and to use carbon tax revenues to reduce indirect tax is the best way to protect economic growth. Protections for households should also mainly rely on carbon tax revenue recycling.

A domestic carbon emission trading system is another possible important mitigation policy choice for China. The outline of the national twelfth five-year plan has addressed to establish an emissions trade market step by step and thus there is good reason to carry out studies on the possible impact of such a trade system in China. The CEEPA model was applied to assess the social-economic impacts of different allowance allocation methods for China.

Three ways to allocate primary permits have been assessed; allocation of the permits for free, not for free and a combination of free and not for free. Free allocation means that the primary permits are allocated for free to sectors or enterprises according to a given rule. Non-gratuitous allocation mainly includes auction and sale at fixed price. The mixed mechanism is a mix of auction and free allocation either simultaneously or time dependent.

Considering the macro-economy aspects of particular interest of the government when designing policies, this study identified gross national product (GDP), employment level (Lab), consumer price index (CPI), total consumption (Cons) and the government income (GovI) as the main objects to address when assessing the macro-economy impacts of different allocation approaches.

The result shows that all studied allocation approaches lead to negative social and economical impacts. The analysis shows that no one of the designed approaches can provide the best effects with regards to all addressed objectives, and that is there is no single optimal allocation approach. Thus, a number of aspects should be considered in the design of the future allowance allocation approach when carrying out the emission trade system:

- From the perspective of comprehensiveness, the better choice is that permits are auctioned and the revenue is used to reduce the indirect taxes.
- If the protection of people's life in short term is of highest concern, permit auctioning combined with direct revenue transfer to household could be the core allocation mechanism, however it should not be the core allocation mechanism in the long term.
- If the function to raise the fiscal funds is emphasized, a mixed approach in which each sector can get a certain amount of free permit while the remaining needed permits are auctioned could be the core allocation mechanism, while it should not be the core allocation mechanism in long term.

III.5 Additional results

The project has generated a large amount of results of which many are yet to be analysed in detail. It has also led to a number of studies, which are based on the collaboration within the project and the project results but which have not been included in the main project reports. Abstracts, and to some extent conclusions from these four studies are presented below.

The POEM project has also already contributed to a number of other studies; e.g. v Ruijven et al 2011, Kainuma et al 2012, Krey et al 2012, v Ruijven et al 2012b; see the reference list.

1. Effects of international climate policy for India: Evidence from a national and global CGE model (published as Kiel Working Paper No. 1810, November 2012)

Matthias Weitzel, Joydeep Ghosh, Sonja Peterson, Basanta K. Pradhan

In order to reach the 2-degree target it is necessary to control CO2 emissions also in fast growing emerging economies such as India. The question is how the Indian economy would be affected by e.g. including the country into an international climate regime. Existing analyses with either a global model or a single country computable general equilibrium model miss important aspects such as distributional issues or international repercussions. By soft-linking models of these two classes, we provide a more detailed view on these issues. In particular, we analyze different options of transferring revenues from domestic carbon taxes and international transfers to different household types and how different assumptions on exchange rates affect transfer payments. We also show effects stemming from international price repercussions. Our analysis focusses on how these transmission channels affect welfare of nine different household types.

This paper shows that soft linking of the two model types can give a more detailed and accurate view for India. In the global model with only one representative agent in particular distributional effects are missing. For India, such effects are crucial for policy makers when assessing the impacts of climate mitigation policy. As the national model shows, welfare effects can differ significantly for different household types so that average welfare numbers are of little use. In addition, redistribution of revenue from a carbon tax and international transfers to poorer households – which cannot be captured in the global model – does benefit the poorer households but comes at the cost of overall higher GDP/welfare losses. The analysis also shows that accounting for the international transfers often ignored in national models indeed reduces negative welfare effects for India. Income distribution is furthermore affected by international price repercussions, which are also normally not accounted for in national models. By passing on price changes from the global to the national model we can show that poor household groups benefit least from lower international fossil fuel prices and also have higher welfare losses when revenues are used for investments which is most efficient in terms of GDP or overall welfare losses. This does not mean that revenues need to be allocated to poor households exclusively; we show that transfers to all households on a per capita basis already make poor households better off than the baseline. Generally, accounting for international price repercussions has significant implications for the outcome of the national model.

We also see that the rather small negative or even positive welfare effects of international climate policy have to be treated with care. Even though the differences in our model analyses partly stem from different implicit abatement costs, neglecting exchange rate adjustments and overall welfare effects of different revenue recycling lead to overly optimistic results in the global model.

While the model soft linking allows a more detailed view on distributional effects of international climate policy in India and allows identification of the relative importance of the different channels, our scenarios are necessarily highly stylized. Other use of the revenues such as financing clean energy or other “green technologies” would be possible but cannot be analyzed in our modeling framework. The insights could be further improved through a more complete coupling which could include a further harmonization of the baseline scenarios and potentially also feedbacks from the Indian model to the global model.

2. Energy system changes for China and India under different climate stabilization pathways

Paul Lucas, P.R. Shukla, Wenying Chen, Subash Dhar, Amir Bazaz, Bas J. van Ruijven, Michel M.G.J. den Elzen and Detlef P. van Vuuren

In order to limit global mean temperature increase to the UN climate goal of 2°C, deep reductions in greenhouse gas emissions are needed. We compare abatement costs and changes in the energy systems of China and India derived from three energy system models under two global emission pathways that are in line with a medium likelihood of meeting 2°C: a least-cost pathway and a pathway that postpones mitigation action by implementing the Copenhagen Accord pledges for 2020. Both pathways have similar cumulative CO_2-eq emissions for 2010-2050. The analysis shows that postponing mitigation action increases cumulative mitigation costs for both China and India. Furthermore, postponing mitigation action increases the dependence on fossil fuels on the short-term, but decreases dependence on the longer term due to the deeper required emission cuts to compensate for the short-term emission growth. Differences between India and China relate to different periods of rapid economic change and capital stock turnover of power production capacity. China still has a significant share of conventional coal power plant in the mitigation scenarios in 2050 (possible combined with CCS), while Indian power production is almost CO_2-neutral by 2050. It should be noted that climate policy also interferes with other energy-related issues that are important in both India and China. It may induce risks, such as increased indoor air pollution, but can also synergize with energy security and urban air pollution. These relations are important to take into account when designing national policies.

3. The impact of carbon taxes on growth, emissions and welfare in India: A CGE analysis

Basanta K Pradhan and Joydeep Ghosh

The main objective of this paper was to analyze the impact of two post-Kyoto climate policy regimes on GDP growth, CO_2 emissions, and welfare in India. The first regime is a global carbon tax (CT) while the second regime is based on emission trading permits where the distribution of permits is based on the Common but Differentiated Convergence (CDC) approach. Both climate policy regimes are consistent with the objective of limiting the increase in average global temperature below 2°C over the long term. The results suggest that assumptions about the climate policy regime, model closure and values of substitution elasticities (between value added and energy) play an important role in determining the effects of climate policies.

The CO_2 emissions profiles are significantly lower under both policy regimes relative to the BAU path. In the BAU scenario CO_2 emissions increase from 1220 million tons (1.1 tons per capita) in 2005 to 5403 million tons (3.3 tons per capita) in 2050. The projected per capita CO_2 emissions in 2050 are lower than the global average per capita CO_2 emissions in 2005. In the CT regime, emissions peak at 3267 million tons (2.1 tons per capita) in 2040, and thereafter decline to 2631 million tons (1.6 tons per capita) in 2050. In the CDC regime, emissions peak at 3232 million tons (2.1 tons per capita) in 2040, and thereafter decline to 2475 million tons (1.5 tons per capita) in 2050.

The maximum loss in GDP occurs during 2045–50 under both the policy regimes. The growth rate falls from 4.3 per cent in the BAU scenario to 3.2 per cent in the CT scenario and to 3 per cent in the CDC scenario. In other periods, the decline in GDP growth rate is not more than 0.3 percentage points. The welfare loss is relatively lower in the CDC regime relative to the CT regime due to price effects. The inflow of capital that takes place as a result of trade in emission permits in the CDC regime leads to exchange rate appreciation, and thus lower consumer prices and lower welfare loss, relative to the CT regime.

Further, the climate policy regimes lower the energy intensity of GDP and facilitate the substitution of fossil fuels by renewable energy. However, expectedly, fossil fuels retain their dominant position in the energy mix even in 2050.

The substitution elasticity between value added and energy was found to play a significant role in determining the effects of climate policies. A higher value of the substitution elasticity leads to lower emissions and higher welfare relative to the BAU path. Finally, the results suggest that climate policies could influence the country's trade balance, and the degree of influence depends on the exchange rate regime. A stable (fixed) exchange rate is relatively beneficial for the economy.

4. Carbon taxes vs productivity shocks: A comparative analysis of the costs in a CGE framework for India

Basanta K Pradhan and Joydeep Ghosh

The main objective of this paper was to compare the costs of climate policy scenarios with those of probable climate change induced agricultural productivity shocks using a recursive dynamic CGE model in case of India. The social cost of carbon, in terms of agricultural productivity loss, is estimated to be about 17 and 14 percent of GDP, using zero and 3 percent discount rates, respectively. In comparison the costs of climate policy regimes are estimated at 3 and 2 percent, using similar discount rates, respectively. There is a strong case for the adoption of mitigation policies by India, along with other countries, to reduce the level of CO_2 emissions in order to protect the agriculture sector from climate change induced productivity shocks. Besides, revenues generated from the implementation of climate policies could be a means to support the adoption of energy efficient technologies and augment capital formation in the economy.

III.6 Final remarks

The policy and modeling analysis was done in a top-down fashion, starting with a global burden-sharing agreement and the global models and then concluding with the impact at the national levels. A bottom-up approach, starting with national policies and objectives could have been chosen instead. These two general approaches were considered and the top-down approach was chosen because the analyzed scenarios were strongly supported by the Chinese and Indian project partners and are broadly in line with national Chinese and Indian proposals. The choice of the top-down approach was also the result of a decision to be consistent with the long-term 2-degree target. With a bottom-up approach we would not have had this guarantee. In some sense such global scenarios are also the natural starting point for using the newly developed modeling framework, which was at the heart of the POEM project. Yet, we see the importance of bottom-up approaches and this is strongly recommended for any future work. Such an approach could then also focus on issues like green financing and CDM and could possibly lead to a strong involvement of national policy makers in India and China at an early stage of the project.

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Part IV - Project impact

The expected impact should, quoting the work programme of the topic ENV-2008.1.1.6.3, be *"to provide a portfolio of policy options for emerging economies to engage in climate change protection measures under a post-2012 regime."* The project is not only presenting a portfolio of policy options under a post-2012 regime but also attempting to quantify these policy options possible impact on the economy and to some extent also on other societal sectors in terms of socio-economic development. The project is thus obviously highly policy relevant since the main outcome of the project is to contribute to support for policy makers.

The work has targetted India and China since these two countries are the emerging giants and any global climate agreement requires their particpation. The work is thus country specific for these two countries and is addressing details on a sectoral level specific for these two countries. However, since the project has addressed an identification and discussion of similarities and dissimilarities between the countries, there are many conclusions of a more general validity also for other emerging countries.

In addition, the project provides a unique integrated modelling framework, which has been developed during the project and which is being able of assessing economic and energy systems impacts of climate and other policies combining models of different kinds and scales. The modelling framework could possibly also have a value for future projects in the area and the impact of the project in this respect goes far beyond the actual project.

The project has also contributed to the developement of all models utilised in the project, and significantly to some of the models, and this model development will have a large impact far beyond the project since the models will continue to be used for future studies.

After considerable discussions in the project consortium, it could be decided to use the so-called common but differentiated convergance (CDC) burden sharing regime as the main policy scenario. This is a relative recent addition to the number of proposals for burden-sharing regimes, see the POEM WP2 report for details of the CDC regime and all other major proposals for burden sharing regimes. Impacts of the choice of the CDC regime as the main policy scenario of the POEM project are both that the project is adding knowledge on the possible outcomes of this regime and also contributing to the knowledge and general acceptance of the regime.

The POEM project has built upon the concept of soft linking of a number of advanced computable models in different fields. The approach is not unique but the soft linking has worked out rather well despite it required some time-consuming comparisons and harmonisation processes. This shows on a possible way of combining various models in a strucutured way and might have impact on how similar analysis are carried out following upon the POEM project.

Since the modelling part of the project required considerably more time than the DoW allowed, with its strict time-frame, much of the planned discussion with representatives from both national governments and international organisations engaged in climate change negotiations is yet to be made. The outcome should be of value for national and international, as well as European, organisations and will continue to be fed in into the policy debate.

The project website is presenting the project and its delivarables but it is unclear what impact this has had so far.

The project partners include a number of researchers who are active within different research networks. Due to this multi-disciplinarity, the multiplying effect is likely greater than it otherwise would be when researchers from only one research community are working together within a project. Some of these research networks are wide-ranging and, naturally, these have been and will continue to be be used for communication of the project outcomes. Further, since some project members are actively engaged in the IPCC work and regularly contribute to the assessment reports and COPs, there is an active two-way communication in a broader policy context. The POEM scenarios are also likely contributing to the IPCC work.

The research methodology and final results has been presented at a number of scientific workshops and conferences and will continue to be so in particular during the first year after the end of the project.

It was expected that three - four scientific publications could be published in different scientific journals but already now at the end of the project one article is published in a scientific journal, a second article is submitted, and four other articles are close to completion, see abstracts elsewhere in this report, and it is likely that the project will result in a further three-four scientific articles. In addition to this, the project has contributed so far to at least four other scientific articles, mentioned elsewhere in this report. Thus, the scientific outcome of the the project is far beyond expectations as presented in the original project plan, and this will naturally have a large impact.

Major dissemination events

As planned, in each of the countries India and China one major national workshop has been organised by the country partners:

- POEM workshop in New Delhi, Thursday, September 6, 2012 India International Center (IIC), New Delhi.
- POEM workshop in Beijing, Tuesday, September 25, 2012, at the Hotel Nikko New Century Beijing, Haidian District, Beijing.

Despite a not very large total attendande to the workshops (30-40 people at each), there was a mixed attendance of academic and policy people.

There was a also a workshop in Brussels planned for Sep 28, 2012 but several days after the registration dealine, with only three days to the workshop, it was cancelled due to no registrations received.

At three of the project meetings there has been an open seminar with a large number of external guests and where the project has been presented in a broader context. In particularly during the second workshop in New Delhi there was a major event as part of the project meeting at which high level policy makers attended and made presentations.

The project methodology and results have been presented at a large number of seminars, workshops and conferences, national as well as international by all project partners/beneficiaries. The project will continue to be presented at different occasions.

The dissemination of the project results is an ongoing process, which will continue even after the project is finished.

Part V - Project website and contact details

The project web site is hosted by Chalmers at

http://www.chalmers.se/ee/poem-en.

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