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A TALE OF TWO COUNTRIES: EMISSIONS SCENARIOS FOR CHINA AND INDIA

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SUMMARY The aim of the paper is to present evidence that China and India are, and will remain, two very different actors in international negotiations to control global warming. We base our conclusions on historical data and on scenarios until 2050. The Business-as-Usual scenario (BaU) is compared to four Emissions Tax scenarios to draw insights on major transformations in energy use and in energy supply and to assess the possible contribution of China and India to a future international climate architecture. We study whether or not the Copenhagen intensity targets require more action than the BaU scenario and we assess whether the emissions reductions induced by the four tax scenarios are compatible with the G8 and MEF pledge to reduce global emissions by 50% in 2050.

Keywords: Climate Change, China, India, Energy Efficiency, Energy and Development

JEL: Q32, Q43, Q54, O53, P52

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1. Introduction

China and India are two Asian giants and global players. They are home to about one-third of the world population and they are both experiencing prolonged periods of high economic growth. China's real Gross Domestic Product (GDP) per capita has grown at the striking average rate of 9.5% per year from 1990 to 1999; from 2000 to 2009 the expansion of the economy has further accelerated, with an average annual growth rate of 10.5% per year. Double-digit growth rates over twenty years have generated a stunning five-fold increase of GDP per capita in China. India's economic growth has been slower in comparison with China, but still remarkably high during the last twenty years.[1] India's GDP per capita growth rate has been equal to 5% per year, on average, from 1990 to 1999; growth has accelerated in this decade, with an average increase of 7.4% per year from 2000 to 2009. The average Indian citizen is now 2.4 times richer than in 1990. However, despite this unprecedented period of prosperity, she is still three-times poorer than her Chinese counterpart. The economic gap between the two countries has widened over the past twenty years: in 1990 average GDP per capita was twenty percent higher in China than in India, in 2000 it was twice higher and in 2009 three times higher.

Chindia – as many commentators now refer to the two Asian giants[2] – is certainly a useful geo-political construct, but the two countries are still very diverse. The gaps in income, energy use and emissions – both in per capita and in absolute levels – will very likely remain wide for several decades. When discussing the future impact of the two countries' development pattern on global climate change and possible ways to include them in the efforts to contain global warming, we definitely still need to tell a tale of two countries. Often blamed together for not doing enough to reduce their Greenhouse gases (GHGs) emissions, China and India have two very distinct historical and future development trajectories.

China's carbon intensity of energy – the carbon dioxide embodied in each unit of energy – was 30% higher than India's in 1990 and still is 23% higher in 2007; the energy intensity of output in China – the energy embodied in each

[1] Data on GDP, energy use, electricity use and carbon emissions are from the World Development Indicators 2009, The World Bank.

[2] According to Wikipedia, the credit of coining the now popular term goes to Jairam Ramesh, an Indian politician.

unit of GDP – was twice higher than in India in 1990, 30% higher in 2000 and 45% higher in 2007. As a result, despite a remarkable decline over the past twenty years, the carbon intensity of GDP is today 30% higher in China than in India. All the dynamics of income per capita, of carbon intensity of energy, of energy intensity of GDP and the level of population, explain why China's carbon dioxide emissions from fuel combustion in 2005 were roughly five times higher than India's emissions (6.5 Gt per year in China and 1.2 Gt per year in India). China was responsible for 22% of global carbon dioxide emissions in 2005; India for only 4%. For a comparison, emissions of carbon dioxide from fuel combustion in the United States were equal to 6.4 Gt in 2005, slightly lower than China's emissions; the emissions of Japan were roughly equal to India's emissions, with a total population only one-ninth of the Indian one.

The aim of this paper is to present evidence that China and India are, and will remain, two very different actors on the scene of international negotiations to control global warming. We base our conclusions on historical data from the World Bank Development Indicators and on scenarios developed using the hybrid Integrated Assessment Model (IAM) WITCH. A Business-as-Usual (BaU) scenario explores the optimal economic and energy system dynamics without any policy explicitly conceived to reduce GHGs emissions. It is important to stress that the BaU scenario does however implicitly include all the policies that are enacted to respond optimally to changing prices of inputs, both at domestic (capital, labour) and at international level (fuels, investment cost in renewables, knowledge spillovers). Policies whose aim is to increase energy efficiency are therefore implicitly included in the BaU scenario. Policies to reduce GHGs emissions – i.e. by switching from coal to natural gas or to renewables – are instead part of the four Tax Scenarios.

It is by all means unrealistic to expect that either China or India will introduce a tax on GHGs emissions anytime in the near future. We use here the Tax scenarios to illustrate significant issues, similarities and differences, that would emerge as an optimal response to economic and regulatory incentives to reduce GHGs emissions. We focus our attention on the implications that a tax on emissions has on both carbon intensity of energy and energy intensity of GDP, on total GHGs emissions and on the marginal and macroeconomic cost of the climate policy.

China and India have captured the attention of researchers in all disciplines. Energy and environmental economists are not an exception. The International Energy Agency has dedicated the 2007 World Energy Outlook to a careful analysis of the energy sector in China and India (IEA 2007). Long-term scenarios of energy demand and supply for China and India have been developed by all modelling groups participating in the recent Energy Modelling Forum 22 (EMF22 2009; Clarke et al 2009), by McKibbin, Wilcoxen and Woo (2008), Hengyun Oxley and Gibson (2009), Vöhringer et al (2010), Li (2008).[3] Pachauri and Jiang (2008) compared the energy transition in China and India at household level and found many significant differences between the two countries.

We complement this growing literature by highlighting those aspects that emerge from the analysis of energy and emissions scenarios for China and India that are relevant for the next rounds of negotiations. The target is not an audience of energy experts or the IAMs community. We rather aim at reaching the diverse community of negotiators and policy makers engaged in promoting actions against global warming at local, national and international level.

The rest of the paper is organized as follows. Section 2 introduces the reader to historic data and to the BaU scenario. Section 2 also contains a brief overview of the WITCH model. Section 3 presents the four Tax scenarios. The implications in terms of energy demand, emissions and economic cost in China and India will be discussed thoroughly. Conclusions follow.

2. Historic data and the BaU scenario

In this Section we merge historical data and future scenarios to sketch a profile of China and India that highlights crucial issues for future negotiations on climate change. Scenarios on future economic growth, energy use and carbon emissions were generated using the hybrid Integrated Assessment Model (IAM) WITCH – World Induced Technical Change Hybrid model (Bosetti et al 2006; Bosetti, Massetti and Tavoni 2007;

[3] Recently, the Integrated Assessment Modelling community has gathered to discuss long-term energy and emissions scenarios for Asian economies in the Asia Modelling Exercise. However, a whole set of new scenarios will not be published until the end of 2011.

Bosetti et al 2007; witchmodel.org).[4] Key characteristics of WITCH are (1) an economic growth engine that allows the study of economic development over long time horizons; (2) a "perfect foresight" approach that incorporates events that are expected to happen in the future in present decisions; (3) a focus on endogenous technical change dynamics; and (4) the description of non-cooperative interaction among world regions on several global public goods – e.g. global climate, scientific knowledge and natural resources.

2.1. Economic growth

China and India start from two very different levels of economic development. China is a major world economy with a GDP three times higher than the GDP of India in 2005. The difference remains remarkable even if we account for a larger population in China: India's GDP per capita is only 40% of the GDP per capita in China. The gap between the two countries has doubled during the past fifteen years due to the extremely fast expansion of the Chinese economy. India is now catching up with Chinese economic growth rates and we expect that the Indian economy will grow faster than the Chinese economy from 2005 until 2050. However, in our BaU scenario the gap remains as wide as the present one for the next fifty years due to the current large absolute difference and higher population growth in India. China's GDP per capita surpasses the average of the rest of the world (ROW) in 2050, while India's GDP per capita remains 60% lower than in the ROW.

The remarkable economic performance of both countries during the past fifteen years is so striking that it tends to obscure the fact that the average Chinese and the average Indian citizens remain poor. GDP per capita in China and India was only 5% and 2% of GDP per capita in OECD countries in 2005.[5] In our BaU scenario both China and India narrow the gap with respect to OECD economies in the next decades. However, the differences remain disproportionate even in 2050: China's GDP per capita is one-third of the GDP per capita in OECD economies, India's GDP per capita is one-tenth. The fact that the gap will remain large for many years in the future is confirmed by other

[4] By combining the economy, energy, ecosystems and climate, IAMs allow the creation of scenarios on future GHGs emissions and the study of transition pathways towards a low-carbon world. For a discussion of key characteristics and use of IAMs see, among others, Dowlatabadi (1995), Ackerman et al (2010) and Weyant (2010).

[5] Using Purchasing Power Parities (PPP) instead of Market Exchange Rates (MER) to compare GDPs internationally would narrow the income gap between poor and rich countries.

long-run scenarios. For example, McKibbin, Wilcoxen and Woo (2008) see the Chinese GDP converging toward the US GDP in 2100; India would converge only in 2150.

It is therefore clear that, for many years to come, China and India will accept to pay only a minimal fraction of the global cost to reduce GHGs emissions. This is not equivalent to saying that China and India will not contribute to the mitigation target. It rather suggests that high income countries need to pay for a large fraction of emissions reductions in China and India.

	1960	1975	1990	2005	2020	2035	2050
The Economy							
GDP (trillions constant 2000 US$)							
China	0.07	0.13	0.44	1.91	7.38	17.00	28.00
India	0.06	0.14	0.27	0.64	2.21	5.58	11.23
OECD	6.07	12.00	19.49	27.75	46.98	63.00	79.82
World	7.28	14.70	24.22	36.71	69.70	110.27	159.47
GDP per capita (constant 2000 US$)							
China	105	146	392	1464	5164	11587	19741
India	145	220	318	589	1600	3587	6772
OECD	8523	14501	21403	27743	41069	53792	68047
World	2400	3611	4587	5676	9094	12846	17356
GDP Growth rate (percentage, average over fiftheen years interval)							
China	--	2.2	6.8	9.2	8.8	5.5	3.6
India	--	2.8	2.5	4.2	6.9	5.5	4.3
OECD	--	3.6	2.6	1.7	2.6	1.8	1.6
World	--	2.8	1.6	1.4	3.2	2.3	2.0
The Energy System							
Energy use (Mt of oil equivalent)							
China	--	484	863	1690	2698	4008	4951
India	--	177	318	534	720	1135	1630
OECD	1884	3529	4322	5239	5991	6619	7152
World	--	6094	8556	11090	13391	16936	20167
Energy use (kg of oil equivalent per capita)							
China	--	528	760	1296	1887	2731	3491
India	--	289	375	488	522	730	983
OECD	2763	4266	4746	5238	5237	5652	6098
World	--	1366	1666	1769	1747	1973	2195
Fossil fuel energy consumption (% of total)							
China	--	64	75	85	89	91	92
India	--	39	56	68	79	87	90
OECD	94	93	84	82	92	90	89
World	94	83	81	81	88	89	89

	1960	1975	1990	2005	2020	2035	2050
CO2 Emissions							
CO2 emissions (Gt)							
China	0.78	1.14	2.46	5.61	9.32	13.91	17.44
India	0.12	0.25	0.69	1.41	1.94	3.43	5.15
OECD	5.70	9.85	10.94	12.40	17.06	19.35	21.85
World	9.44	16.91	22.53	29.21	38.49	50.41	62.54
CO2 emissions (metric tons per capita)							
China	1.17	1.25	2.17	4.30	6.52	9.48	12.30
India	0.28	0.41	0.81	1.29	1.41	2.21	3.11
OECD	8.01	11.90	12.01	12.40	14.91	16.52	18.63
World	3.11	4.15	4.27	4.52	5.02	5.87	6.81
Population, total (billions)							
China	0.667	0.916	1.135	1.304	1.430	1.468	1.418
India	0.435	0.613	0.850	1.095	1.379	1.554	1.658
OECD	0.712	0.828	0.911	1.000	1.144	1.171	1.173
World	3.032	4.071	5.279	6.467	7.664	8.584	9.188
Efficiency Indicators							
Carbon Intensity of Energy (t of CO2 per Mt of oil equivalent)							
China	--	2.4	2.8	3.3	3.5	3.5	3.5
India	--	1.4	2.2	2.6	2.7	3.0	3.2
OECD	3.0	2.8	2.5	2.4	2.8	2.9	3.1
World	--	2.8	2.6	2.6	2.9	3.0	3.1
Energy Intensity of GDP (t of oil eq. per 1,000 constant 2000 US$)							
China	--	3.63	1.94	0.89	0.37	0.24	0.18
India	--	1.31	1.18	0.83	0.33	0.20	0.15
OECD	0.31	0.29	0.22	0.19	0.13	0.11	0.09
World	--	0.41	0.35	0.30	0.19	0.15	0.13
Carbon Intensity of GDP (t of CO2 eq. per 1,000 constant 2000 US$)							
China	--	8.58	5.53	2.94	1.26	0.82	0.62
India	--	1.86	2.55	2.19	0.88	0.61	0.46
OECD	0.94	0.82	0.56	0.45	0.36	0.31	0.27
World	--	1.15	0.93	0.80	0.55	0.46	0.39

Notes: 1960-2005 historic data aggregated by the World Bank Development Indicators. Fossil fuel comprises coal, oil, petroleum, and natural gas products (source: International Energy Agency). Energy use refers to use of primary energy before transformation to other end-use fuels (source: International Energy Agency). Carbon dioxide emissions are those stemming from the burning of fossil fuels and the manufacture of cement (source: CDIAC). GDP at purchaser's prices data are in constant 2000 U.S. dollars. Dollar figures for GDP are converted from domestic currencies using 2000 official exchange rates (Source: World Bank national accounts data, and OECD National Accounts data files). Population data is from a variety of sources, midyear estimates. 2020-2050 data are from the WITCH model Business-as-Usual scenario.

Table 1. Historic data and future scenario on the economy, energy system and emissions.

2.2. Energy intensity and carbon intensity

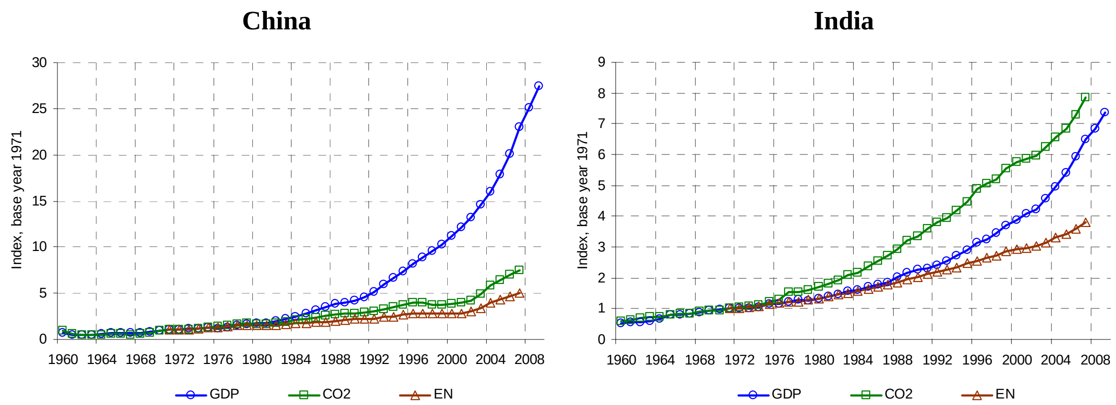
Figure 1 and Figure 2 offer a synthetic look at the historic economic and energy development of China and India. Two major similarities emerge: in both countries GDP has grown at a faster rate than energy use and carbon dioxide emissions have grown faster than energy. However, these changes have happened at two very different speeds. Energy intensity in China has declined at an average rate of 4.6% per year from 1975 to 2005, in India by only 1.5% per year. Carbon intensity of energy has increased in both countries, but in India almost twice as fast as in China (+2.1% and +1.1% per year, on average).[6] The increase of emissions per unit of energy has been particularly strong in India due to a long-term decline of traditional biomass as a source of energy.[7] The increase of the carbon intensity of energy has been so strong in India, that it more than compensated the energy efficiency gains, causing an overall increase of carbon emissions per unit of GDP (at an average rate of 0.5% per year). In China, instead, the carbon intensity of GDP has declined at an average 3.5% per year.

However, China started from a much higher level of energy content per unit of output and despite the relatively better performance, China still has 26% more carbon emissions per unit of energy and 7% more energy use per unit of GDP than India. As a result, the carbon intensity of GDP is 34% higher in China than in India.

In the BaU scenario the carbon intensity of energy continues to grow in both countries, faster in India than in China, with the two countries converging to similar levels in 2050. The energy intensity of GDP is instead declining in both countries, at similar rates. China's development path will remain relatively more intensive in energy use: in 2050 the carbon content of each unit of GDP is going to be 34% higher in China than in India, exactly as in 2005. Compared to other world regions, China and India will continue to have energy and carbon intensity higher than the average. The gap with the world average disappears in 2050, but a large difference remains with respect to OECD economies, which continue to be much more efficient and less carbon intensive than China and India (see Table 1).

[6] For a detailed analysis of energy intensity trend in China and for a review of policies to increase energy efficiency see Levine and Aden (2008), Levine, Zhou and Price (2009), Zhou, Levine and Price (2010).

[7] Wooden fuels are cause of no net carbon emissions. When they are replaced with fossil fuels the carbon content energy increases considerably.



Source: see notes to Table 1. Base year 1971.

Figure 1. Long-term time series of GDP, CO_2 emissions and energy use.

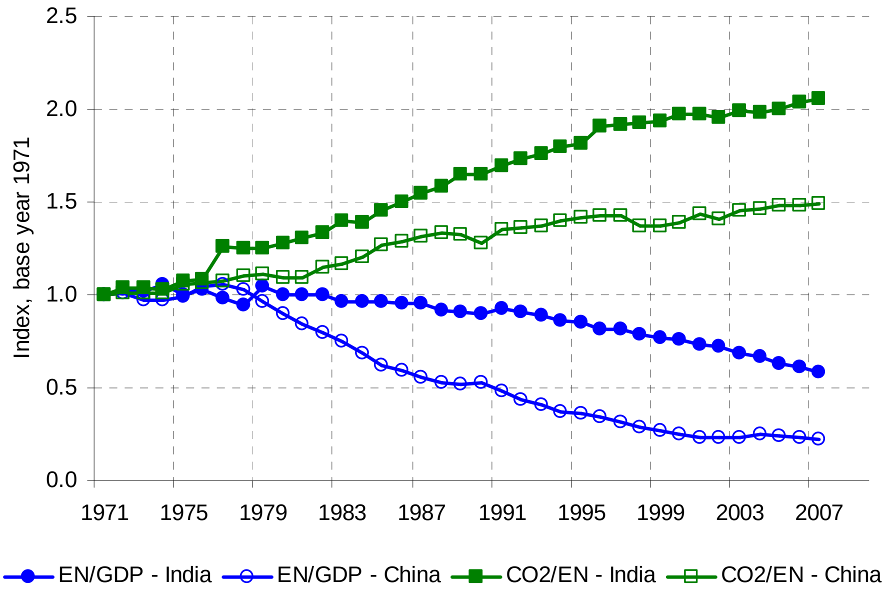


Figure 2. The indices of energy intensity of GDP and of carbon intensity of energy.

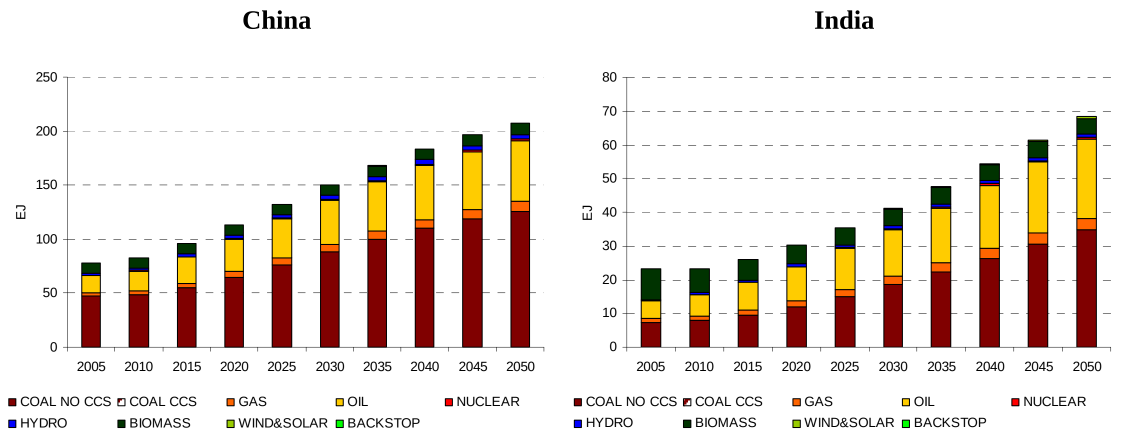
2.3. Energy demand and emissions

The scale of the two Asian giants is so big that any efficiency gain is more than compensated by the sheer size of economic growth. Despite energy use per unit of GDP was cut four-fold between 1975 and 2005, energy demand has increased 3.5 times during the same period in China. In India energy use was cut by 40% from 1975 to 2005, but energy use has increased by 70%. The rapid expansion of the economy has transformed China in one of the key players of the global energy commodities market. India's demand for energy is growing, but its demand is still one third less than China's. The gap between the two countries will remain substantially unchanged in percentage terms, but will become huge in absolute terms: China will consume about 3,300 Mtoe more than India in 2050, twice the present level of energy use in China. China will absorb 25% of global energy supply, India "only" 8%. Again, this tells a story in which both countries are expected to become giants of future global commodities markets, but China will be in a totally different position from India.

In both countries energy consumption per capita is substantially lower than in OECD economies and lower than the global average, in 2005. The gap with OECD economies remains wide even after many decades of growth in our scenario. However, while India is below global energy per capita average use, China surpasses the global average in 2050.

Differences between China and India are also present in the composition of total primary energy supply (TPES), as detailed in Figure 3. While the energy mix of China is similar to the global one in 2005, with roughly 80% of total energy coming from fossil sources, India has a larger share of energy coming from traditional biomass – e.g. fuelwood.[8] The use of traditional biomass in India is expected to decline in the next decades in favour of more efficient liquid fuels. Eventually, the fossil fuels content of energy is expected to converge at approximately 90%.

[8] Still 80% of cooking in rural India comes from fuelwood; in 2030 this share is expected to decline to about 55% (IEA 2008).

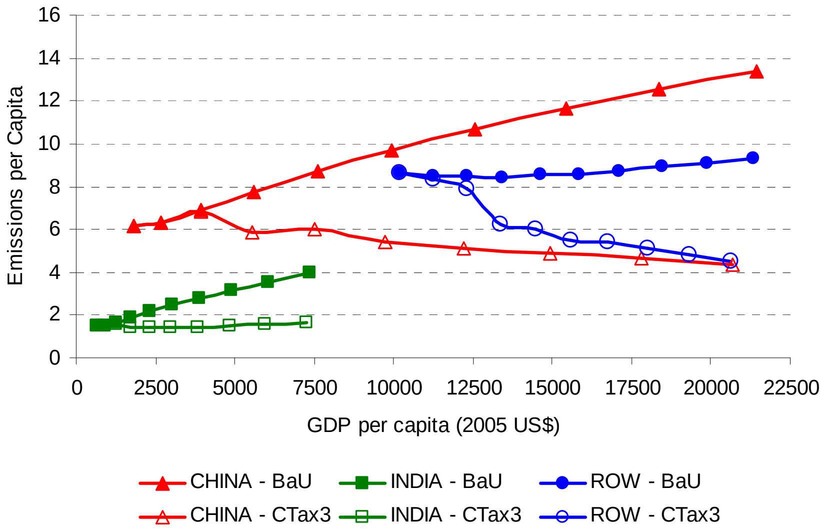


Notes: The vertical axes have different scales in the two figures. Source: WITCH model BaU scenario.

Figure 3. Total primary energy supply in China and India.

2.4. A tale of two countries

The differences between the Chinese and the Indian development pattern are summarized in Figure 4. We report the combination of all GHGs emissions per capita and GDP per capita for China, India and the ROW, from 2005 to 2050, at five-year time intervals. India starts from a lower level of income and emissions per capita. As the economy grows, India's per capita emissions increase, but emissions per capita remain always lower than in China, at any stage of economic development. The Chinese development pattern is highly intensive in emissions also compared to the ROW: at the same level of economic development China is expected to emit roughly three extra tonnes of CO_2-eq than the ROW in 2050.

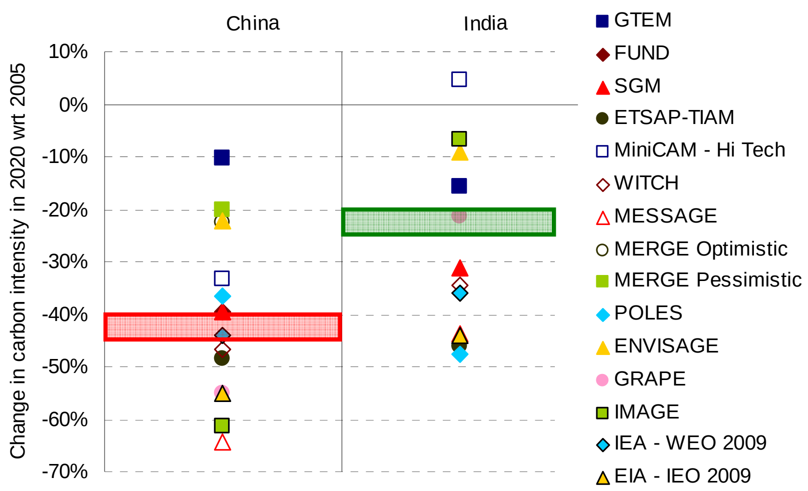


Notes: Each data point marks the combination of GDP per capita and GHGs emissions from 2005 to 2050. BaU and CTax3 scenarios. ROW: Rest of the World (World minus China and India). Source: WITCH model.

Figure 4. GHGs emissions and development.

Large populations, fast economic expansion, high energy and carbon intensities, all explain why Chinese and Indian emissions have an increasing role in shaping global concentrations of GHGs. In 2005 China and India together accounted for 29% of global carbon dioxide emissions from fuels use; in 2050 this share is expected to increase to 36%, according to our BaU scenario. Again, however, it is still a tale of two different countries: while China will be by far the largest emitter in 2050, India will have emerged as a global actor, but its share will remain "only" 8%, smaller than the EU27 and the USA in 2050 in our BaU scenario.

The importance of including India in a global climate agreement soon is therefore probably overrated in the literature and in the policy debate. China and India start from two very different levels of economic prosperity and different levels of GHGs emissions and their development patterns do not seem to converge: India's CO_2 emissions in 2050 – both in absolute and in per capita level – will be roughly comparable to China's emissions in 2005 (see Table 1). It is therefore unfair, to treat these two countries equally in the next rounds of negotiations. Further elements that suggest a differential treatment between China and India in international negotiations are discussed in Section 3, when we present four alternative emissions tax scenarios.



Notes: Carbon intensity reductions for China as predicted in the reference scenarios of the EMF22 participating models (Clarke et al 2009), the International Energy Agency (IEA) World Energy Outlook 2009, the Energy Information Administration (EIA) International Energy Outlook 2009. The shadowed box marks the -40/-45 percent target of China and the -20/-25 percent target of India, pledged in the Copenhagen Accord. The contraction of carbon intensity of energy for the WITCH model does not correspond to what reported in the text because a different value of carbon intensity for 2005 was used to allow comparability among models. *Source*: adapted from Tavoni (2010).

Figure 5. Carbon intensity reductions for China and India in 2020.

2.5. The Copenhagen pledges

Before exploring future scenarios, it is instructive to assess what is the level of ambition embedded in the pledges that China and India have made at the Fifteenth Conference of Parties (COP15) in Copenhagen, in November 2009. Both China and India have preferred intensity targets (GHGs emissions per unit of GDP) to absolute targets: China has pledged to reduce the emissions intensity of its economy by 40/45% in 2020 with respect to 2005, and India by 20/25%.[9]

The official pronouncements made in Copenhagen sparked an intense debate to assess whether China and India's promises implied explicit action to reduce GHGs emissions or whether their emission reduction targets will be achieved as part of the BaU development pattern. As mentioned above, the BaU pattern does not exclude decisions to increase energy efficiency or to expand carbon-free energy sources, that are taken for the national interest, not for slowing down climate change.

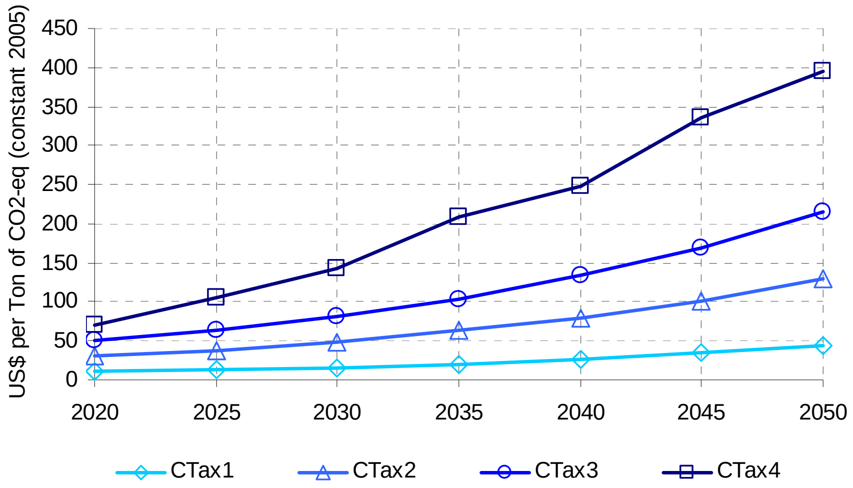
According to our BaU scenario the carbon intensity of the economy will decline by 57% in China and by 45% in India. The emissions intensity (including all GHGs) will decline by 59% in China and by 50% in India.[10] Well above both countries' pledges. How do our results compare with analogous studies in the literature?

Tavoni (2010) gathered energy and emissions scenarios from the Energy Modelling Forum 22 (EMF 22), the International Energy Agency (IEA) World Energy Outlook 2009 and the Energy Information Administration (EIA) International Energy Outlook 2009, to compare China's and India's pledges to scenarios in the literature. The result is shown in Figure 5. Nine out of fifteen models expect that China will achieve the -40% target in the reference scenario, with the median exactly at -40%. Eight out of twelve models expect that India will achieve the -20% target in the reference scenario, with the median lying at -33%, well below the target. This does not mean

[9] China also committed to increase the share of non-fossil fuels in primary energy consumption to around 15% by 2020 and to increase forest coverage by 40 million hectares and forest stock volume by 1.3 billion cubic meters by 2020 from the 2005 levels. The emissions from the agriculture sector will not be part of the assessment of emissions intensity of India. See Carraro and Massetti (2010) for a wider comparison of the Copenhagen Pledges.

[10] The reduction of carbon intensity is calculated using WITCH's 2005 base year. There are differences between our base year and data for 2005 displayed in Table 1 due to different sources. Therefore Table 1 implies different rates of carbon intensity reductions.

that the two targets will come at no cost. Rather, it implies that the two countries' pledges appear to be part of national strategies to reduce the energy intensity of the economies for domestic reasons. With a stable, or slightly increasing carbon content of energy, these domestic commitments deliver also carbon intensity reductions. Reduced emissions come as an unintended side effect of domestic energy policy.



Notes: All GHGs emissions included. Source: WITCH model.

Figure 6. The emissions tax scenarios.

3. The tax scenarios

In this Section we explore scenarios in which policy measures are explicitly taken to reduce the level of GHGs emissions in China and India. We focus on four emissions tax scenarios and we assume that the same tax applies to all GHGs, in all world regions. It is not realistic to assume that either China or India, or both, will introduce taxes on GHGs emissions in the next years. However, taxes are a good proxy for other policy tools – i.e. command-and-control measures, clean development mechanisms, cap-and-trade systems linked to international carbon markets – that must be implemented to reduce emissions. The four tax scenarios all start from 2020, beyond the horizon of the Copenhagen Accord. The CTax1 scenario starts with a tax on all GHGs emissions fixed at 10 US$ per ton of CO_2-eq; the CTax2 scenario starts from 30 US$ per ton; the CTax3 from 50 US$ (Figure 6). Then, in all three scenarios the tax increases by 5% per year and tax revenues are rebated lump-sum in the economy. We study a fourth scenario (CTax4) which induces emissions reductions in line with a global GHGs concentrations target of 535 ppm at the end of the century.[11]

2.6. Emissions trajectories

Figure 7 displays the optimal trajectory of emissions in the four policy scenarios and in the BaU. The CTax4 scenario induces the biggest cuts in emissions, followed closely by the CTax3 scenario and the CTax2 scenario. The lowest tax achieves only "moderate" emissions reductions.[12]

Figure 8 displays the percentage deviation of emissions in each tax scenario with respect to the BaU and with respect to the level of emissions in 2005. A first important message is that in no case taxes are sufficiently high to push India's emissions below the 2005 level. Even in 2050, when the CTax4 achieves a remarkable level (400 US$ per tCO_2-eq). The picture is different for China: all the tax scenarios except for the CTax1 push emissions below the 2005 level. The different response of the two economies is explained by the fact that India has relatively higher marginal abatement costs (see Figure 10), higher economic growth over the period under exam, it starts from lower levels of energy and emissions per capita, and it will have a larger population than China in 2050. The contraction of emissions with respect to the BaU scenario is instead remarkable in both countries – although still higher in China than in India. Even a modest climate policy (CTax1) would save the planet 7Gt CO_2-eq in 2050, 8% of global GHGs emissions in the BaU scenario. This explains how important it is that China and India enact even a modest climate policy in the next decades.

It is instructive to compare the change of emissions under the tax scenarios with respect to 2005 with the global emissions reduction target of -50% set forth by the G8 and Major Economies Forum (MEF) countries in L'Aquila in July 2009. G8 countries have agreed to lead the mitigation effort and have committed to reducing GHGs

[11] The emissions tax is obtained by solving the model imposing a global pattern of emissions that is consistent with the 2100 concentration target and allowing countries to trade emissions allowances internationally to equate marginal abatement costs. We then run the model imposing the carbon price as a tax, thus avoiding complex distribution issues. This concentration target is equivalent to a temperature increase of 2.5°C above the pre-industrial level with median probability in 2100, well above the stated objective of keeping temperature increase below the 2°C.

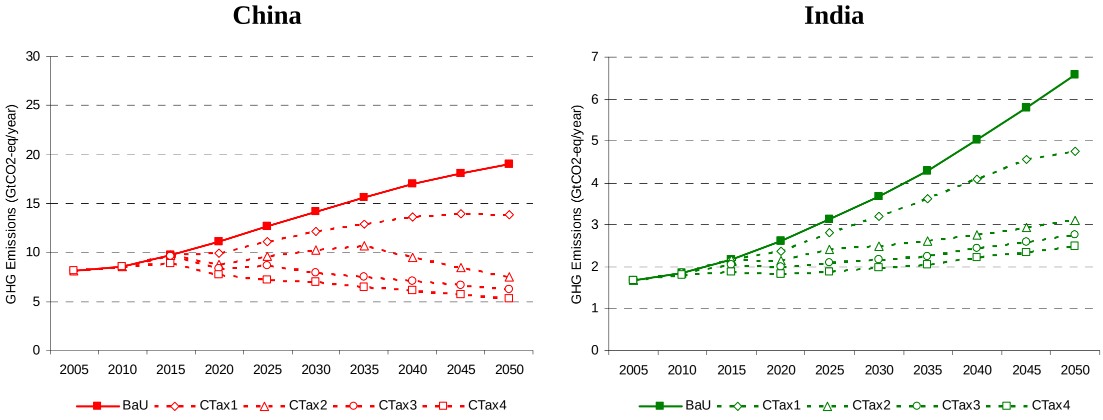
[12] WITCH is a perfect foresight model. The level of future taxation influences present decisions. Therefore it is optimal to smooth the transition to a regime of emissions taxes in WITCH. This explains why emissions decline with respect to the BaU before 2020 in Figure 7 and Figure 8. Equivalently, the high level of taxes in 2050 affects investment decisions in earlier years.

emissions by 80% in 2050.[13] This implies that the rest of the world needs to reduce emissions by roughly 25-30% in 2050 to achieve the -50% target.[14] What is the implicit tax level that would guarantee those emissions cuts in China and India?

We have seen that none of the tax levels considered would deliver emissions in 2050 lower than those in 2005 in India; in China instead the CTax3 scenario would generate the necessary emissions reductions. In order to appreciate the effort needed to achieve the target, we need to consider that a -25% contraction of emissions with respect to 2005, in 2050, implies a -68% reduction below BaU for China and a -80% contraction for India. This reveals that the level of commitment of the two countries in the next forty years will necessarily be different and the peculiar role of China stands clearly out: not rich enough to afford stringent emissions cuts, but not poor enough to justify the lowest level of commitment. If we refer again to the G8 and MEF pledge, a more realistic distribution of effort would see China reducing emissions roughly by -35% in 2050 with respect to 2005, and India limiting the increase of emissions to 50% above 2005. The marginal abatement cost would be equivalent in both countries and it would correspond to the highest level of taxation that we consider in this study. However, the realism of this level of taxation in both countries is highly questionable and casts doubts on the possibility to achieve the global target set forth by G8 and MEF countries.

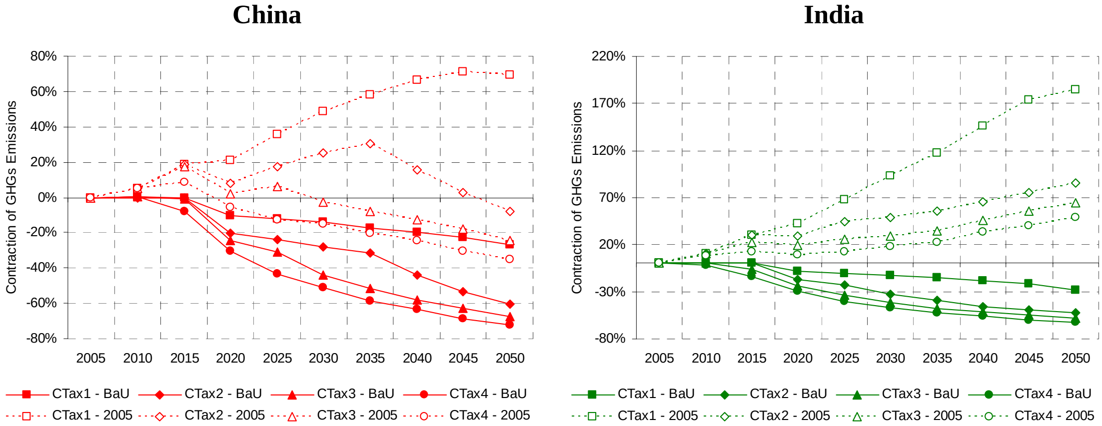
[13] The reference year for the emissions cuts is not clear. We use here 2005. An alternative would be 1990. Using the BaU as a reference would imply emissions levels not coherent with the 2°C target.

[14] If the -80% target is valid for Annex I countries Non-Annex I countries must reduce emissions by 22%. If the -80% target is valid only for G8 countries, Non Annex I countries must reduce emissions more.



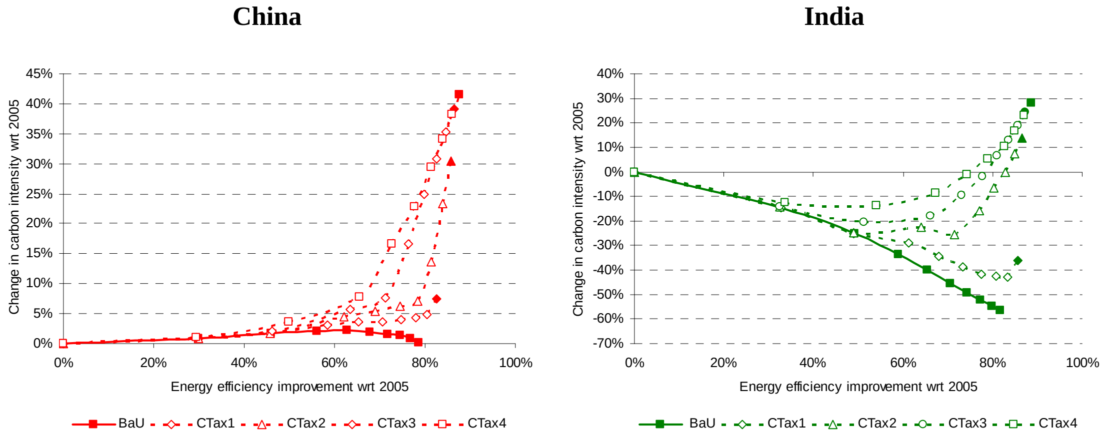
Notes: The vertical axes have different scales. *Source:* WITCH model.

Figure 7. The time pattern of Greenhouse Gases (GHGs) emissions in India and China, in the BaU and in the tax scenarios.



Notes: Solid lines mark the change of GHGs emissions with respect to the BaU level. Dashed lines mark the change of GHGs emissions with respect to the level in 2005. Vertical axes have different scales. Source: WITCH model.

Figure 8. Change in Greenhouse Gases (GHGs) emissions trajectories in India and China economies, in the tax scenarios.



Notes: Each data point marks the combination of decarbonization of energy and energy efficiency improvements with respect to 2005. Negative values of decarbonization improvements mean that the carbon content of energy is increasing. Source: WITCH model.

Figure 9. The time pattern of carbon intensity of energy and energy intensity of GDP in India and China, in the BaU and in the tax scenarios.

	COAL (NO CCS)	GAS	OIL	NUCLEAR	HYDRO	WIND and SOLAR	TPES
China							
2030-2005 (average per year)							
BaU	2.5%	3.9%	3.9%	4.6%	3.5%	7.9%	2.7%
CTax1	1.8%	4.0%	3.9%	5.7%	3.5%	9.3%	2.3%
CTax2	0.8%	3.9%	3.6%	7.4%	3.5%	11.4%	1.7%
CTax3	-0.8%	4.0%	3.6%	8.6%	3.5%	12.8%	1.3%
CTax4	-1.6%	3.4%	3.1%	9.0%	3.5%	13.3%	1.1%
2050-2005 (average per year)							
BaU	2.2%	2.8%	2.9%	3.8%	2.2%	7.8%	2.2%
CTax1	1.3%	3.0%	2.7%	5.2%	2.2%	9.6%	1.7%
CTax2	-0.5%	2.7%	2.2%	6.7%	2.2%	11.6%	1.2%
CTax3	-1.2%	2.8%	1.8%	7.1%	2.2%	12.2%	1.1%
CTax4	-1.4%	2.1%	1.2%	7.5%	2.2%	12.8%	0.9%
India							
2030-2005 (average per year)							
BaU	3.8%	3.1%	4.1%	5.1%	3.3%	8.5%	2.3%
CTax1	2.7%	3.5%	4.1%	6.2%	3.3%	9.8%	1.9%
CTax2	-0.4%	3.9%	4.0%	8.0%	3.3%	11.9%	1.3%
CTax3	-1.9%	3.5%	3.8%	8.2%	3.3%	12.3%	1.2%
CTax4	-2.7%	2.6%	3.3%	8.6%	3.3%	12.9%	0.9%
2050-2005 (average per year)							
BaU	3.5%	2.6%	3.4%	4.6%	2.1%	8.6%	2.4%
CTax1	1.9%	3.2%	3.3%	6.0%	2.1%	10.4%	1.9%
CTax2	-1.6%	2.9%	3.0%	6.4%	2.1%	11.1%	1.7%
CTax3	-2.0%	2.5%	2.6%	6.5%	2.1%	11.4%	1.6%
CTax4	-2.2%	1.7%	2.2%	7.0%	2.1%	12.1%	1.3%

Notes: Coal with Carbon Capture and Storage (CCS) and backstop carbon-free technologies not included because not used in 2005.

Table 2. Average growth rate of different components of Total Primary Energy Supply.

2.7. The energy sector

The transformations induced by climate policy can be grouped into two major categories: those increasing energy efficiency and those decreasing the carbon content of energy. WITCH produces scenarios with the optimal mix of action along these two trajectories (Figure 9). The sufficiently high detail of the energy sector also allows the study of the optimal mix of alternative energy technologies (Table 2).

Figure 9 gives a synthetic description of optimal movements along the dimension of energy efficiency and of de-carbonization of energy. The solid lines in both panels refer to the BaU scenario. The introduction of emissions taxes reinforces the trend of energy efficiency improvements and tilts all the curves upward, indicating a substantial de-carbonization of energy in all scenarios, with the exception of the CTax1 scenario which reduces emissions mainly by means of energy efficiency improvements. The optimal contraction of the carbon content of energy induced by the highest tax scenario is similar in China and India: an average -5.4% and -4.2% per year from 2020 to 2050, respectively.

What are the transformations needed in the power sector and in the energy system as a whole to bring along the much needed contraction of the carbon content of energy in a climate policy scenario? Table 2 presents synthetic information on major energy technologies that are used both in the BaU and in the climate policy scenarios. The fastest growing components of TPES in the BaU are wind, solar and nuclear. In all climate policy scenarios it is optimal to expand wind, solar and nuclear even further momentum. Coal that is not burnt using CCS is the biggest loser in a climate policy scenario, although in the CTax1 scenario coal loses only shares of TPES but grows from the 2005 level, at both the 2030 and 2050 time horizons. With the CTax2 scenario Coal grows in absolute terms at least until 2030 in China. The optimal rate of expansion of TPES declines substantially, especially from 2030 until 2050, but TPES will be higher in 2050 than in 2030 and 2005. With the most stringent climate policy scenario TPES grows 43% in China and 80% in India, from 2005 to 2050. Oil demand will increase by 70% in China and by 163% in India, during the same period.

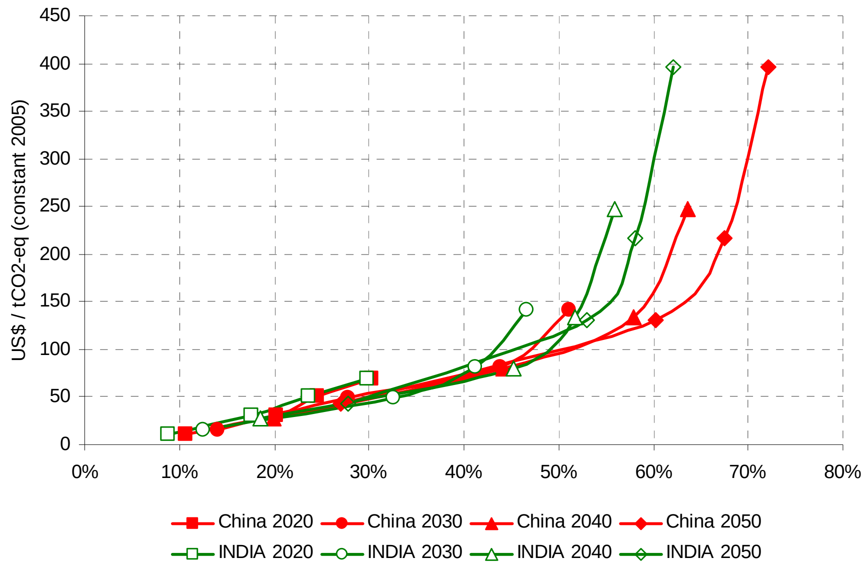
2.8. Marginal and total costs

What are the marginal and total costs of reducing emissions in China and how do they compare with each other? Figure 10 and Figure 11 present information on these important aspects.

The first message is that marginal abatement cost curves (MACCs) are time-specific in long-term IAMs. The economy, the technology, the cost of fuels, all change as time goes by and they affect the cost of reducing emissions. Technical progress in carbon-free technologies is a major driver of MACCs. Learning-by-doing and learning-by-researching will reduce the cost of installing and operating wind mills, for example. For this reason Figure 10 displays MACCs from 2020 to 2050 at ten-year intervals, using data from the four tax scenarios.

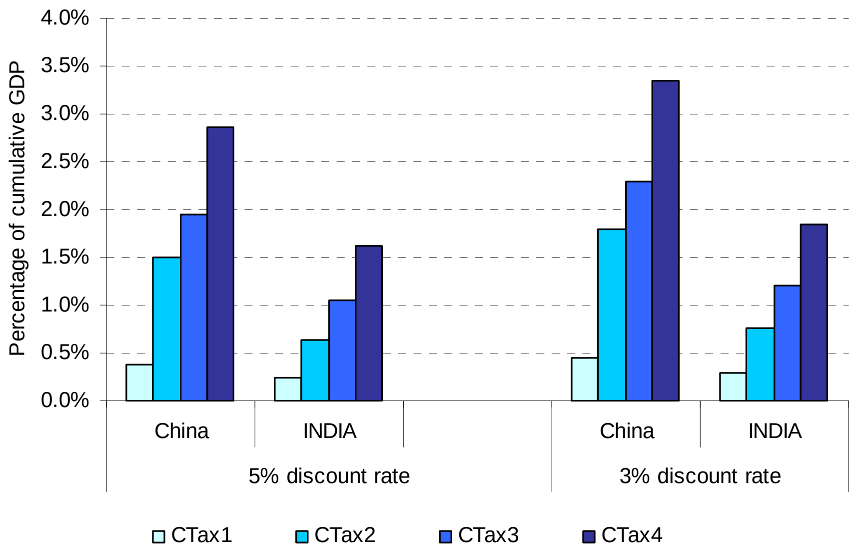
A first analysis of Figure 10 clearly shows that MACCs are highly non-linear, in each given year. Pushing the rate of emissions abatement beyond a given threshold increases costs beyond what might be economically and politically acceptable. The second key message that emerges from Figure 10 is that India has steeper MACCs than China. An emissions tax equal to 216 US$ per ton of CO_2-eq induces a 57% contraction of emissions in India and a

67% contraction in China. This means that it is not efficient to allocate high levels of emissions reductions to India.



Notes: Marginal abatement cost curves include all GHGs. Abatement potential at different GHGs emissions values. Abatement potential expressed in percentage of emissions reductions in the BaU for comparability. Source: WITCH model.

Figure 10. Marginal abatement cost curves.



Notes: Costs are expressed as the ratio between the discounted sum of GDP losses with respect to the BaU scenario and cumulative discounted GDP in the BaU scenario. Two alternative discount rates are used. Source: WITCH model.

Figure 11. The cost of reducing GHGs emissions.

Total costs of emissions reductions are displayed in Figure 11. We consider macroeconomic costs, which take into account the fact that tax revenues are rebated lump-sum economy-wide. Costs therefore emerge as a consequence of a sub-optimal allocation of resources in the economy (not considering the environmental damage). Costs are gross of the economic benefits from limiting climate change and are expressed as a ratio between discounted GDP losses and BaU discounted GDP. Discount rates of 3% and 5% are used.

The four emissions taxes scenarios generate much higher costs in China than in India. This is explained by the larger area under the Chinese MACCs displayed in Figure 10 for any level of taxation – i.e. China's contribution to the global public good is higher than India's contribution. The information on the slope of MACCs and on the total cost of climate policy thus reveals that a hypothetical international agreement that fixes the same percentage reduction of emissions for both China and India would be preferred by China. India would instead reject an international agreement that fixes the same taxation level as in China.

Figure 11 has important implications for future negotiations on climate change as countries will not accept excessively high policy costs. Bosetti and Frankel (2009) have examined an international climate architecture which is based on the postulate that countries will not cooperate to reduce emissions if – among other conditions – costs will exceed 1% of GDP in discounted terms. This implies that China would not accept any policy that bears, implicitly or explicitly, a price on emissions greater than the CTax1 scenario; India would not accept a tax above the CTax2 level. A "politically feasible" treaty would therefore see China increasing emissions by 70% with respect to 2005, India by 85%. It is therefore evident that the G8 and the MEF declarations appear totally unrealistic. Either G8 countries reduce emissions more than what they have pledged (but they can hardly go below zero by 2050), or they need to mobilize massive financial aid to support mitigation in developing countries.

Conclusions

In this paper we use historical data and future scenarios produced by the Integrated Assessment Model WITCH to highlight the many differences between the two Asian giants. China and India are too often cited together in the climate change debate. However, although some similarities do exist – a large population and booming economies above all – they are two very different countries in many respects.

There is first a problem of scale: China's carbon dioxide emissions – the most important among all Greenhouse Gases (GHGs) – were four times higher than India's emissions in 2005, and our Business-as-Usual (BaU) scenario says that in 2050 they will still be 3.5 times higher. Second, there is a problem of equity: India is expected to achieve China's same level of emissions per capita not earlier than 2050 and China will have a GDP per capita three times higher than India at least until 2050, according to our BaU scenario. Therefore it is neither realistic, nor fair, to expect these two very different countries to make similar engagements in climate change negotiations.

All the differences that we highlight in historical data and in the BaU scenario are magnified by a hypothetical tax on GHGs emissions. In all the four scenarios examined, China appears to be more responsive to climate policy than India. India has relatively high abatement costs and requires very high levels of taxation to reduce its emissions below the 2005 level. In our highest tax scenario China would reduce its total GHGs by 35% with respect to 2005, while a 50% emissions increase would be optimal for India.

More importantly, despite all the emphasis that surrounds the remarkable economic performance of both countries, China and India remain two relatively poor countries if compared to richer economies: in 2050, after a prolonged period of growth China's GDP per capita is expected to be only one-third of the average GDP per capita in OECD countries; India's GDP per capita will only be one-tenth. It is therefore extremely unlikely that both countries will accept binding stringent emission reductions targets in the next two or three decades. The Copenhagen pledges of China and India confirm their – comprehensible – reluctance to contribute to global emissions reductions. Indeed, emissions intensity targets appear to be part of a national strategy to increase energy efficiency rather than part of a deliberate plan to reduce global warming.

China and India, in particular, are therefore likely to remain marginal players in the fight against global warming for still some time. A realistic commitment would be in line with the lowest level of taxation that we have examined. A set of domestic policies that establishes an implicit or explicit tax on all GHGs equal to 10 US$ per tonne of CO_2-eq in 2020 and then increases to 50 US$ in 2050 would cut global emissions by 8% in 2050. Even if the price of emissions is the same in the two countries, India would abate less GHGs than China and thus suffer lower costs, in this scenario.

However, this "politically feasible" commitment from China and India would clash against the G8 and MEF target of reducing global emissions by 50% in 2050, which would require – even if accounting for an equitable distribution of emissions reductions – a much greater effort from both countries. If rich economies really want to maintain their promises they need to provide massive financial aid to China and in particular to India.

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