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# A Comment on the Copenhagen Accord Feasibility and Costs

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| **Sammendrag:** | **Abstract:** The Copenhagen Accord has been followed up by national pledges of greenhouse gas emissions reductions in the year 2020 without specifying measures to enforce actions. As a consequence, the capacity of parties to fulfil their obligations is of basic interest. This article outlines the effects of full compliance with pledges on greenhouse gas emissions, economic growth, and trade. The study is based on the global computable general equilibrium model GRACE distinguishing between fossil and non-fossil energy use. Global emissions from fossil fuels in 2020 turn out to be 15% lower than in a business as usual (BAU) scenario and 3% below the global emissions from fossil fuels in 2005. China and India increase their emissions in 2020 to 1 and 5 per cent above BAU levels in 2020, respectively. We find some carbon leakage towards India, China and Russia within the energy intensive industries steel and cement.. |
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# 1 Introduction

The fifteenth session of the Conference of the Parties (COP15) to the United Nations Framework Convention on Climate Change (UNFCCC), took note of the Copenhagen Accord of 18 December 2009 by way of decision 2/CP.15. The key sentence in this decision is:

> «We agree that deep cuts in global emissions are required according to science, and as documented by the IPCC Fourth Assessment Report with a view to reduce global emissions so as to hold the increase in global temperature below 2 degrees Celsius, and take action to meet this objective consistent with science and on the basis of equity.» (§2).
>
> Following this decision, major players have pledged to reduce greenhouse gas emissions or carbon intensity by 2020 . Thus, several developed countries have provided quantified economy-wide emissions targets for 2020, while many developing countries have offered nationally appropriate mitigation actions (NAMAs) for the same year (UNFCCC 2010) often in the form of intensity targets ($CO_2$ or greenhouse gas emissions per unit of GDP). For further details, see (UNFCCC 2011): http://unfccc.int/home/items/5265.php

Several reports have analyzed the expected climate impacts of these pledges (Perry 2010, Rogelj et al. 2010, Stern and Taylor 2010, UNEP 2010, den Elzen et al. 2010, see also (UNEP 2010: http://www.unep.org/climatepledges). Generally, they find the pledges to be inadequate with respect to the 2 degrees Celsius target (although the 2 degrees Celsius target is of a longer term nature than the pledges). Nordhaus (2010) have analyzed the longer term implication of the 2 degrees scenario.

In this paper we will, by use of a global computable general equilibrium (CGE) model (GRACE), investigate the effect on global emissions and the economic costs to major players of fulfilling their pledges within the same time frame as the pledges themselves. McKibbin et al., (2010) has provided the most analogue analysis to ours by using their GCubed model, while Jotzo (2010) have compared the pledges according to different metrics like absolute emission reductions related to a common base year (2005), reductions in emission intensities, per capita emissions and reductions relative to business as usual emissions pathways.

A broad international agreement would facilitate a market for $CO_2$ emission reductions and modify the costs of mitigation, thus reducing the gap in mitigation costs among countries. COP15 did not reach this kind of agreement and instead invited to uncoordinated polices. Parallel and uncoordinated actions might lead to highly different mitigation costs among countries and regions imposing different constraints on regional growth and trade than a common price on $CO_2$. Possibly, carbon leakage in terms of shifting polluting industries to countries without binding greenhouse gas emission targets might be more marked. Among countries without binding constraints are those pledging flexible GHG targets, like a carbon intensity target, as do China, India and Brazil. China is a country with substantial coal reserves and the capacity to expand its energy intensive industries like steel and cement. India and Brazil are also candidates to taking a higher share of global production and trade in energy intensive goods. Due to such indirect or spill over effects, model based analyses are needed to trace the economic implications and identify the net effects on economic growth and GHG emissions associated with the Copenhagen Accord. The final outcome in terms of global emissions reductions is likely to differ from the sum of the single reduction pledges as implemented.

In this paper we compare the results of implementing the Copenhagen Accord pledges with a business as usual scenario roughly corresponding to the reference scenario as presented in World Energy Outlook 2009 (IEA 2009). The Model for Global Responses to Anthropogenic Changes in the Environment (GRACE) applied in this paper is basically the GRACE model version developed previously at CICERO (Aaheim and Rive 2005), a multi-sector, multi-region, recursively dynamic global computable general equilibrium (CGE) model.

# 2 The GRACE model

The GRACE model has been applied to integrated air quality and climate policy analysis (Rypdal et al. 2007), analysis of climate change impacts on the forestry sector (Rive et al. 2005), analysis of the future of European electricity sector (Eskeland et al. 2008), and used for macroeconomic analysis of adaptation to climate change (Aaheim et al. 2009a; Aaheim et al. 2009b). An updated version of GRACE is described in a recent application by Rive (2010) and used in this paper after some modification. The most substantial modification is the introduction worldwide of a disaggregated electricity sector with specific technologies for power generation based on coal, gas, oil, or a non-fossil option covering hydro, nuclear, solar, bio and wind technologies. Linear production functions and sunk capital costs in all electricity producing sectors modify the response to price variation on fossil fuel consumption.

The GRACE model is calibrated around the GTAP v7 database with 2004 as a base year (Badri and Walmsley 2008). In this study, we consider only $CO_2$ emissions from fossil fuels combustion from an auxiliary database provided by GTAP (Lee 2007). In GRACE, the world is divided into 8 regions: USA, Canada, EU, Japan, China, India, Russia and the rest of the world (ROW). The first seven regions are considered key players in global climate policy decisions. The depiction of each region's economy includes activities in 15 aggregated production sectors, which are listed in Table 1A in the Appendix.

Within each region and time period the endowment of production factors, i.e. labour, capital and natural resources are exogenous. Labour is floating freely among production activities within a region, whereas capital and natural resources are activity-specific and cannot be reallocated among sectors. The model assumes full utilization of all available resources within each region.

Trade is modelled as bilateral with substitution among regional contributions. The substitution elasticities are based on those in the MIT EPPA model (Paltsev et al. 2005).

Income to a region includes fixed income shares of the remuneration to the primary factors of production (labour, capital and natural resources) and direct and indirect taxes collected by the regional governments.

Saving is a fixed share of total income by region. A virtual global bank collects all savings and allocates investments to regions and sectors with the highest observed returns to capital. The reallocation is subject to elasticities of transformation. The returns to capital are equalized in the long run.

Economic growth is mainly driven by savings and investments, but is also determined by population growth, change in the availability of natural resources and technological change. The regional rates of technological change are assumed to be the same for both the baseline scenario and a policy scenario where the Copenhagen Accord is implemented by individual actions of each player. This is clearly a simplification, as climate policies normally would affect the rate of technological change, in particular the rate of energy efficiency improvement. However, the time horizon of this study is relatively short and the newly developed technology in response to the policies might be expected to affect emissions predominantly at a later stage.

# 3 The business as usual (BAU) scenario

The baseline or business-as-usual (BAU) scenario depicts a plausible path of future economic development with average annual growth rates of GDP during 2004-2020 as reported in Table 1. The BAU scenario assumes no new carbon abatement policy by any region and serves as a reference for policy analysis associated with regional pledges in the Copenhagen Accord.

China and India are assumed to have average annual growth rates above 5% over the period to 2020. The industrialized regions have on the other hand average annual growth rates between 1 and 2%. Russia falls in the middle with an average annual growth rate of 3.5%. Globally, the economic growth is 2.3% per year on average.

**Table 1. Average annual growth in GDP in the business as usual (BAU) scenario over the period 2004-2020. Per cent.**

| USA | EU | Canada | Japan | China | Russia | India | RoW |
|---|---|---|---|---|---|---|---|
| 1.6 | 1.4 | 1.8 | 1.2 | 6.4 | 3.5 | 5.4 | 2.3 |

The $CO_2$ emissions from fossil fuel combustion by regions in our BAU scenario are reported in Figure 1. All regions emit more in 2020 compared with 2005 in the baseline scenario, although Japan barely so.

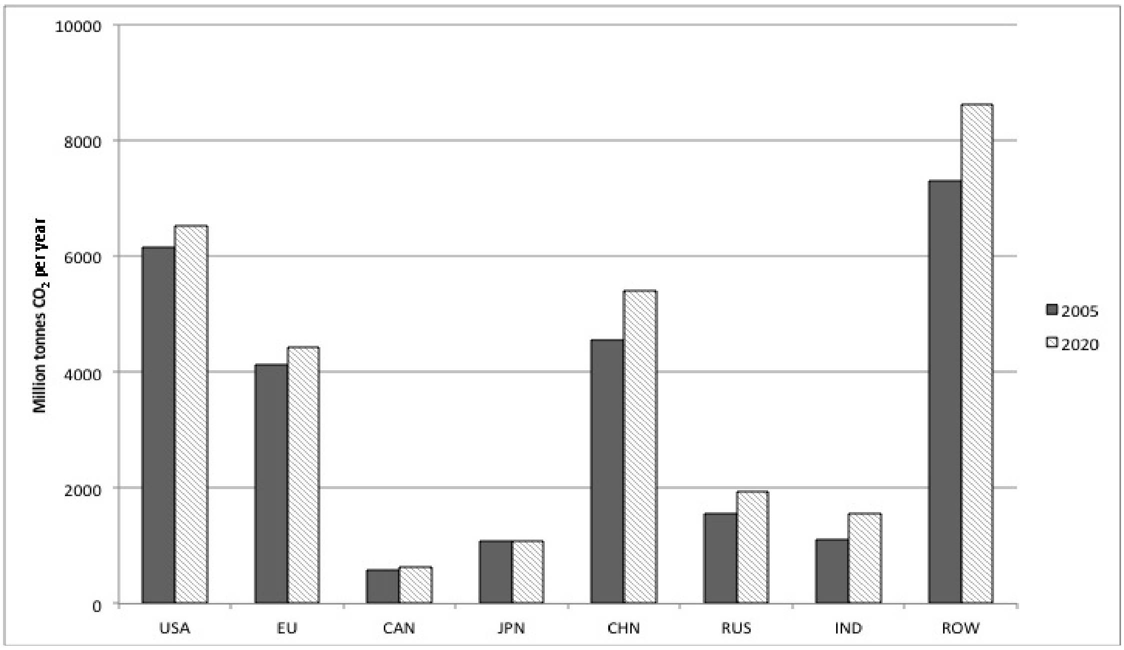


**Figure 1. $CO_2$ emissions in 2005 and 2020 according to the BAU scenario.**

Changes in $CO_2$ emission intensities (emissions per unit GDP) in the various regions in our BAU scenario are reported in Figure 2. We notice a general improvement in emission intensities of about 1% per year in many regions. Russia and India are above that level, with India having an improvement of more than 2% per year, but the real outlier is China, where the intensity improvement in the BAU scenario is close to 5% per year for the period to 2020. We will come back to a discussion of this below.

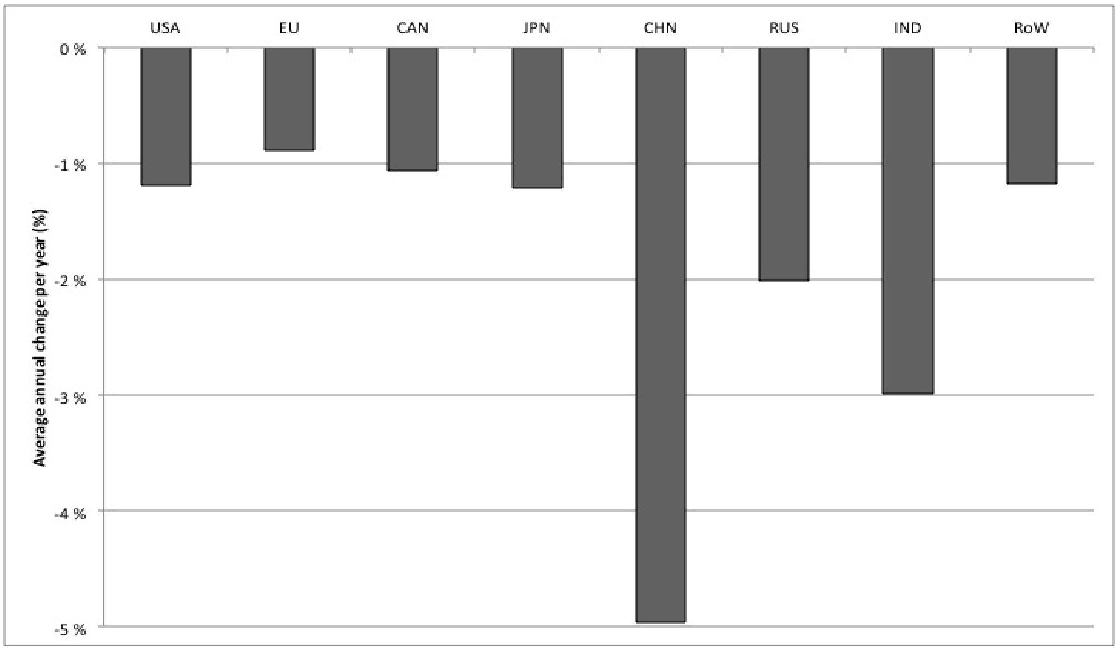


**Figure 2. Average annual changes in $CO_2$ emission intensities over the period 2005 - 2020 in the BAU scenario.**

# 4 The Copenhagen Accord scenario (SN1)

The Copenhagen Accord scenario, which we designate SN1, reflects a situation where no binding international agreement is reached, but where major economies and emitters follow their own independent climate policies to fulfil their pledges relating to the Copenhagen Accord as shown in Table 2. Some of the pledges made cover other aspects than emission levels or emission intensities. For instance China has put forward a target related to the share of non-fossil energy in their primary energy mix, and also a reforestation target. Here, we only take into account the pledges made with regard to the overall emissions levels or emissions intensities as shown in the last column of Table 2 (next page).

## Table 2. Copenhagen Accord Pledges

| Region | Reductions and actions | Base year | Implementation |
|---|---|---|---|
| Canada | 17%, to be aligned with the final economy-wide emission target of the United States in enacted legislation. | 2005 | Reduce $CO_2$ emissions by 17% by 2020 with 2005 as base year. |
| EU | 20/30%. As part of a global and comprehensive agreement for the period beyond 2012, provided other developed countries commit themselves to comparable emission reductions and that developing countries contribute adequately according to their responsibilities and capabilities. | 1990 | Reduce $CO_2$ emissions by 30% by 2020 with 1990 as base year. Participants in ETS reduce by 30% by 2020 and other participants by 10% by 2020. Relative to 2005, the EU reduced emissions by almost 25% in 2020. |
| Japan | 25%, premised on the establishment of a fair and effective international framework in which all major economies participate and on agreement by those economies on ambitious targets. | 1990 | Reduce $CO_2$ emissions by 25% by 2020 with 1990 as base year. Compared to 2005, the reduction is almost 40%. |
| Russian federation | 15-25% provided:<br>Adequate provision for the potential of Russian forests in the context of their contribution to the fulfilment of emission reduction obligations<br>The adoption by all major emitters of legally binding GHG emission reduction obligations. | 1990 | Reduce $CO_2$ emissions by 15% by 2020 with 1990 as base year. Compared to 2005 level, Russia reduces the emission level by 22% in 2020. |
| USA | In the range of 17%, in conformity with anticipated US energy and climate legislation. | 2005 | Reduce $CO_2$ emissions by 17% by 2020 with 2005 as base year for all sectors. A 25 USD upper bound on quota price is implemented. |
| China | China will endeavour to lower its carbon dioxide emissions per unit of GDP by 40-45% by 2020 compared to the 2005 level, increase the share of non-fossil fuels in primary energy consumption to around 15% by 2020 and increase forest coverage by 40 million hectares and forest stock volume by 1.3 billion cubic meters by 2020 from the 2005 levels. | 2005 | Reduce the $CO_2$ emissions per unit of GDP by 40% by 2020 compared to the 2005 level. |
| India | 20-25% reduction in emission intensity and a deviation from BAU of at least 7%. | 2005 | Reduce the $CO_2$ emission per unit of GDP by 20% by 2020 compared to the 2005 level. |

The basis for these uncoordinated efforts is the shared understanding of the climate change issues and need for action. In this scenario, the European Union (EU), the United States of America (USA) and China behave as leaders and implement their voluntary commitments to the UNFCCC. India, Japan, Canada, and Russia follow up, accepting the leaders' actions to be sufficient basis for their conditional commitments as stated in their pledges (UNFCCC 2010). The rest of the world (RoW) is assumed to keep the emissions at the same level as in the BAU scenario.

The pledges of regions are implemented individually by introducing local competitive carbon markets within each region. Such carbon markets are assumed to be economic efficient and will allow us to compare the marginal costs of reducing the $CO_2$ emissions (carbon prices in the carbon market) in order to achieve their pledges.

### EU

The overall target of EU is a 20% reduction of $CO_2$ emissions from 1990 level by 2020 and 30% reduction conditional on behaviour of other parties. In the model we adopt 30% reduction for sectors participating in the emission trading system (EU-ETS) and 10% for other sectors. Sectors allowed to trade $CO_2$ are iron and steel, cement, other manufacturing, electricity generation, crude oil, gas, coal mining, air, sea and other transportation. All carbon allowances in the power sector are assumed to be 100% auctioned from 2010 whereas other sectors in EU-ETS will receive transitional allowances free of charge according to EU rules. Free allowances will be phased out and auctions implemented progressively from 12% in 2010, 20% in 2013 to 70% in 2020. Sectors that do not participate in ETS, among them households, face the target of 10% reduction from the 2005 level by 2020 and the target will be achieved by a carbon tax.

### USA

The target of the USA is a 17% reduction in $CO_2$ emissions compared to the 2005 level. A cap and trade system (C&T) by assumption covers the same sectors as the EU-ETS and provides the potential advantage of an upper bound of 25 USD per ton $CO_2$. If the carbon price in the C&T goes above 25 USD per ton $CO_2$, the participants only pay 25 USD and the government will pay the difference. For other sectors, the 17% target is achieved by a carbon tax.

### China

China fulfils the target of 40-45% reduction of carbon intensity by 2020 compared with the 2005 level. The other targets for non-fossil share and forest are not considered here.

### India

India will reduce the emission intensity of its GDP by 20-25% by 2020 in comparison to the 2005 level. This is to be achieved by a tax on carbon emissions by industries and private households.

### Canada, Japan and the Russian Federation

Canada will reduce its carbon emissions by 17% compared with the 2005 level; Japan by 25% relative to the 1990 level; and Russia by 15% of 1990 level, following their pledges. For the rest of the world, the emissions in the policy scenario do not exceed the level in the BAU scenario.

# 5 Results and analysis

First, comparing annual average GDP growth over the period 2005-2020 in our policy scenario (SN1) and the business-as-usual (BAU) scenario, we find that the impacts of the Copenhagen Accord on annual GDP growth rates are very small, less than one tenth of a percentage point. USA, EU, Canada, Japan, the Russian Federation, as well as the Rest of the World (RoW) all experience a slight decline in growth rates. Perhaps counter intuitively, the GDP growth of both China and India increase slightly as the policy measures are introduced. The reason for this is that the pledges of China and India are fulfilled already in the BAU scenario due to rapid economic growth and efficiency improvement. This holds even though we have a lower economic growth for China in BAU than the other studies we compare with. Hence, the intensity targets of China and India are not binding in our Copenhagen Accord scenario. Also, the contraction of the economies of other regions is not large enough to reduce their GDP through export reductions. Rather, when other large regions introduce stricter emission policies, China and India can grow because of cheaper fossil fuels and carbon leakage of high emitting industries.

Figure 3 shows the emissions levels in 2020 in the two scenarios (BAU and SN1) together with 2005 emissions. Only China and India emit more in the policy scenario than in the BAU scenario since they have higher economic growth and only flexible targets of carbon intensity. The global emissions from fossil fuel combustion in 2020 decrease with 4.4 $GtCO_2$ or 17% compared with the baseline scenario, from 26.6 to 22.1 $GtCO_2$.

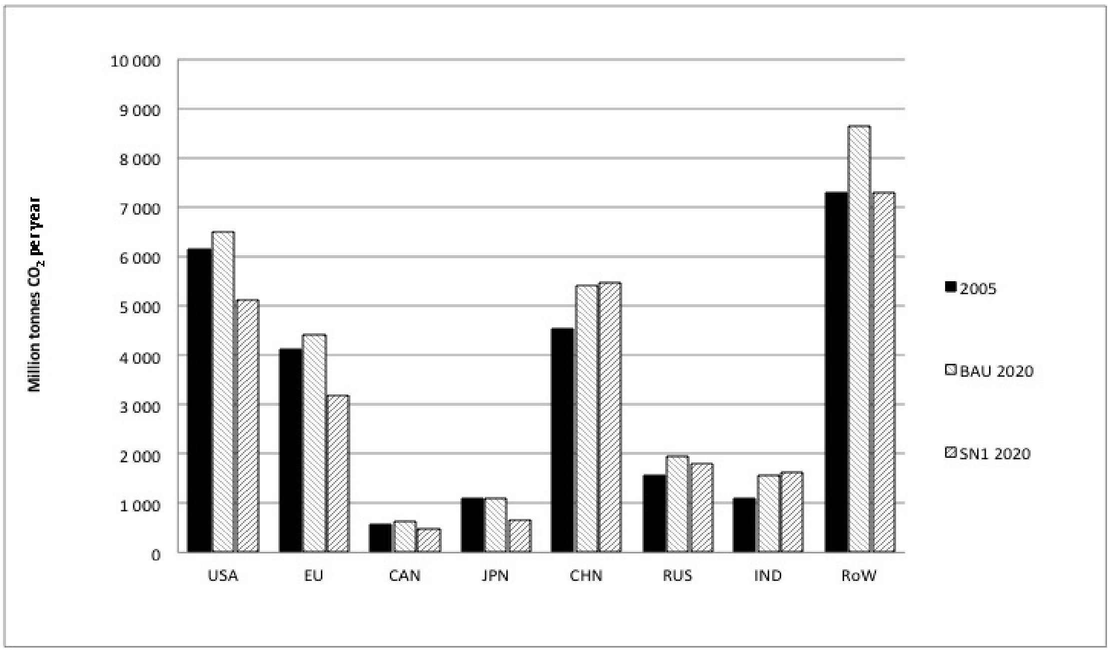


**Figure 3. $CO_2$ emissions levels in 2005 and 2020**

The pledges are related to the base years 1990 or 2005. Even with the same base year and pledges the economic growth potentials of regions might differ and determine how strict the carbon policies are felt regionally. When looking at the reduction of emissions in 2020 compared with the BAU in 2020, Japan is by far undertaking the largest reduction with 38%. Then follows EU with 30%, Canada and USA with 22 - 24% and the Russian Federation with a little less than 10%. Having flexible targets, the emissions levels of China and India are relatively unpredictable. India is increasing its emissions by 5%, which is far from complying with India's pledge to reduce emissions to at least 7 per cent below BAU level in 2020, as

BAU is depicted in our study. China's emissions are only slightly increased to approximately 1% above the BAU level in 2020.

The development of the regional emission intensities in the BAU and the policy scenario are shown in Figure 4. Reductions in emissions intensity comes from energy efficiency improvements, fuel switch and structural changes in the economy. Moving away from more energy intensive industries towards service industries is a rapidly on-going process in developing countries with a high share of manufacturing as in China. We note that emission intensity reductions from the BAU to the policy scenario are quite considerable in most regions, in Japan in particular, while we detect a slight increase in emission intensity in China and India, although their pledges on energy intensity are still fulfilled. These increases reflect that these countries take a higher share of emission intensive industries like steel and cement in a global context, and that this effect on energy intensity dominates the effect of an increased share of services in their GDPs.

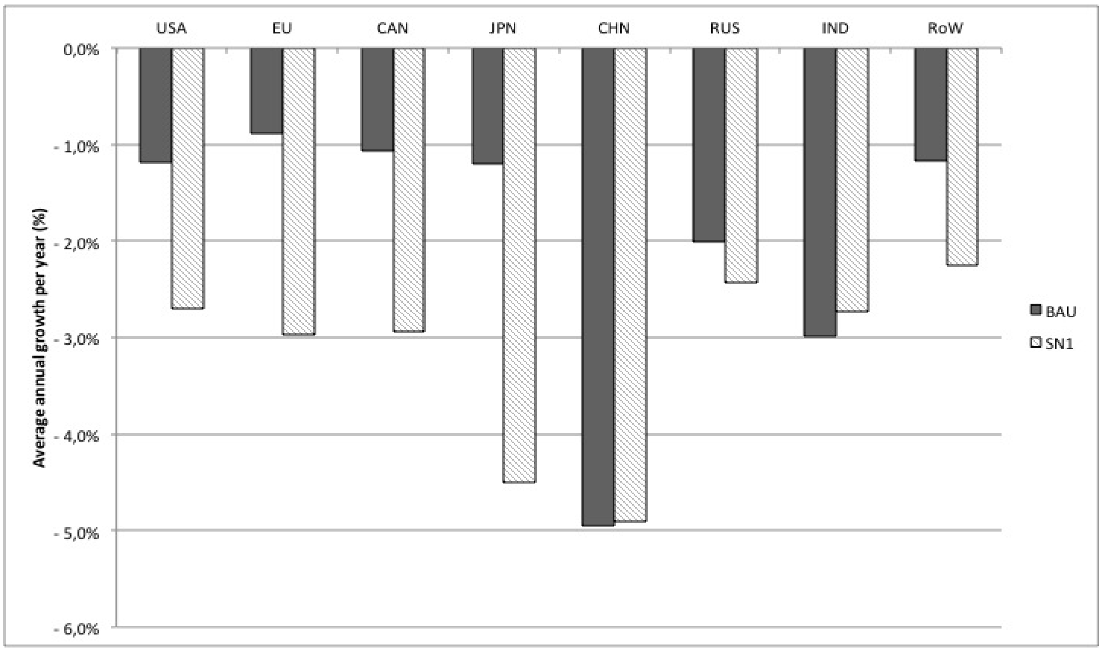


**Figure 4. Average annual growth rates of $CO_2$ emission intensities from 2005 to 2020 in the BAU and the policy scenario (SN1)**

What are the costs for each region of implementing the Copenhagen Accord? Since China and India already meet their pledges in the baseline scenario, there are no costs for them - they actually benefit from the implementation of the Copenhagen Accord in terms of an increase in GDP. The other regions may suffer to different extent from their pledges. This can be illustrated by virtual carbon market prices or marginal costs of carbon reduction by region in 2020, see Figure 5. Japan has the highest marginal costs of reducing carbon emissions and Russia has the lowest. The differences in marginal costs are modest for the other four regions: EU, USA, Canada, and the rest of the world.

Interestingly, the cost of $CO_2$ reductions in the US stays below the (hypothetical) upper limit (USD 25) of the quota price in the US carbon trading market. Hence, subsidies to keep emissions low may seem unnecessary, which is convenient for a debt ridden US economy.

Japan's pledge involves almost 40 per cent reduction compared with the 2005 emission level. Japan is the only country expected to have a negative annual growth in primary energy use. In the IEA reference scenario the decline is 0.2% per year. A reduction in primary energy use should hold back the costs of reducing $CO_2$ emissions. The emission intensity in Japan's BAU scenario is falling approximately 1% p.a. – about the same as in EU, US and Canada, while in the policy scenario, Japan's emission intensity is reduced about as fast as China's (figure 4). RoW represents countries with a low energy intensity; hence emissions reductions also turn out to be relatively expensive.

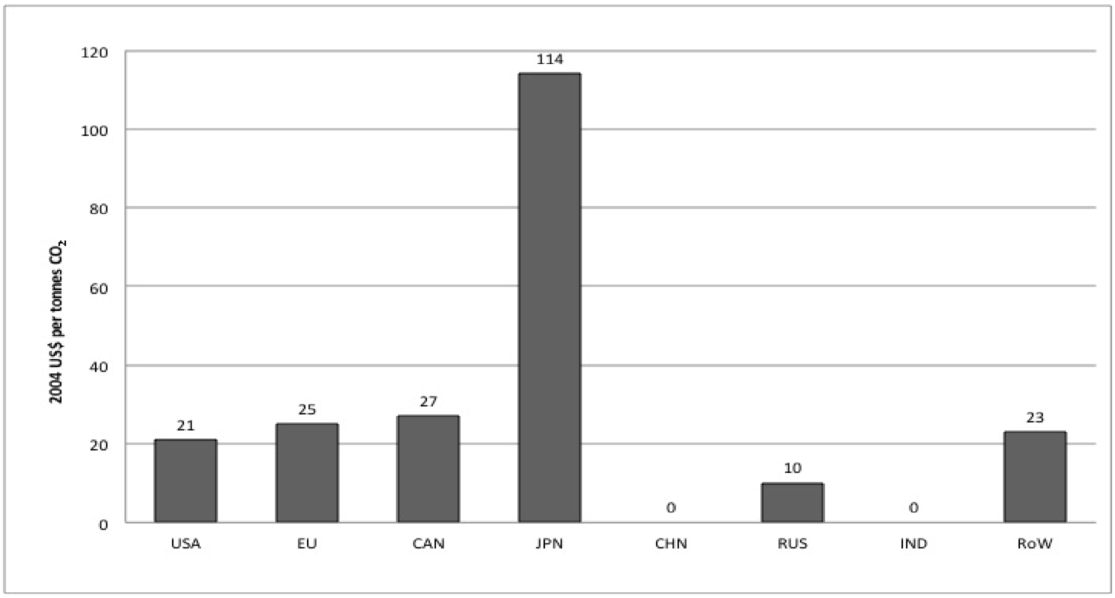


**Figure 5. The marginal costs of Copenhagen pledges by regions in 2020**

Generally, purchaser prices on fossil fuels differ across regions due to market regulations and regional policies with regard to taxes and subsidies. Figure 6 shows the effects on regional fossil fuel prices in 2020 in going from the BAU to the policy scenario. Prices are reduced relative to the BAU paths in all regions for all of the fossil fuels, generally most for coal, followed by gas and oil. China differs from the other regions in experiencing a lower reduction in coal and gas price growth as compared with the price reduction of oil. Also, the price reductions are less in China, Russia and India than in other regions, as demand for these fuels are reduced modestly or even increased as a consequence of the pledges made in the Copenhagen Accord. These costs occur in spite of the option to switch from fossil to non-fossil fuel as feedstock in electricity production. However, due to linear technologies in electricity production and sunk capital costs, this substitution effect is a time consuming process and does not offer an easy escape from mitigation costs during the time horizon of this study.

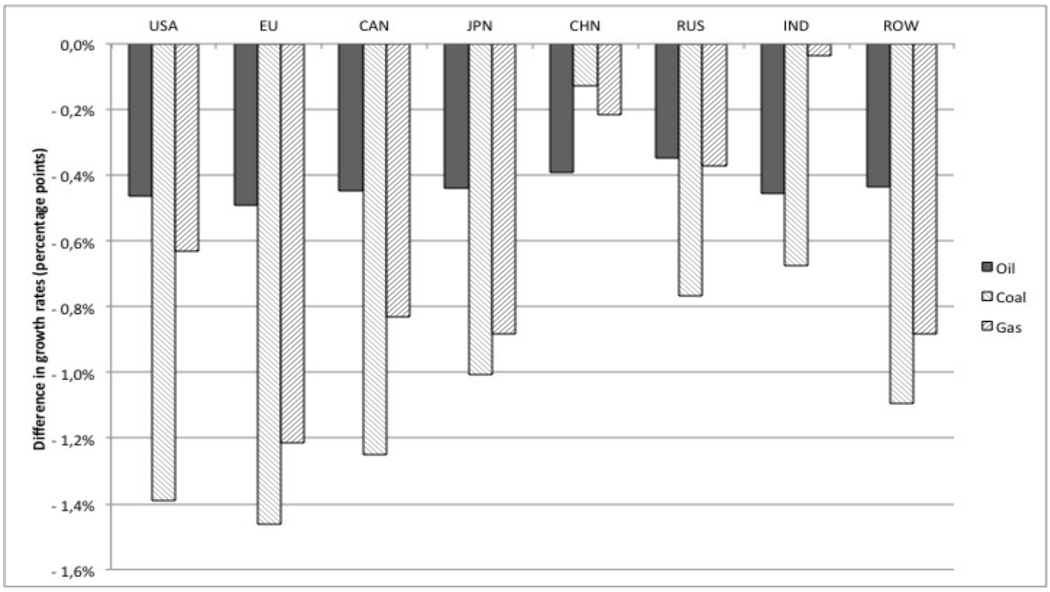


**Figure 6. Difference in annual growth rate of fossil fuel prices between the policy scenario (SN1) and the BAU scenario**

The fall in fuel prices encourage energy intensive industries in countries without binding emissions constraints even further. An illustration of this carbon leakage is shown in Figure 7a, depicting changes in net export in value terms of steel and cement in 2020 in going from the BAU scenario to the policy scenario (SN1). Figure 7b shows change in net export as a percentage of the BAU domestic production in 2020. We see that net export of steel is reduced in most countries, but increases in China, Russia and India. RoW is losing export markets, being less able to compete with more rapidly growing economies with high investment levels and capacities to phase in more efficient technologies. This occurs in spite of market decreases in regional prices of coal and gas. For cement the picture is more mixed, as cement is not traded globally to the same degree as steel.

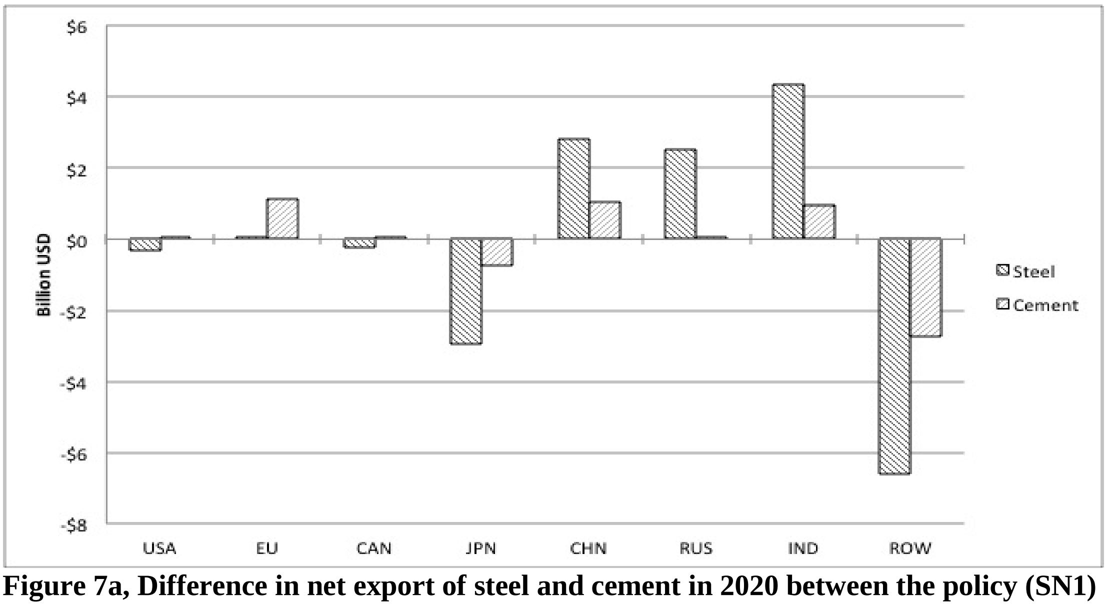


**Figure 7a, Difference in net export of steel and cement in 2020 between the policy (SN1) and BAU scenario**

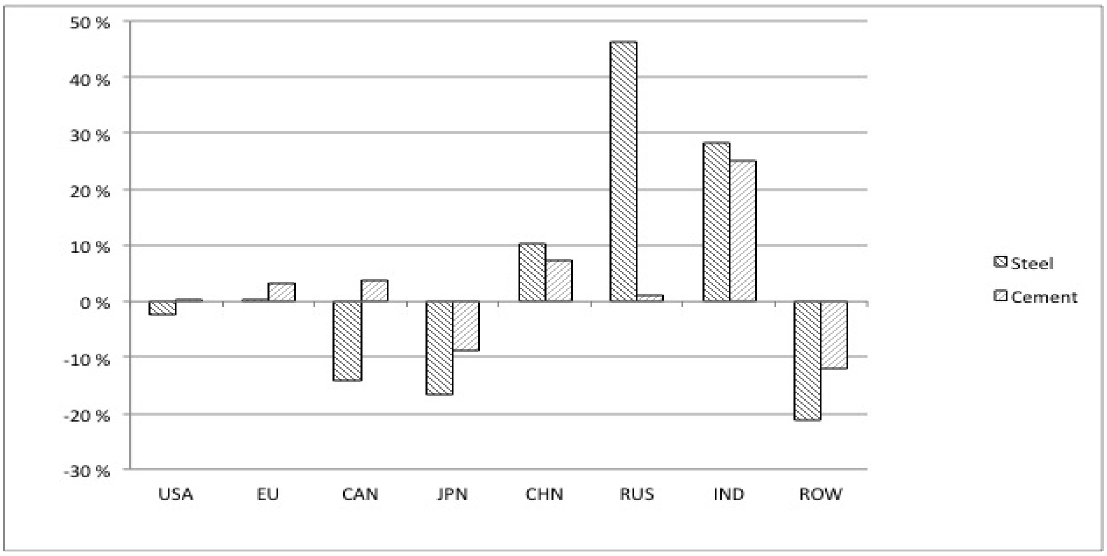


**Figure 7b. Difference in net export of steel and cement in 2020 between the policy (SN1) and BAU scenario as share of domestic production in BAU 2020**

Russia undertakes the largest expansion of steel exports relative to their BAU production in 2020, with more than 40 per cent increase. India comes next with nearly 30 per cent increase for steel and 25 per cent for cement. Leakages to China are also positive, but of a smaller relative size.

# 6 Energy intensities: History and pledges

Results as presented above are influenced by the fact that the pledges made in the Copenhagen Accord are not binding for China and India. This is again a partial reflection of the assumptions made in formulating their BAU scenarios. For instance, the average annual reduction in $CO_2$ emission intensity in our BAU scenario for China is close to 5% p.a. (cf. Figure 2) ensuring that the Copenhagen pledge of China is not a binding constraint. A reasonable question then is whether this rate of emission intensity reduction is realistic. We will approach this question by comparing the rate of intensity reduction in the BAU scenario for China with historical data and with similar data from some other recent studies.

Looking at history we get a mixed answer. Figure 8 shows emission intensity reductions in regions over various time periods. Most regions show reduction rates of 1-3% p.a. China is one of the exceptions, with an average reduction rate of more than 5% p.a. for the period 1980-2000. Thereafter, however, the reduction in China is reversed to a (small) growth for the period 2000-2007 and the whole period 1980-2007 saw a reduction in emission intensity of somewhat less than 4% p.a. Clearly, continued improvement in emission intensity of the order of 4-5% p.a. is not coming ‘automatically’. Hence, the experience over the last decade could lead us to question if China’s pledges are feasible based only on efficiency improvements as depicted in our BAU-scenario.

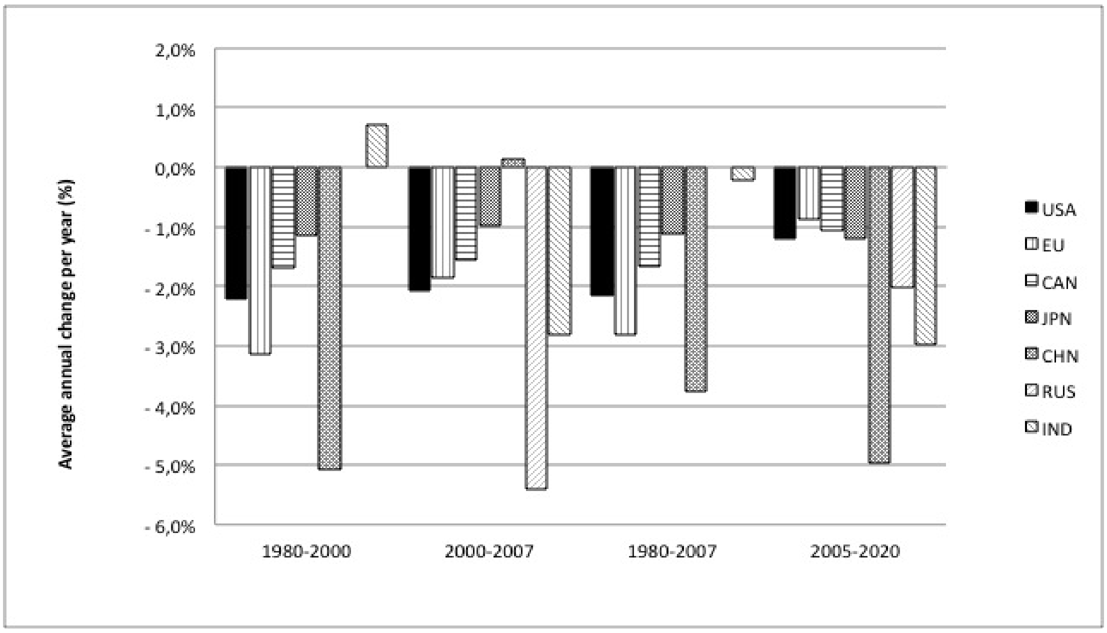


**Figure 8. Historical and future (BAU) average annual changes in emission intensities. Source: http://cait.wri.org/ and own calculations**

The 12th five-year plan adopted for the period 2011-2015 in China, stipulates as one target a 17% reduction in emissions intensity. The BAU reduction in emissions intensity corresponds closely to this target.

Generally the main focus of both policy and analysis is on the impact of technical energy efficiency improvements. However, in a rapidly developing economy like China's and India's, structural changes might also contribute to reductions in overall emission intensities.

In Figure 9 we illustrate to what extent reductions in carbon intensities rely on technology versus structural change related to impacts of income growth, consumer preferences and trade as emerging through general equilibrium effects. The direct contribution to a reduction in carbon intensity is associated with what happens if sector composition of GDP is fixed as in the base year and the economy and the scale of each activity is adjusted in line with GDP growth. In this frozen technology scenario the energy use is adjusted for annual energy efficiency improvements only. The other component is the effect via changes in sector composition and represents the energy intensity impact that results from higher income levels and changes in consumer demand, and effects via domestic and international price changes.

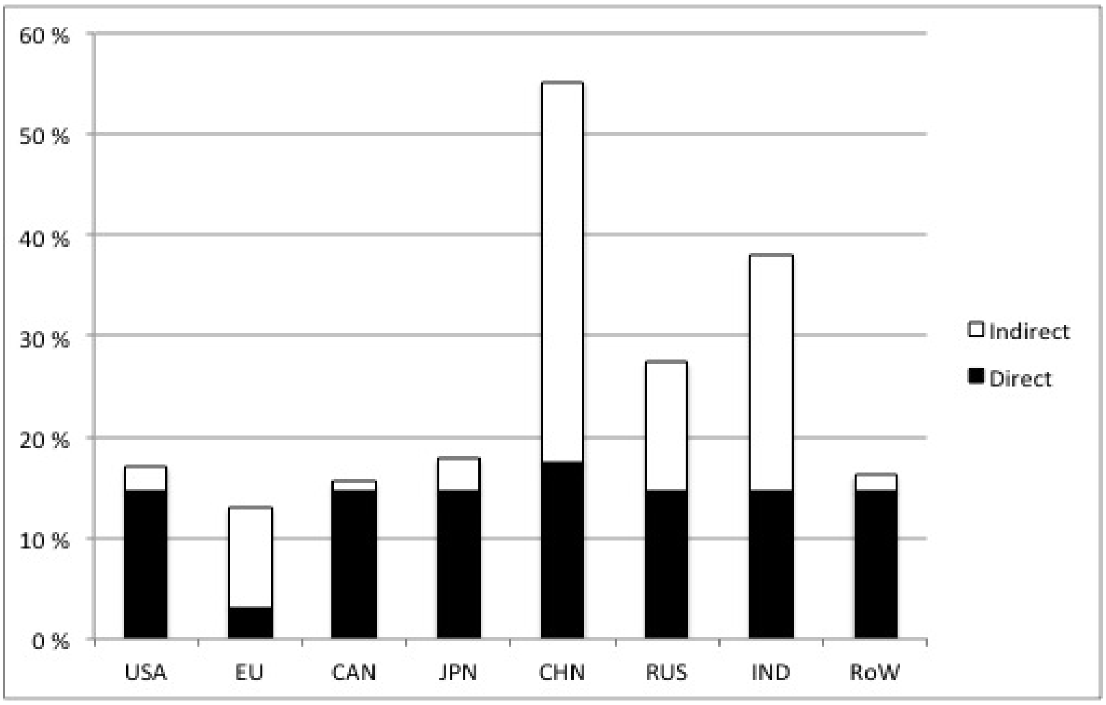


**Figure 9. Contribution from structural change and energy efficiency to change of carbon intensity from 2004 to 2020**

As shown in figure 9, there is a considerable structural component in China's carbon intensity reduction. The contrast to India is marked. Whereas the direct energy efficiency components are fairly similar, the structural component of China reduces intensity by 38 percentage points, for India only 23 percentage points.

In the EU the reduction in $CO_2$ intensity is predominantly from structural change, whereas USA, Canada and Japan hardly are supported by structural change when reducing their carbon intensity.

# 7 Comparison with other studies

When comparing our results with those from other studies, it is necessary to take into account the differences embedded in the BAU scenarios and the underlying models. Figure 10 compares the economic growth rates of our BAU scenario with some BAU scenarios from other reports. The comparison cannot be exact because of somewhat different definitions of regions and time period in the various reports. Nevertheless, Figure 10 provides some insights and references for our BAU-assumptions. In the figure, GWA refers to this study, MMW refers to McKibbin et al. (2010), IEO refers to U.S. Energy Information Administration (2009) as reported by McKibbin et al (op. cit.), den Elzen refers to den Elzen et al. (2010), Jotzo refers to Jotzo (2010) and CCICED BAU refers to China Council for International Cooperation on Environment and Development (2009) providing a BAU economic growth rate only for China. Among the more rapidly growing large economies, the largest variation in relative terms among studies is found for Russia. Japan has the largest gap between growth forecasts. Interestingly, for China we find a larger discrepancy among assumed or calculated economic growth rates than for India. The overall impression from Figure 10 is otherwise that our study assumes a lower economic growth than most other reports and studies except for Japan. This is likely to contribute to relatively lower economic costs of attaining the emission targets pledged in the Copenhagen Accord in our study.

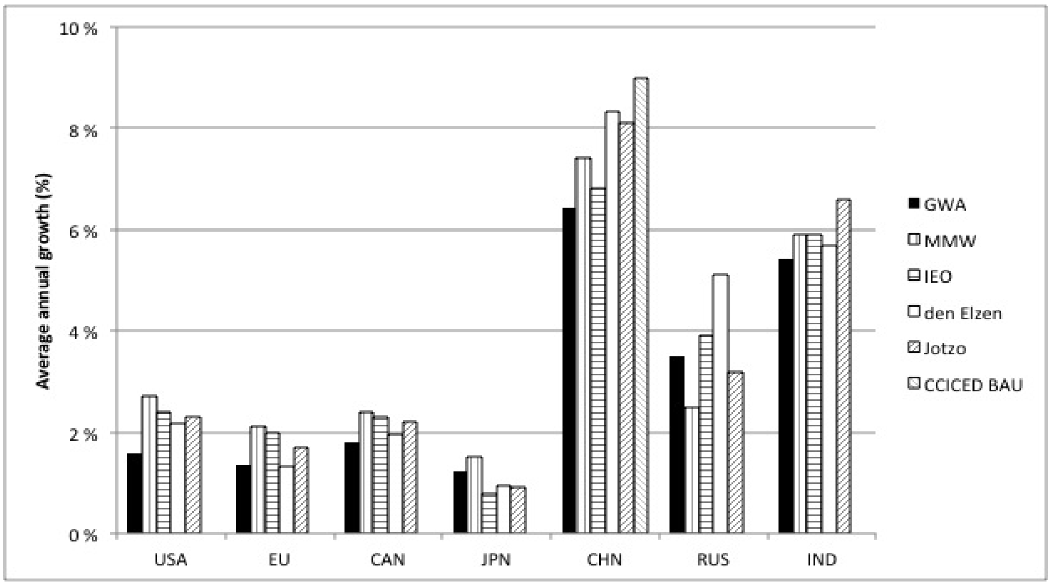


**Figure 10. Comparing BAU average annual economic growth rates over the period 2005-2020 in different studies**

Figure 11 compares our BAU-emissions growth rates with those of other BAU emission scenarios reported in the literature. Emission growth estimates vary considerably for China, India and Russia. Our results for China is at the lower end, for India more in line with an average of the other studies, whereas we (GWA) find a much higher growth in Russian emissions than the other studies.

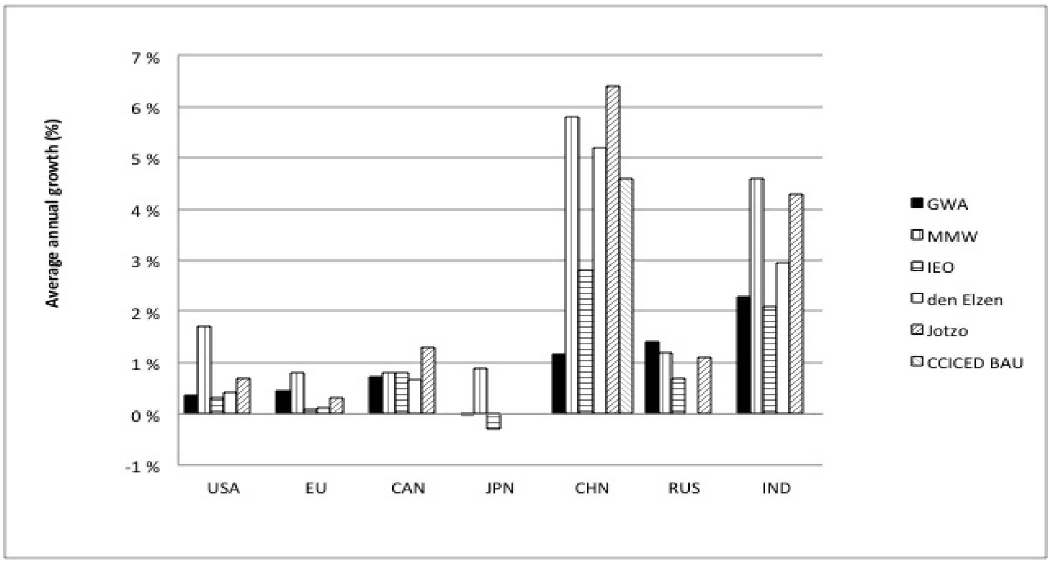


**Figure 11. Average annual growths in $_2$ emissions in different studies 2005-2020**

Combining GDP growth rates and emission growth rates, we can compare how emission intensities vary among the studies. This is depicted in Figure 12.

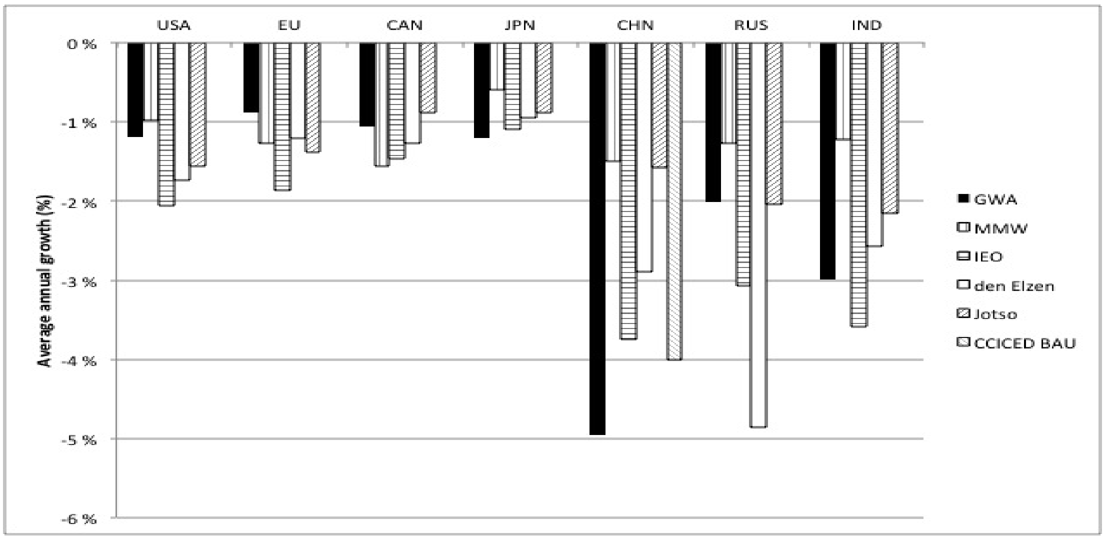


**Figure 12. Average annual emission intensity growth rates over the period 2005-2020 in BAU scenarios by regions and studies**

We note that the relatively high emissions growth rates in McKibbin et al. (MMW) (Figure 11) is due to both a high economic growth rate and a low reduction rate in emission intensities (Figure 12). Among the studies covered here, emission intensities vary most for China, Russia and India.

McKibbin et al. (MMW) operate implicitly with an annual reduction in energy intensity of 1.3% per year on average, whereas our study has 2.0% per year.

The scope for energy efficiency in Russia has been huge, as overconsumption was built into the Sovjet industrial infrastructure (IEA 2009). In 2007, after more than 5% p.a. steady decline since year 2000, the energy intensity in Russia was still 3 times higher than the OECD Europe average although 2/3 of the gap had been closed between 1998 and 2007 (IEA 2009).

On that background a future annual reduction of 1.3% may seem somewhat low, US Department of Energy (IEO) assume a rate of 3.5% per year.

# 8 Conclusion

The Copenhagen Accord seems to be the bottom-up climate regime for the time being. There are no measures of ensuring compliance involved beyond the good intentions behind the national pledges to reduce emissions of greenhouse gases.

However, several factors support a core of realism of these intentions. Energy security issues, the fight of local air pollution, the need for modernizing the industrial structure and securing access to future export markets are all reasons for reducing greenhouse gas emission intensities adding to concerns about climate change in most countries and regions. China is an example of a country that sees a low carbon future as a necessity to stay competitive and secure a relative prosperous future for the country. The question is how much it will cost. Our study shows that costs are modest in the case where mitigating efforts are directed towards reducing fossil fuel use. Extending the mitigating options to other GHGs and emission sources will probably reduce the cost further.

Our study shows that global emissions of $CO_2$ from fossil fuel combustion will be 15% or 4.6 Gt $CO_2$ below BAU in 2020 as a result of the Copenhagen Accord. By 2020 the global emissions of $CO_2$ from fossil fuels will be 3 per cent below the 2005 level. India raises emissions by 5%, and China by 1%. Both China and India comply with their pledges in terms of emission intensity reductions.

China and India benefit slightly from the Copenhagen Accord in terms of increasing GDP. The GDP losses are marginal for other countries and regions, including the rest-of-the-world (RoW) region.

We estimate some carbon leakages, but not to a serious and game changing extent. India, China and Russia increase their roles as international suppliers of energy intensive goods like steel and cement. Still, structural change in China and India is the dominating source factor behind their reductions in emissions intensities.

With the implementation of the Copenhagen Accord, real coal prices decline markedly from the BAU scenario, except in China. Gas prices fall the most in the EU, the least in India, whereas oil prices experience similar, but modest rates of decline in all regions at approximately 0.4% p.a.

We estimate low costs to most regions as measured by the decline in GDP in 2020 between the BAU and the policy scenario. Japan seems the most vulnerable with a high marginal cost of $CO_2$ reduction and ambitious pledges leading to relatively high costs in terms of GDP loss. The marginal cost of $CO_2$-reductions in Japan reaches above 100 USD2004 in 2020. The recent accident at the Fukushima nuclear power plant and associated setback of the nuclear power industry might, however, undermine this already challenging emission target. For USA, EU and Canada the cost settles around 21-27 USD2004.

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# Appendix

**Table 1A. Sectors in GRACE**

| Brief | Explanation |
|---|---|
| agr | Agriculture |
| ser | Services |
| frs | Forest |
| fsh | Fisheries |
| iron | Iron and steel |
| nmm | Non-Metallic minerals including cement, plaster, lime, gravel, concrete (cement) |
| pro | Other manufacturing |
| air | Air transport |
| sea | Sea transport |
| tran | Other transport |
| cru | Crude oil |
| col | Coal |
| ref | Refined oil |
| elc | Electricity |
| gas | Gas |