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Executive Summary

The political accord struck by world leaders at the United Nations negotiations in Copenhagen in December 2009 allows participating countries to express their greenhouse gas commitments in a variety of ways. For example, developed countries promised different percent emissions reductions relative to different base years by 2020. China and India committed to reducing their emissions per unit of gross domestic product (GDP) relative to 2005 by 40 and 20 percent respectively. Such flexibility promotes consensus by allowing each country to use its preferred commitment formulation. However, the disparate approaches and widely varying baseline trends across different economies complicate comparing the likely emissions reductions and economic efforts required to achieve the commitments.

This paper provides such a comparison by analyzing the Copenhagen targets using the G-Cubed model of the global economy. We begin by formulating a no-policy baseline projection for major world economies. We then model the Copenhagen Accord's economy-wide commitments, with a focus on fossil-fuel-related CO_2. We show how different formulations make the same targets appear quite different in stringency, and we estimate and compare the likely economic and environmental performance of major emitters' Copenhagen targets. The analysis also explores the spillover effects of emission reductions efforts on countries that did not adopt economy-wide emissions targets at Copenhagen.

We emphasize that this work is not a policy analysis or a prediction about how countries will actually achieve their commitments. Rather, it offers a way of standardizing and comparing heterogeneous proposals with an eye towards assessing their relative environmental and economic consequences.

1. Introduction

World leaders met in Copenhagen in December 2009 for the fifteenth Conference of the Parties (COP) to the United Nations Framework Convention on Climate Change (UNFCCC). The resulting agreement, called the Copenhagen Accord (the Accord), is not legally binding. However, heads of state struck the deal personally so it carries significant political weight. Negotiations are currently underway towards a more enforceable agreement, but prospects for its conclusion before the end of the Kyoto Protocol's commitment period in 2012 are uncertain. Thus, the Copenhagen Accord reflects the broad willingness of major economies to commit, at least politically, to measurable emissions limitations through 2020.

Emissions commitments by Annex I countries appear in Appendix I of the Accord, formulated as economy-wide reductions in greenhouse gas emissions relative to a base year of each country's choosing.[1] Developing countries' commitments appear in Appendix II of the Accord.[2] Their commitments are more varied and include, for example, emissions reduction targets relative to business as usual projections, reductions in emissions per unit of gross domestic product (GDP), expansions in forest cover, and investments in energy efficiency and biofuels.

[1] Appendix I of the Copenhagen Accord is available here: http://unfccc.int/home/items/5264.php.
[2] Appendix II of the Copenhagen Accord is available here: http://unfccc.int/home/items/5265.php.

Table 1 below reports the commitments of some of the largest emitters as they were reported to the UNFCCC. As might be expected given that the Accord is not a legally binding document, these commitments are different in several ways from the commitments by Parties to the Kyoto Protocol. For example, the Accord targets refer only to a single year's emissions, 2020, whereas the Kyoto Protocol capped total emissions over a five year period. The Accord makes no mention of the paths of emissions from 2013, the first year after the Kyoto Protocol compliance period, through 2019. The Accord is also silent about the degree to which targets would be met domestically or through emissions trading or international offsets.

As Table 1 reports, some Accord participants offered ranges of emissions targets, with more stringent levels being contingent on other countries' actions or the enactment of domestic legislation. For example, the E.U. offers an unconditional 20 percent reduction and a 30 percent reduction contingent on "comparable emissions reductions" by other developed countries and "adequate contributions" by developing countries. While the Kyoto targets are predominantly percentage reductions in emissions relative to 1990 levels, averaged over 2008 to 2012, the base years of emissions reduction targets in the Copenhagen Accord differ across participants. The U.S. and Canada both promised reductions of 17% relative to 2005 levels, while the E.U., Russia, and Japan chose a base year of 1990. Australia opted for 2000.

Table 1. Commitments under the Copenhagen Accord

Country	Greenhouse Gas Emissions Targets for 2020	Base Year
USA	[Reduction of emissions] in the range of 17%, in conformity with anticipated U.S. energy and climate legislation, recognizing that the final target will be reported to the Secretariat in light of enacted legislation.	2005
Japan	25% reduction, which is 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
Australia	5% unconditionally; up to 15% or 25% with international action; Australia will reduce its greenhouse gas emissions by 25% on 2000 levels by 2020 if the world agrees to an ambitious global deal capable of stabilizing levels of greenhouse gases in the atmosphere at 450 ppm CO2-eq or lower. Australia will unconditionally reduce emissions by 5% below 2000 levels by 2020, and by up to 15% by 2020 if there is a global agreement which falls short of securing atmospheric stabilization at 450 ppm CO2-eq and under which major developing economies commit to substantially restrain emissions and advanced economies take on commitments comparable to Australia's.	2000
European Union	20%/30% ; As part of a global and comprehensive agreement for the period beyond 2012, the EU reiterates its conditional offer to move to a 30% reduction by 2020 compared to 1990 levels, provided that other developed countries commit themselves to comparable emission reductions and that developing countries contribute adequately according to their responsibilities and respective capabilities.	1990
Canada	17%, to be aligned with the final economy-wide emissions target of the United States in enacted legislation.	2005
Russia	15-25 % the range of the GHG emission reductions will depend on the following conditions: - Appropriate accounting of the potential of Russia's forestry in frame of contribution in meeting the obligations of the anthropogenic emissions reduction; - Undertaking by all major emitters the legally binding obligations to reduce anthropogenic GHG emissions.	1990
China	lower CO2 emissions per unit of GDP by 40-45%; increase the share of non-fossil fuels in primary energy consumption to around 15%; increase forest coverage by 40 million hectares and forest stock volume by 1.3 billion cubic meters	2005
India	reduce the emissions intensity of its GDP by 20-25% by 2020 in comparison to the 2005 level.	2005

Notably, unlike under the Kyoto Protocol, some major developing countries made economy-wide emissions commitments in the Accord. In particular, China and India committed to reducing by 40 and 20 percent reductions respectively their emissions per unit of GDP. This approach is consistent with many developing countries' longstanding opposition to hard emissions limits on the grounds that limits on emissions levels could impose inadvertently stringent constraints given these countries' potentially large but uncertain economic growth. Also consistent with longstanding positions, both countries cite in their Copenhagen commitments the UNFCCC provision that stipulates that developing country actions depend on developed country actions, including the provision of financial resources and technology transfer.[3]

The presumption that binding commitments can take only the form of a percentage reduction relative to specific historical levels hampered efforts to reach agreement, not just because it alienates rapidly industrializing countries such as China and India. All Parties face uncertainty in their commitments because many factors that affect the burden of achieving the target evolve between the year of negotiation and the commitment period. The recent financial crisis and global economic downturn are clear reminders of the volatility in the underlying economic environment in which parties make these emissions commitments. Additional uncertainties include unanticipated economic growth, technology breakthroughs, prices for renewables and natural gas (a lower-emitting alternative to coal), and political upheavals. The results of this paper also indicate that another source of uncertainty is the effects of other countries' mitigation actions.

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[3] UNFCCC, Article 4, Paragraph 7.

Trends in national emissions and economic growth have varied widely since 1990. Also, historical patterns of energy use and marginal costs of greenhouse gas (GHG) abatement also vary widely across countries. This means that targets that look similar can require very different levels of effort in different countries, and commitments that produce similar economic outcomes can look inequitable. The tension between equivalent appearances and equivalent effort has been a chronic challenge in climate negotiations. Indeed, the failure of the G-8 to set a base year for its agreed 80 percent reduction of emissions by 2050 illustrates the contention in formulating even collective targets.

The notion that the efforts underlying different countries' climate commitments should be comparable is enshrined in the UNFCCC's 2007 Bali Plan of Action, which called for the next agreement to ensure the "comparability of efforts" across developed countries while "taking into account differences in their national circumstances." The term "comparable" has two quite distinct meanings: "similar" and "expressed in a way that can be compared." This analysis shows that under simplifying assumptions the commitments can be compared, but that different measures of outcomes lead to different conclusions about the relative "efforts" of the participants.

The Accord's flexibility promoted consensus at Copenhagen by allowing countries to express their commitments in ways that enhance their apparent stringency, accommodate economic growth, and preserve the option for less ambitious efforts if they are not reciprocated. However, the disparate base years and commitment formulations, along with widely varying recent emissions trends and projections across different economies, make it difficult to compare the likely emissions reductions and economic efforts required to achieve these commitments. Using the G-Cubed model of the global economy, this paper estimates and compares the economic and environmental performance of major emitters' Accord commitments. We emphasize that this work is not a policy analysis or a prediction about how countries will actually achieve their commitments. Rather, it offers a way of standardizing and comparing heterogeneous proposals on the basis of their environmental and economic outcomes.

We estimate and compare the overall costs, price signals, and emissions outcomes of the agreement. A number of insights emerge. Climate policy debates often surround concerns about the effect of commitments on participants' own economies and the potential competitive disadvantages or emissions leakage that may result if other countries do not adopt similar measures. Our analysis emphasize that the reverse is also important: there can be very significant domestic consequences from external adoption of multilateral agreements.

Section 2 provides a summary of the modeling approach. It describes the no-policy baseline projections for the modeled regions and the design of the Copenhagen Accord policy scenario. Section 3 explores the emissions reductions in the Accord relative to common base years and projections of business as usual emissions. We show how the choice of base year affects how stringent different targets *look* while implying the same actual emissions level. Section 4 explores the emissions and economic results of the Copenhagen Accord under several simplifying assumptions. Section 5 concludes.

2. Modeling Approach

The G-Cubed model is an intertemporal computable general equilibrium (CGE) model of the world economy.[4] A brief technical discussion of G-Cubed appears in McKibbin et al. (2009) and a more detailed description of the theory behind the model can be found in McKibbin and Wilcoxen (1999).

This study uses a version of the model that includes the eleven geographical regions listed in Table 2. The United States, Japan, Australia, China, India, and Brazil are each represented by a single modeled region. The model aggregates the rest of the world into five composite regions: Western Europe, the rest of the OECD (not including Mexico and Korea) (ROECD); Eastern Europe and the former Soviet Union (EEFSU); OPEC oil exporting economies; and all other developing countries (LDC). Appendix I reports the details of these regional groupings.

[4] The type of CGE model represented by G-Cubed, which has macroeconomic dynamics and various nominal rigidities, is closely related to the dynamic stochastic general equilibrium models appearing in the macroeconomic and central banking literatures.

Table 2. Regions in the G-Cubed Model (Country Aggregation D)

Region Name	Region Description
USA	United States
Japan	Japan
Australia	Australia
Europe	Western Europe
ROECD	Rest of the OECD, i.e. Canada and New Zealand
China	China
India	India
EEFSU	Eastern Europe and the former Soviet Union
Brazil	Brazil
LDC	Other Developing Countries
OPEC	Oil Exporting Developing Countries

The Baseline Scenario

One of the most important factors in modeling emissions commitments is the model's assumptions (or in the case of G-Cubed, its endogenous projections) about future emissions and economic activity in the absence of climate policy. This is called the baseline scenario, and it is a major factor in explaining why different economic models produce different estimates for the cost of a particular emissions target: the lower emissions are in the reference scenario, the less abatement is needed to hit a particular cap. A detailed discussion of the baseline and how it is generated in G-Cubed can be found in McKibbin, Pearce and Stegman (2009).

In this study, we construct a baseline scenario for the entire world that reflects our best estimate of the likely evolution of each region's economy without concerted climate policy measures. To generate this scenario, we begin by calibrating the model to reproduce approximately the relationship between economic growth and emissions growth in the U.S. and other regions over the past decade. Appendix II reports more details about the projections in the baseline scenario and how they compare to analogous projections in the Energy Information Administration's *International Energy Outlook*.

In the baseline, no country adopts an economy-wide price on carbon through 2050. Although some countries in the model have commitments under the Kyoto Protocol, most do not currently have an economy-wide price on carbon, with the European Union a notable exception. Kyoto Protocol participants may or may not actually achieve their targets, and those that do (such as Russia) may do so without strong policy measures.

Figure 1 shows fossil CO_2 emissions by region in the baseline scenario. Clearly the largest source of projected world emissions growth is China, although other developing countries also contribute an increasing share.

The Policy Scenario

We assume that the Accord policy scenario begins in 2012, at which time the countries with economy-wide targets under the Copenhagen Accord place a price on all carbon dioxide emitted from fossil fuels. In the policy scenario, all countries achieve their targets domestically (i.e. with no offsets or emissions trading) by imposing an economy-wide price signal on carbon in 2012 that rises at a four percent real rate of interest such that the 2020 targets are met.[5]

The stipulation that all abatement is domestic could differ markedly from the actual implementations of the Accord. For example, draft U.S. legislation would allow a substantial share of domestic compliance using credits for certain emissions reductions ("offsets") achieved outside the energy sector (for example in forest carbon) or abroad. In this analysis, we exclude offsets for two reasons. First, we are modeling a simplified and stylized interpretation of the Accord commitments. Since the agreement is silent on emissions trading there is no clear way to anticipate the quantity or price of imported reductions that a country might use to comply with its commitments. Second, the policy scenario includes economy-wide targets for two of the largest potential sources of offsets, China and India. It is unclear how these economy-wide targets would be compatible with offset sales. To avoid double counting, only reductions outside energy or beyond the Copenhagen commitments would be eligible. To the extent that Accord participants meet some of their abatement requirements abroad or outside the energy sector, then they may lower the overall costs of their environmental accomplishments. On the other hand, if they deploy a policy that is less efficient than an economy-wide price on fossil carbon they may increase the overall cost of their goals.

We assume all participating countries act in concert, which means the policy scenario accounts for the higher price signals necessary to achieve the targets when world energy

[5] McKibbin et al (2009), p. 6, explains the connection between a price signal that rises at the real rate of interest and cost minimization.

prices fall as a result of declining global demand. Where countries offered a range of potential Accord targets that depend on what other countries do, we assume they achieve the least stringent target they have offered. With these simplifying assumptions, we estimate and compare the overall costs, price signals, and emissions outcomes of the agreement.

Like most global economic models, due to computational constraints G-Cubed groups some countries into composite regions based on geography and the degree of economic development. This means that to model the targets of the Copenhagen Accord, we must ascribe targets to these regional groupings that reasonably reflect the commitments of the individual countries in the group. By definition, this modeling scenario won't be identical to a scenario in which each country in the group achieves its own independent target. For example, we apply a target for the "Rest of the OECD" region (17 percent below 2005 levels) that equals the Accord target of Canada, the largest economy in that group. We set the target for Western Europe to the EU's Accord target of 20 percent below 1990 levels, and apply Russia's Copenhagen target of 15 percent below 1990 emissions levels to G-Cubed's EEFSU region. The two regional groupings of Western Europe and EEFSU do not correspond exactly to the groups of countries taking commitments under the Copenhagen Accord. In particular, the European Union member countries include some countries in Eastern Europe, which fall in EEFSU. For EEFSU, we apply Russia's much less stringent target of 15 percent relative to 1990 levels.

We assume the real price on carbon dioxide in each country rises at four percent each year after 2012 through 2050 or until emissions fall to nearly zero, whichever comes first. When emissions fall to nearly zero, we hold the carbon price constant thereafter. We solve for the initial price on carbon in 2012 in each country such that it hits its target for 2020 as set out in Table 3.

Table 3. Emissions Targets for 2020 for the Policy Scenario

	Reduction Percent	**In Emissions**	**Relative To**
USA	17	Level	2005
Japan	25	Level	1990
Australia	5	Level	2000
Europe	20	Level	1990
ROECD	17	Level	2005
China	40	Per Unit GDP	2005
India	20	Per Unit GDP	2005
EEFSU	28	Level	1990

For the Chinese and Indian commitments to reduce emissions per unit GDP, we assume the intensity targets refer to emissions per unit *real* GDP. This is an important assumption. Even without any other change in the economy or emissions, inflation reduces the emissions intensity measured in nominal terms.

We assume the price signal and emissions targets in the policy scenario apply only to CO_2 from fossil fuel consumption from the energy sector, including combustion of coal, natural gas, and oil. For example, if the target specifies a reduction of 17 percent below 2005 emissions levels by 2020, then we compute a scenario in which CO_2 emissions from the energy sector in 2020 are 17 percent lower than emissions from those same sources in

2005. Including other GHG sources in the analysis would result in potentially lower marginal abatement costs, but higher overall levels of abatement, with unclear net effect on costs relative to the results we present below.

CO_2 from energy-related fossil fuel consumption includes a large majority of total U.S. greenhouse gas emissions and the vast majority of emissions growth since 2000. For example, according to the U.S. Environmental Protection Agency, fossil fuel combustion comprised 94 percent of all U.S. CO_2 emissions in 2007, and over 80 percent of total U.S. greenhouse gas emissions on a CO_2-equivalent basis.[6] In addition, the increase in net growth in all U.S. GHG emissions from 2000 to 2007 came almost entirely from increases in CO_2 from energy-related fossil fuel combustion. In fact, fossil energy CO_2 emissions grew by 174 million metric tons from 2000 to 2007, but were partially offset by declines in other emissions for a net growth in all U.S. GHG's of 142 million metric tons of CO_2 equivalent (MMTCO$_2$E).

We assume that each of the non-OECD regions in our model that have not promised economy-wide targets (Brazil, Other LDC's, and OPEC) do not adopt an economy-wide price on carbon through the duration of the analysis. Brazil committed under the Accord to eleven sector-specific measures and targets, such as reductions in deforestation and increases in alternative energy. Brazil anticipates these proposed measures will reduce its emissions in 2020 by about 36 to 39 percent relative to baseline projections. However, because Brazil has committed to the actions rather than the projected emissions outcomes,

6 U.S. Environmental Protection Agency (2009), p. ES-4, Table ES-2. Figures do not account for carbon stored in terrestrial carbon sinks.

the policy scenario for this analysis treats Brazil as not adopting an economy-wide emissions target or price on carbon.

3. Comparing the Commitments in Common Terms

This section explores the Copenhagen commitments in common terms in several dimensions, including as changes in emissions levels, changes in emission intensity (emissions per unit GDP), and changes in per capita emissions.

Emissions Levels

Using the baseline and policy scenarios described in Section 2, we can convert the disparate targets under the Accord into common formulations. Table 4 and Figure 2 below report the Copenhagen Accord emissions commitments for 2020 in common historical base years (1990, 2000, and 2005) and relative to emissions in the 2020 baseline scenario, or business as usual (BAU) emissions. For China and India, commitments are reported using the emissions levels in 2020 that produces the targeted reductions in emissions per unit real GDP. For the regions without Accord targets (Brazil, LDC, and OPEC), emissions in the policy scenario are measured against their historical emissions and BAU projections for 2020.

Table 4. Emissions in 2020 that Result from Copenhagen Accord[7]

	2020 Target as a Percent Change in Emissions in 2020 Relative To Emissions in the Indicated Year			
Country	**1990**	**2000**	**2005**	**BAU in 2020**
USA	-1	-15	**-17**	-33
Japan	**-25**	-37	-39	-48
Australia	30	**-5**	-18	-35
Europe	**-20**	-24	-27	-36
ROECD	10	-7	**-17**	-25
China	496	350	146	-22
India	346	159	120	0.4
EEFSU	**-15**	28	18	-1.3
Brazil	168	73	61	0.6
LDC	211	119	85	0.9
OPEC	180	105	60	1.3
World	90	70	43	-17.5

As might be expected, Table 4 shows that emissions increase relative to baseline in regions without targets as they experience lower fossil energy prices and inflows of investment. Regional emissions results range from an increase of 1.3 percent relative to baseline in OPEC to a decline of 48 percent in Japan. The net result of the changes that result from the Accord is a decline in world emissions of more than 17 percent relative to baseline in 2020.

Table 4 reveals how the formula for the target affects its apparent stringency. In particular, it shows how reductions relative to historical base years bear little relation to reductions relative to business as usual. For example, the model suggests that China's

[7] Boldface numbers represent the commitment formulas in the Copenhagen Accord. Negative numbers are reductions, and positive numbers are increases relative to the base year.

emissions goal under the Accord implies a nearly five-fold increase in emissions relative to 1990 levels, but the target still represents a 22 percent departure from Chinese baseline emissions in 2020, nearly as ambitious as the 25 percent reductions from baseline by the ROECD countries. EEFSU's 15 percent reduction relative to 1990 levels represents about a one percent decline relative to BAU.

Table 5 re-interprets the results for Accord participants in Table 4. For each base year, it ranks the regions' commitments relative to each other, with a rank of one for the region with the greatest percent emissions reductions and the rank of eight for the region with the lowest percent emissions reductions. Highlighted cells in the table are the commitment formulas chosen by each country for its Accord commitment.

Table 5. Ranking of Participants by Reductions in Emissions Levels

Rank	Change Relative to 1990 Base Year Emissions	Change Relative to 2000 Base Year Emissions	Change Relative to 2005 Base Year Emissions	Change from 2020 BAU Emissions
1	Japan	Japan	Japan	Japan
2	Europe	Europe	Europe	Europe
3	EEFSU	USA	Australia	Australia
4	USA	ROECD	USA/ROECD	USA
5	ROECD	Australia		ROECD
6	Australia	EEFSU	EEFSU	China
7	India	India	India	EEFSU
8	China	China	China	India

Table 4 and Table 5 show that of all the modeled regions, Japan pursues the largest emissions reduction commitment relative to all base years. Japan's target for 2020 is almost half its baseline emissions. Western Europe, Australia, and the U.S. committed to similar departures from BAU with projected emissions declines by 2020 of 36, 35, and 33 percent respectively. Table 4 shows that India's commitment to reduce by 20 percent relative to 2005 its emissions per unit GDP implies a 356 percent increase in emissions levels from 1990 but close to baseline emissions levels in 2020.

Table 5 illustrates the negotiating complications if countries must agree on a common base year but each country has the incentive to pick a base year that makes it look most stringent relative to its peers. For example, Australia ranks sixth with a 1990 base year, but rises to third in ambition relative to BAU. Likewise, the EEFSU's commitment means minimal reductions relative to baseline but ranks third in the 1990 roster. The rankings of commitments by Japan and the EEFSU don't vary by formulation. The highlighted cells in Table 5 show that when given flexibility in its commitment formulation, not all countries choose the approach that maximizes their rank. Australia would have looked more ambitious relative to its peers had it chosen a 2005 base year, and the U.S. would have ranked higher with a 2000 base year formulation.

Other Measures of Emissions Reductions

Table 6 below shows the emissions outcomes of Table 4 recast in terms of emissions per unit GDP, or emissions intensity. To calculate emissions intensity, we divide emissions levels by historical data for real GDP for the 1990, 2000, and 2005 base years and projected GDP for 2020, all in 2006 US dollars. The second column in Table 6 is emissions intensity in 2020 in the baseline and the third column is the same measure under the policy scenario. Column 4 of Table 6 shows that emissions intensity declines from 2005 to 2020 in all regions in the baseline, with the greatest decline of 37 percent in Brazil. Accord participation accelerates those declines.

Table 6. Copenhagen Accord Emissions Commitments in Intensity Terms[8]

	1	**2**	**3**	**4**	**5**	**6**
Region	**Emissions Intensity in 2005 ($MMTCO_2$/ $2006GDP)**	**Baseline Emissions Intensity in 2020 ($MMTCO_2$/ $2006GDP)**	**Emissions Intensity in 2020 under Accord**	**Percent Change in Intensity from 2005 to 2020 in Baseline**	**Percent change in intensity from 2005 to 2020 under Copenhagen Accord**	**Percent Change in 2020 Emissions Intensity Relative to BAU**
USA	0.47	0.38	0.26	-18	-44	-31
Japan	0.28	0.27	0.15	-3	-47	-46
Australia	0.56	0.45	0.31	-20	-44	-30
W. Europe	0.27	0.21	0.14	-20	-46	-33
ROECD	0.53	0.38	0.30	-28	-43	-20
China	2.35	1.73	1.41	-26	**-40**	-18
India	1.40	1.13	1.12	-20	**-20**	0
EEFSU	1.61	1.20	1.22	-26	-25	2
Brazil	0.40	0.25	0.25	-37	-37	1
LDC	0.76	0.49	0.50	-35	-34	1
OPEC	1.12	0.91	0.98	-18	-12	8
World	0.61	0.58	0.49	-5	-19	-15

The sixth column of Table 6 shows the percent change in intensities in the policy scenario relative to the 2020 baseline. Overall, world emissions relative to world GDP

[8] Boldface numbers represent commitments as articulated in the Copenhagen Accord.

declines by 15 percent as a result of the Accord. The relative ambition by different countries is similar to the ambition in emissions levels reflected in Table 4. Again Japan is undertaking the most ambitious commitment with an intensity decline of 46 percent relative to baseline by 2020. Japan is significantly more ambitious than the next most ambitious countries, Western Europe, the U.S., and Australia, with intensity declines of 33, 31, and 30 percent respectively. Table 6 also shows that China's intensity target results in substantial intensity reductions relative to baseline (18 percent), on par with the 20 percent intensity reductions of developed countries in ROECD.

Table 7 shows the as the emissions commitments from Table 6 expressed in per capita terms. This table reveals that on a per capita basis, Japan will lower its emissions per capita relative to baseline the most, by 48 percent.

Table 7. Copenhagen Accord Emissions Commitments in Per Capita Terms

	1	2	3	4
Region	**Emissions Per Capita in 2005**	**Emissions Per Capita in 2020 in Baseline**	**Emissions Per Capita in 2020 under Accord**	**Change in 2020 Per Capita Emissions Relative to BAU**
USA	20	22	15	-33
Japan	10	12	6	-48
Australia	21	23	15	-35
W. Europe	12	14	9	-36
ROECD	18	18	14	-25
China	4	13	10	-22
India	1	2	2	0
EEFSU	11	14	14	-1
Brazil	2	3	3	1
LDC	2	2	2	1
OPEC	8	10	11	1
World	4	7	5	-17

Figure 3 and Table 8 summarize the ranking of emissions reductions reflected in the Copenhagen target in level, intensity, and per capita terms. Figure 3 shows that on all measures Japan reports the greatest emissions declines. Of regions with Accord targets, India and EEFSU are the least ambitious across all measures. The U.S. is within a few percentage points of Western Europe and Australia, followed by the ROECD and China. We find small effects of the Accord in India, Brazil, EEFSU, and other LDCs. Consistent with its energy intensive economy and not having price on carbon, emissions intensity rises in OPEC relative to baseline.

Table 8. Ranking of Participants by Reductions in Different Emissions Measures

Rank	Change in 2020 Emissions Levels relative to BAU	Change in 2020 Emissions Intensity relative to BAU	Change in 2020 Per Capita Emissions Relative to BAU
1	Japan	Japan	Japan
2	Europe	Europe	Europe
3	Australia	USA	Australia
4	USA	Australia	USA
5	ROECD	ROECD	ROECD
6	China	China	China
7	EEFSU	India	EEFSU
8	India	EEFSU	India

4. Environmental and Economic Outcomes of the Copenhagen Targets

To assess how climate policy might affect outcomes of interest, we compare the values of economic and environmental variables in the policy scenario to their values in the reference scenario. This section looks beyond different measures of the target 2020 reductions in Section 3 to examine longer term environmental effects and the burdens countries incur to achieve them. As before, we focus on outcomes as percentage changes from reference.

Figure 4 shows fossil CO_2 emissions by region in the policy scenario. This stacked graph shows a marked departure from the analogous baseline graph, Figure 1. The sharp decline in the policy scenario emissions in 2012 reflects the imposition of the price signal by Accord participants. The graph shows that world emissions are almost 10,000 $MMTCO_2$ lower in 2020 than in the baseline scenario. Figure 5 shows emissions relative to baseline through 2025.

Table 9 shows the percentage change in each country's cumulative emissions between 2013 and 2020. For reference, the percentage changes in 2020 emissions from Table 7 are shown as well. Because Annex I policies become increasingly stringent over time, cumulative reductions for those countries are somewhat smaller in percentage terms than their 2020 commitments. Cumulative U.S. emissions, for example, are 27 percent below the reference case while 2020 emissions are 33 percent lower. These results are sensitive to the simplifying policy assumptions we have made. For example, the cumulative emissions reductions in Table 9 are closer to 2020 reductions than would be the case under a policy scenario that enforced a linear decline in emissions levels rather than the particular increasing real price path we specified.

Table 9. Emissions Outcomes of Copenhagen Accord

Region	Percent change in 2020 emissions levels relative to BAU	Percent Change in Cumulative Emissions, 2013 to 2020, relative to BAU
USA	-33	-27
Japan	-48	-38
Australia	-35	-29
Europe	-36	-28
ROECD	-25	-19
China	-22	-20
India	0	1
EEFSU	-1	-1
Brazil	1	1
LDC	1	1
OPEC	1	2
World	-17	-15

The economic consequences of the Accord vary significantly between countries. Table 10 provides several measures of the effects of each country's commitment. The first two columns provide a measure of the marginal cost of the Accord: CO_2 prices in US dollars per ton of carbon dioxide in 2012 and 2020. Figure 6 shows the trajectory of CO_2 prices in the relevant regions. Measured in these terms, the Accord's stringency is highest in Europe and Japan, both of which have 2012 prices above $50 per ton. Next in order of stringency is the United States, with a 2012 CO_2 price of $28. Somewhat lower are Australia, China and ROECD, all of which have 2012 CO_2 prices below $20 per ton. Finally, India and EEFSU have the substantially lower stringency with 2012 prices around $1 per ton. By 2020, CO_2 prices in all regions are 37 percent larger, reflecting the four percent real rate of growth imposed in the simulation. The relative stringency between countries—measured in terms of CO_2 prices—is identical to that in 2012.

The next three columns in Table 10 provide alternative measures of economic effects of the Accord. It shows the effects on real GDP and consumption in 2020, and on the present value of consumption from 2012 to 2020, all as percentage changes relative to the reference case. By this measure, India actually gains slightly (about one percent). GDP declines in other regions with the largest effects in Australia, ROECD and OPEC (reductions of roughly six percent), followed by slightly smaller effects in Japan and Europe (about five percent), then China (about four percent), the United States and EEFSU (about three percent), and finally Brazil and LDCs (reductions of about one percent).

We emphasize that these results reflect reductions ***relative to the 2020 reference case***. In other words, the Accord slows GDP growth, but GDP generally increases from year to year from 2012 to 2020, even in the regions where the policy impacts are largest. The drop in the average annual growth rate ranges from 0.1 to 0.3 percentage points, with the largest reductions in Japan and Western Europe. The decline for the U.S. is 0.23 percentage points. That is, the average annual U.S. growth rate from 2012 to 2020 declines from 2.66 to 2.43 percent as a result of global greenhouse efforts. This means that under the policy scenario, in 2020 the U.S. GDP would be 22 percent larger than in 2012 rather than the baseline projection of 25 percent larger. The U.S. result is characteristic of most other regions. The one exception to this broad pattern appears in Japan, which has relatively slow baseline GDP growth. Japanese GDP drops slightly from 2012 to 2013 under the Accord, and then rises consistently thereafter.

Table 10. Economic Outcomes of Copenhagen Accord

Region	Economy-wide 2012 price per ton CO2 ($2006)	Economy-wide 2020 price per ton CO2 ($2006)	Percent change in 2020 GDP relative to BAU	Percent change in 2020 consumption relative to BAU	% change in discounted cumulative consumption (2012 - 2020) relative to BAU
USA	$28.09	$38.44	-2.7	0.0	0.9
Japan	$50.36	$68.92	-5.1	-3.1	-2.0
Australia	$15.91	$21.78	-6.3	-2.0	-1.4
W. Europe	$56.76	$77.68	-4.9	-3.1	-1.8
ROECD	$18.06	$24.72	-5.6	-3.9	-3.0
China	$15.22	$20.82	-3.7	-4.5	-2.8
India	$1.02	$1.40	0.7	1.6	2.3
EEFSU	$0.95	$1.30	-2.9	-3.4	-2.6
Brazil	-	-	-0.4	-0.5	-0.1
LDC	-	-	-0.6	-0.5	0.2
OPEC	-	-	-5.9	-13.2	-12.1
World	-	-	-3.2	-2.1	-1.0

Note that the ordering of regions by marginal cost differs significantly from the ordering by GDP effect. For some countries, GDP effects tend to mirror price effects: Japan and Europe have high carbon prices and are among the highest in terms of GDP effects; the United States and China both have moderate carbon prices and moderate GDP effects; and Brazil and the LDCs have zero carbon prices and low GDP effects. In contrast, Australia, ROECD and EEFSU have relatively large GDP effects despite having small or zero carbon prices. For these regions, the GDP effect is exacerbated by strengthening of the U.S. dollar and capital flows out of these regions into the United States. OPEC also suffers a large drop in GDP relative to the reference case although in its case the effect is simply due to a sharp decline in the world demand for oil. Finally, India's terms of trade improve as a result of the Accord and its GDP rises slightly even though it imposes a small price on carbon.

In terms of consumption, the Accord separates the regions into roughly three groups: the developed countries, which have smaller 2020 declines in consumption than in GDP; the developing and transition economies, in which GDP and consumption effects are roughly similar; and OPEC, for which the 2020 decline in consumption is far larger than the contemporaneous decline in GDP. Developed country consumption declines less than GDP in part because the commitments in the Accord raise energy prices enough to induce substantial conservation, which leads to reductions (relative to the reference case) in the output of the energy sectors and the investment needed for new mining and electrical generation capital. In addition, the effect on consumption is also moderated by improvements in the terms of trade of countries formerly importing large amounts of crude and refined petroleum.

The final column in Table 10 shows the effect of the Accord on the discounted present value of consumption. The results parallel the changes in 2020 consumption but are lower in magnitude for the same reason that cumulative changes in emissions are lower than 2020 changes: the policies are phased in gradually over time. A concise comparison of the economic effects of the Accord is shown in Table 11.

Table 11. Rankings of Accord Burden by Economic Outcome

Rank	2012 Price on CO_2	Rank in GDP losses in 2020	Rank in Consumption Losses in 2020
1	**Europe**	**Australia**	**OPEC**
2	**Japan**	**OPEC**	**ROECD**
3	**USA**	**ROECD**	**China**
4	**ROECD**	**Japan**	**EEFSU**
5	**Australia**	**Europe**	**Japan**
6	**China**	**China**	**Europe**
7	**India**	**EEFSU**	**Australia**
8	**EEFSU**	**USA**	Brazil
9		LDC	LDC
10		Brazil	**USA**
11		**India**	**India**

Our goal here is to assess the broad ambition of the commitments in the Accord independent of the as-yet-unwritten rules that will elaborate how they might be achieved. That said, both the emissions and economic outcomes discussed above are importantly dependent on our assumption that each region achieves its commitment domestically through reductions in fossil-fuel-related CO_2. We do not include a number of features that may be part of an eventual binding agreement and would influence the pattern of effects across countries, including: international emissions trading, domestic and international offset programs, changes in land use and forestry, or direct financial and technological transfers from the developed world to developing countries.

Under international emissions trading, each participant would be responsible for meeting its announced target but high-cost countries would be able to substitute low cost reductions abroad for higher cost domestic abatement. Total emissions of participating countries would be the same as the policy scenario modeled here but trading would lead to a single international carbon price and would minimize the overall cost of attaining the joint goal of the participants. The pattern of emissions reductions across countries would differ, as would the economic effects and potentially the effects in non-participating countries as well. The wide spread of carbon dioxide prices illustrated in Figure 6 suggests substantial potential gains from international exchanges that would induce more abatement in lower cost areas in exchange for less abatement in higher cost areas.

The outcome of a scenario combining the Copenhagen commitments with offset programs, including domestic and international land use and forestry activities, is harder to predict. By allowing additional compliance options, abatement in high cost regions and sectors would be lower, so overall costs would be lower. However, the specific rules governing offsets—including the incremental abatement that can be induced through offsets, the actual environmental performance of offsets, and transactions costs involved—would strongly influence the pattern of emissions and economic effects across countries.

5. Conclusion

The Copenhagen Accord marked the beginning of a new approach to international climate agreements. Previously, each round of negotiations generally adopted a fixed base year against which emissions commitments were to be measured and participating countries then negotiated a set of reductions relative to emissions in that year. The Accord breaks away from that approach by allowing each country to choose its own base year and to express its commitment in terms other than absolute reductions in emissions. This flexibility promoted consensus and allowed an agreement to be reached. At the same time, however, it complicates comparing the emissions reductions and economic efforts implicit in the commitments made by the participants.

In this paper, we have provided such a comparison using the G-Cubed model of the global economy. Our results show that alternative ways of expressing a commitment can make a single set of targets appear strikingly different in stringency. Moreover, we show that the actual stringency of the Accord, as measured by either GDP or consumption loss relative to a reference case, differs sharply across countries. This is because the economic consequences of each target depend importantly on a number of factors: the size of each country's economy in 2020; the internal structure of its economy; the extent to which carbon-intensive energy sources are a critical part of the energy system in 2020; the endowment of fossil fuels in each economy; and the ease or difficulty of substituting energy sources of energy intensive goods in production and consumption bundles. All of these factors affect the ambition embodied in the Accord's commitments.

Finally, we also find that for many countries the domestic price on carbon is a poor predictor of the welfare implications of the overall agreement. For example the United States has the third highest carbon price but nearly no loss of consumption. On the other hand, OPEC has no price on carbon and experiences profound consumption losses because other countries are taxing OPEC exports and reducing global demand for these goods. The effect on OPEC suggests that the member countries would have an incentive to collectively raise world fuel prices if they can rather than suffer large losses in their terms of trade.

References

McKibbin W., D. Pearce and A. Stegman (2009) "Climate Change Scenarios and Long Term Projections" *Climate Change*, 97(1-2), pp 23-47.

McKibbin, W., A. Morris, P. Wilcoxen, and Y. Cai (2009), "Consequences of Alternative U.S. Cap-and-Trade Policies: Controlling Both Emissions and Costs," The Brookings Institution, June. http://www.brookings.edu/~/media/Files/rc/reports/2009/07_cap_and_trade/0727_cost_containment.pdf

McKibbin, W J. and P J. Wilcoxen (1999), "The Theoretical and Empirical Structure of the G-Cubed Model," *Economic Modelling*, 16(1999), pp. 123-148.

Appendix I: Country Composition of Regions in the G-Cubed Model

Number	Region Name	Region Description
1	**USA**	United States
2	**Japan**	Japan
3	**Australia**	Australia
4	**Europe**	Western Europe
5	**ROECD**	Rest of the OECD
7	**China**	China
8	**India**	India
9	**EEFSU**	Eastern Europe and the former Soviet Union
10	**Brazil**	Brazil
11	**LDC**	Other Developing Economies
12	**OPEC**	Oil Exporting Developing Countries

Western Europe: Germany, France, Italy, Spain, Netherlands, Belgium, Luxemburg, Ireland, Greece, Austria, Portugal, Finland, United Kingdom, Norway, Sweden, Switzerland, Denmark, Iceland, Liechtenstein

Rest of OECD: Canada, New Zealand

Oil-exporting and the Middle East: Ecuador, Nigeria, Angola, Congo, Iran, Venezuela, Algeria, Libya, Bahrain, Iraq, Israel, Jordan, Kuwait, Lebanon, Palestinian Territory, Oman, Qatar, Saudi Arabia, Syrian Arab Republic, United Arab Emirates, Yemen

Eastern Europe and Former Soviet Union: Albania, Armenia, Azerbaijan, Bulgaria, Belarus, Cyprus, Czech Republic, Estonia, Georgia, Croatia, Hungary, Kazakhstan, Kyrgyzstan, Lithuania, Latvia, Malta, Poland, Romania, Russian Federation, Slovakia, Slovenia, Ukraine, Republic of Moldova, Tajikistan, Turkmenistan, Uzbekistan

Other Developing Countries: All countries not included in other groups.

Appendix II: Baseline Projections

G-Cubed's baseline (no-policy) scenario reflects our judgment about the likely evolution of economic and emissions growth in the absence of concerted policies to control greenhouse gas emissions. Like most studies of climate policies, the results can be sensitive to these baseline projections. Thus we document here how and why the baseline projections in this study differ from another set of projections many modelers use that is produced by the Energy Information Administration (EIA), an independent analytical arm of the U.S. Department of Energy. The EIA publishes the *International Energy Outlook*. The 2009 edition of this report (*IEO2009*) assesses the outlook for international energy markets through 2030.[9]

The procedure we use to generate our baseline follows the approach in McKibbin, Pearce and Stegman (2009). We specify the expected productivity growth in each sector in the U.S. from 2006 to 2100. We then specify the gap in the productivity level of each sector in each country relative to the U.S. in 2006 measured in terms of purchasing power parity. We also specify a time varying rate of catch up between each sector in each country and the equivalent U.S. sector. This time varying catch-up rate reflects assumptions about the ability of countries to catch-up and is intended to reflect the evidence in the convergence literature that group of countries catch-up to the technological frontier at different rates and appear to form "convergence clubs".

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[9] The *IEO2009* is available here: http://www.eia.doe.gov/oiaf/ieo/index.html.

The final choice variable that we use to reflect historical experience is the rate of autonomous energy efficiency improvement in each production sector in each country as well as in the household consumption bundle.

Given these assumptions and predictions of population growth by country from the United National "medium-variant" projections, we use the model to endogenously generate the rate of economic growth by each country given the rate endogenous rate of capital accumulation in response to the exogenous drivers of growth and efficiency outlined above. The composition of each economy is generated endogenously as is the energy use and the type of energy use.

Table A1. Average Annual Percent Change in GDP and Emissions 2006-2030

Region	GDP growth in G-Cubed	GDP Growth in IEO2009	Emissions Growth in G-Cubed	Emissions Growth in IEO2009
USA	2.7	2.4	1.7	0.3
Japan	1.5	0.8	0.9	-0.3
Australia	2.9	3.0	1.4	0.6
W. Europe	2.1	2.0	0.8	0.1
ROECD	2.4	2.3	0.8	0.7
China	7.4	6.8	5.8	2.8
India	5.9	5.9	4.6	2.1
EEFSU	2.5	3.9	1.2	0.7
Brazil	4.8	3.8	2.9	2.5
LDC	6.6	4.0	4.7	1.9
OPEC	4.3	4.0	3.5	1.9

One issue that is immediately obvious in Table A1 is that although the GDP growth rates tend to be similar over the period across the two studies, the rate of improvement in CO_2 emissions per unit of GDP are noticeably different. The G-Cubed numbers are consistent with recent historical experience. There is probably a significant amount of policy already embedded in the IEO numbers which may explain some of the difference. The differences may also reflect an endogenously determined structure in G-Cubed that is different to assumptions made in the *IEO2009*. Either way the results in this paper are different than they would have been had we used the same assumptions as the *IEO2009*.

Figure 1: Baseline Scenario Fossil CO2 Emissions

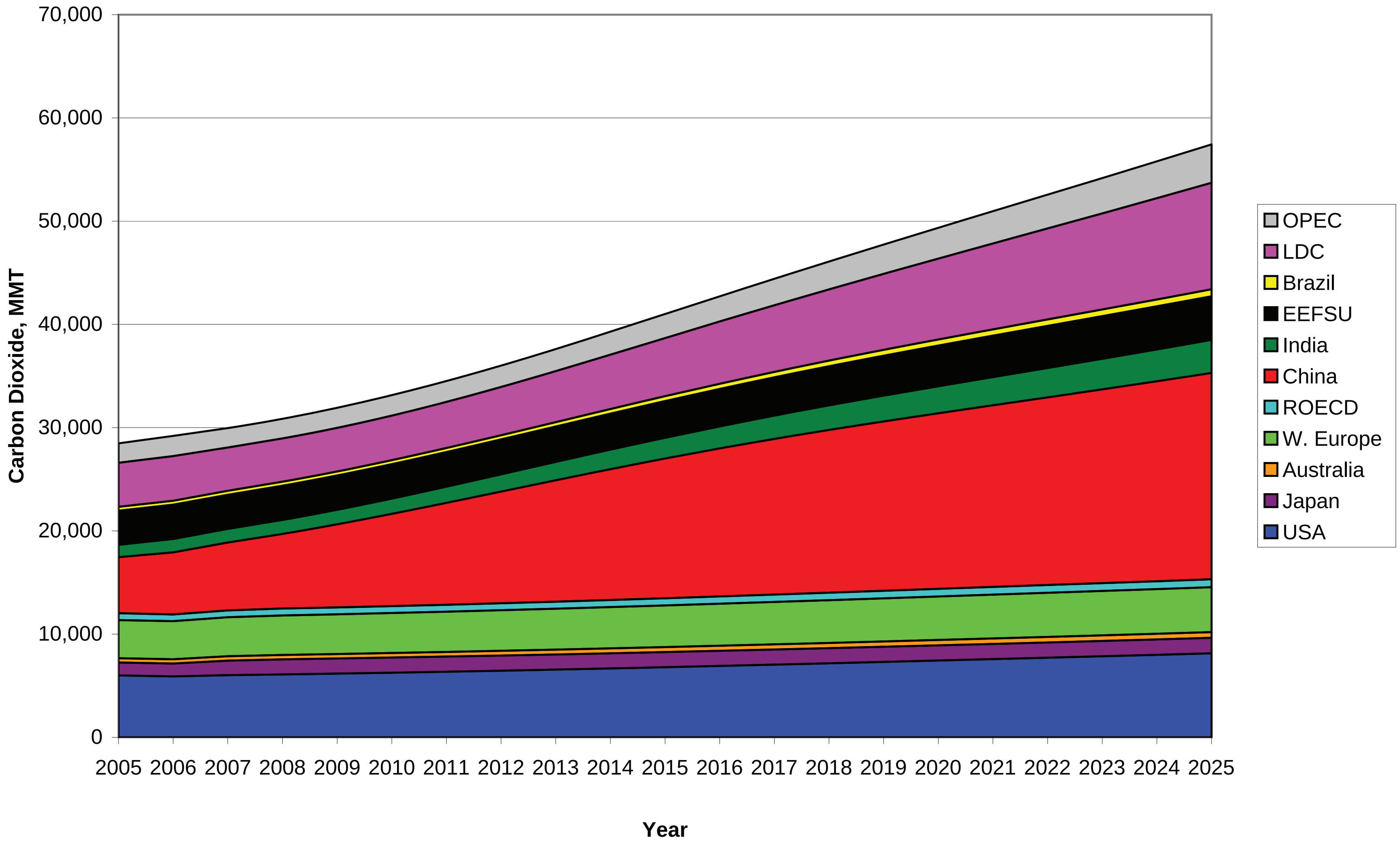

Figure 2: 2020 Policy Scenario Emissions Levels Relative to Different Base Years

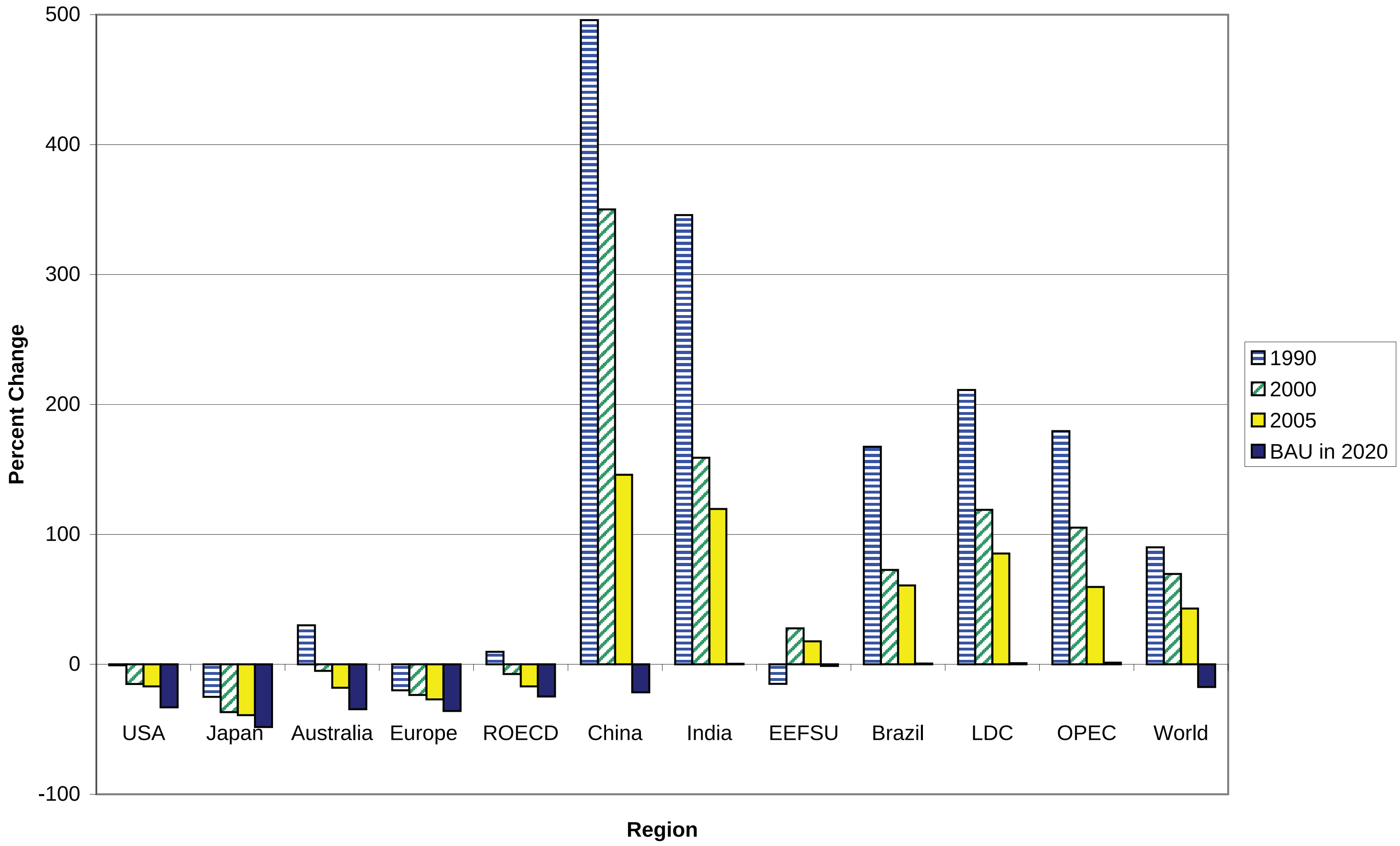

Figure 3: Percent Change in 2020 Emissions Relative to Baseline

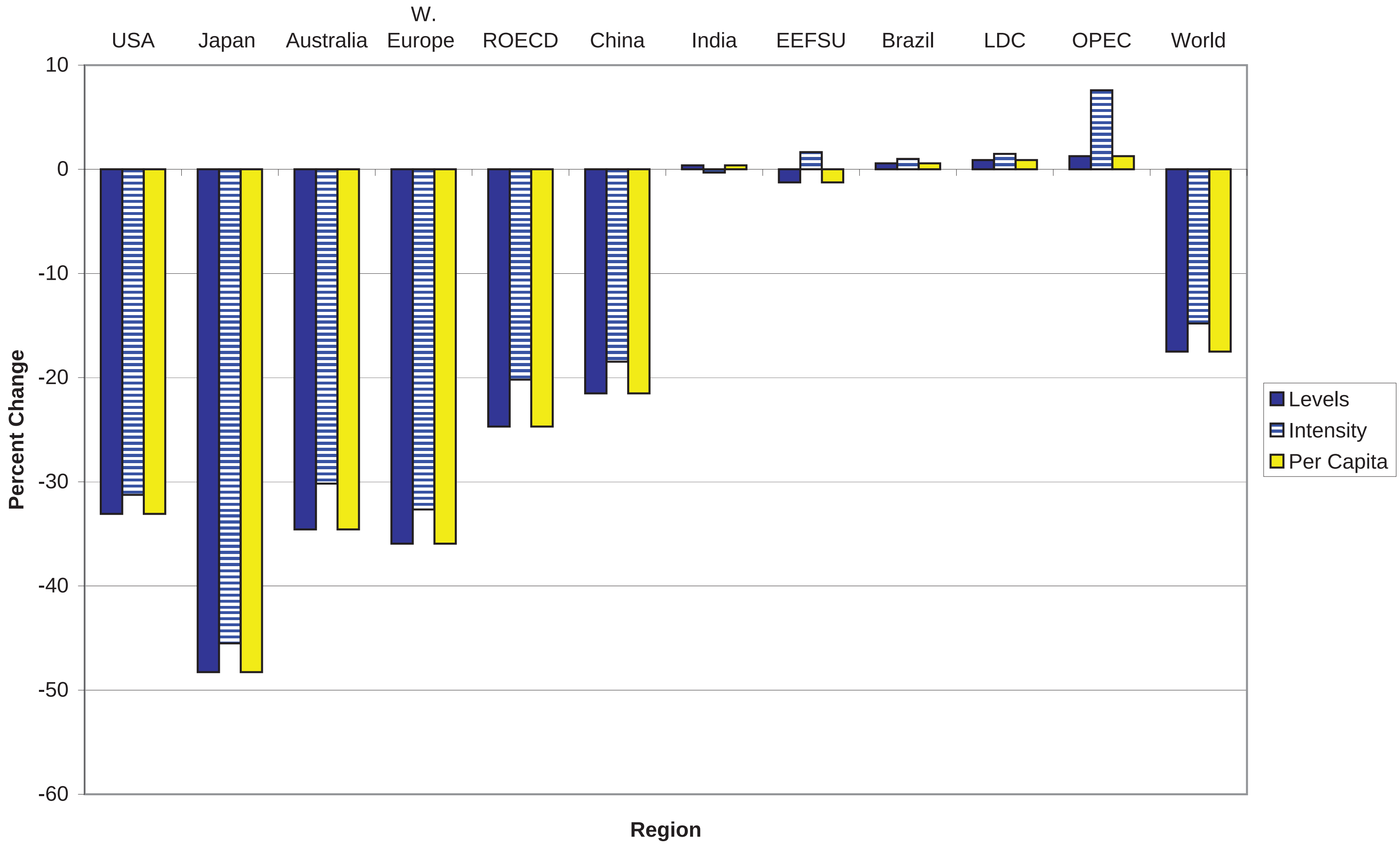

Figure 4: Policy Scenario Fossil CO2 Emissions

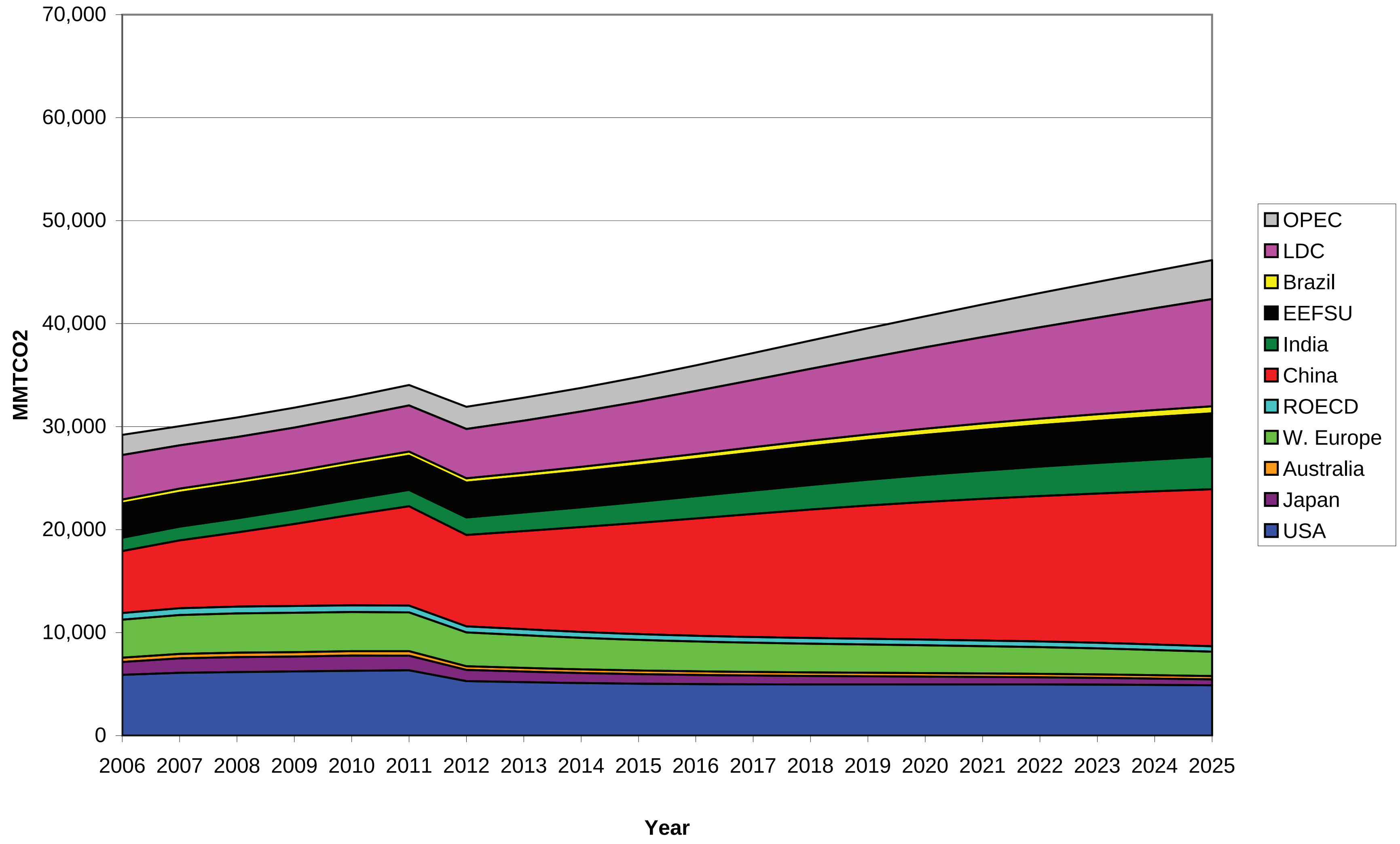

Figure 5: CO_2 Emissions Relative to Baseline

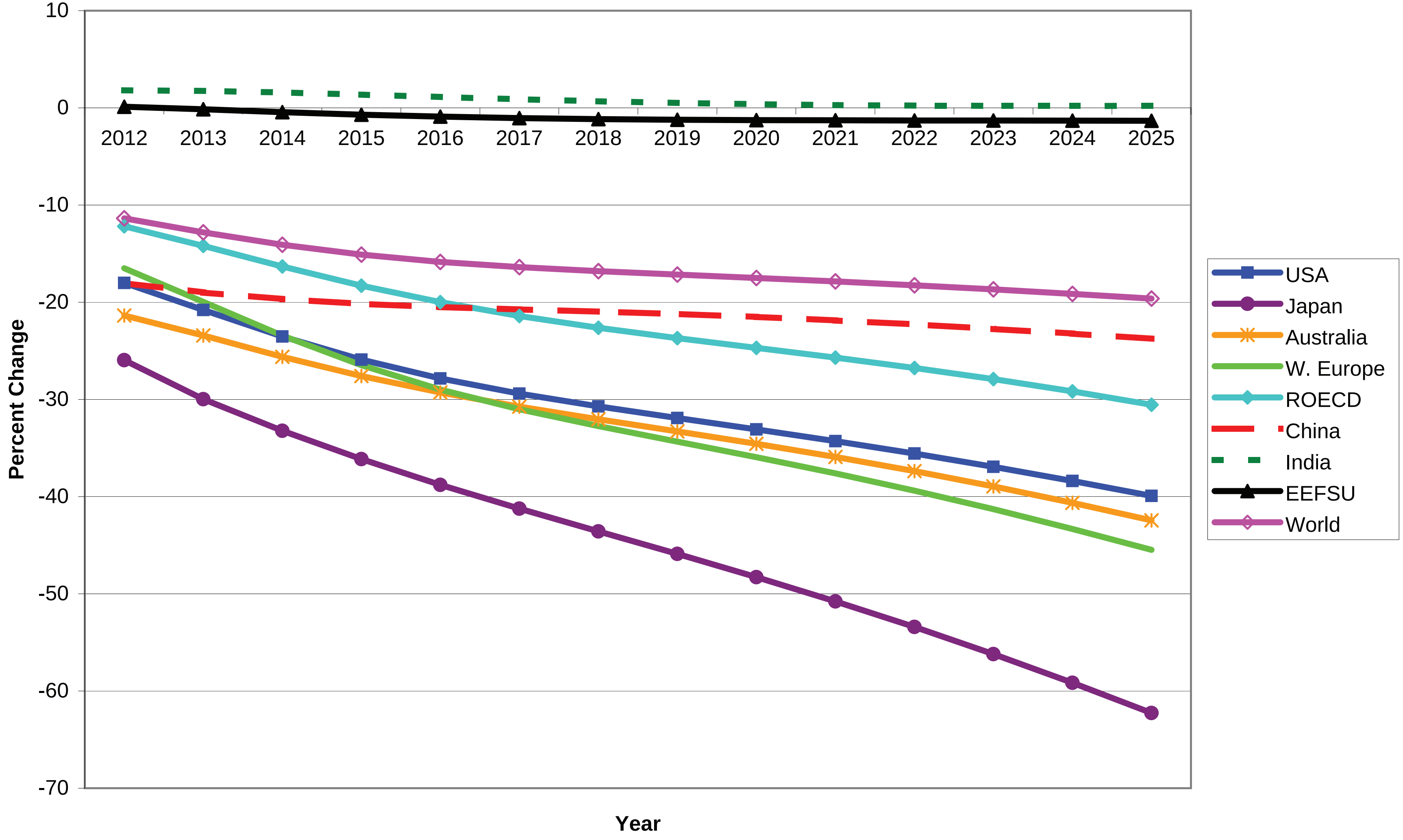

Figure 6: Price per Metric Ton of CO_2