THE CLIMATE GROUP

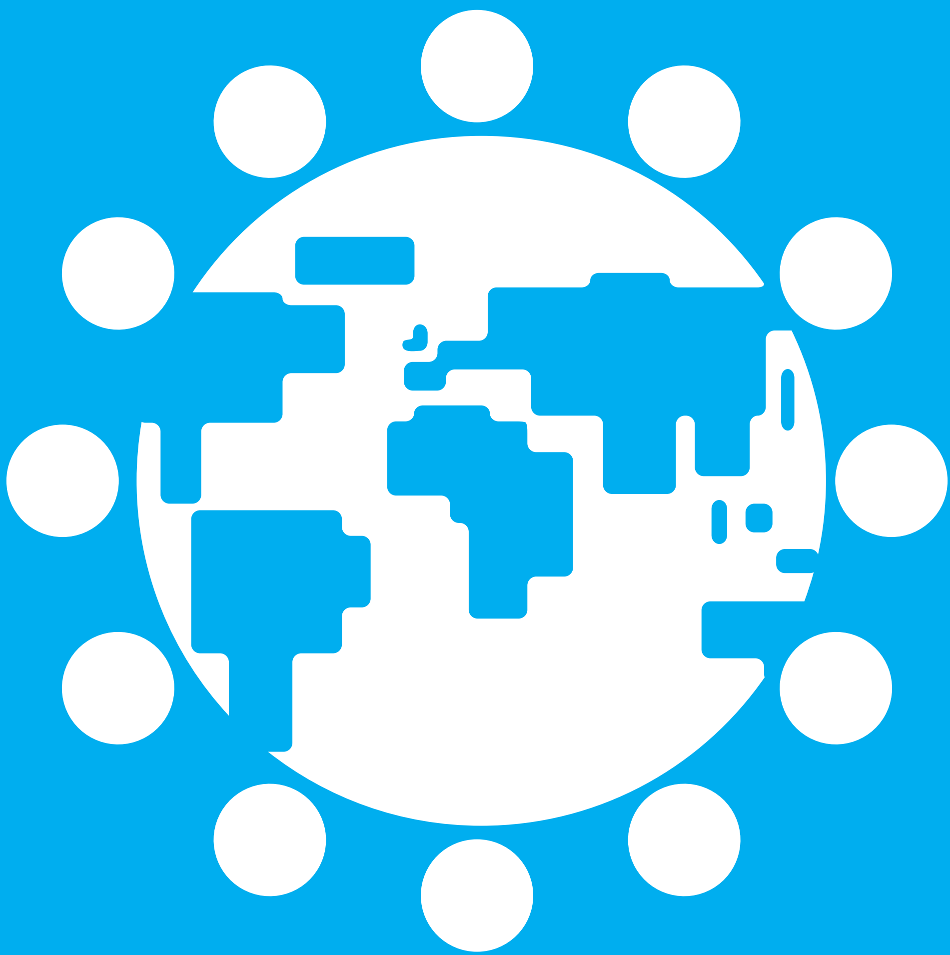
The Office of Tony Blair

BREAKING THE CLIMATE DEADLOCK

CUTTING THE COST

THE ECONOMIC BENEFITS OF COLLABORATIVE CLIMATE ACTION

SEPTEMBER 2009



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FOREWORD

It has not taken long for people to understand that climate change is more than just an environmental issue. The impacts of global warming threaten people's homes, their livelihoods, their food supply and their health. Businesses, transport systems and infrastructure are at risk. The economic consequences of unchecked climate change are likely to be huge.

Dealing with climate change is also primarily an economic issue, affecting investment in the development and deployment of technology, international trade, competitiveness, jobs, equity and growth itself. It is this economic characteristic – coupled with the fact that climate change can only be successfully addressed at a global level - that has made reaching an ambitious international agreement so difficult, particularly in times of economic crisis. And, despite the fact that it is widely recognised that the cost of cutting emissions is far outweighed by the cost of doing nothing, concerns over our ability to deploy the technologies we need and the distribution of the costs has led to further delays.

Since I launched the Breaking the Climate Deadlock Initiative with The Climate Group eighteen months ago, we have addressed these issues head on. In our first report, A Global Deal for our Low Carbon Future, we identified ten key areas that would need to be addressed in order to establish an effective and equitable new international climate agreement. This was accompanied by 14 briefing papers, providing succinct up-to-date information on a range of technological, scientific, economic and institutional issues that will underpin this agreement.

Ahead of this year's G8 and Major Economies Forum meetings, we published Technology for a Low Carbon Future which demonstrated how, over the next decade, we can get on to a path consistent with avoiding dangerous climate change using technologies that are already commercially proven and policies that have already been shown to be successful. A new deal in Copenhagen is not about science fiction but about science fact; it is about doing what we already know, but better and faster.

This latest report, Cutting the Cost: The Economic Benefits of Collaborative Climate Action, presents the results of modelling work that we commissioned from a group of leading Cambridge University economists. We wanted to know whether there was an advantage, and how large it would be, if countries act collaboratively rather than individually.

What is immediately striking is the enormous cost savings that can be achieved if countries work together. Previous economic analysis has shown the global benefits of collective action; what we do for the first time here is show that these benefits accrue to all countries, with costs more than an order of magnitude lower when there is global participation. Moreover, the report shows that an ambitious deal can be good for both economic growth and employment, with potentially up to 10 million additional new jobs created over the next ten years.

Some may choose to quibble about the exact numbers in the analysis, while others may argue that the policy scenarios used are unrealistic. This misses the point. Our objective is not to prescribe the targets and timetables that should be adopted: that is the job of scientists and governments. Rather, the scenarios used in this report have been developed for purely illustrative purposes, to understand whether and how greater collaboration can bring down costs and increase economic benefits. However, the overall message is clear: even ignoring the costs of climate change itself, the world benefits economically from action to cut emissions.

This is not to say that forging a global deal, and then implementing it, will be easy. But what we can say is that world leaders can have the confidence to know that reaching a successful conclusion in Copenhagen this December is both achievable and consistent with their measures to promote economic recovery. In fact, crafted right, an ambitious global deal can be a key part of this recovery. There is no reason to delay.

Tony Blair

Rt Hon Tony Blair

EXECUTIVE SUMMARY

COLLABORATIVE GLOBAL ACTION TO CUT CO_2 EMISSIONS CAN SIGNIFICANTLY LOWER THE COST OF CLIMATE CHANGE MITIGATION AND INCREASE BOTH GDP AND EMPLOYMENT IN ALL MAJOR ECONOMIES.

The economic costs of tackling climate change have long been a point of debate for academics, politicians and business leaders. Concerns about these costs, and where and how they might fall, have proved one of the major obstacles to more ambitious international action on climate change, explaining in large part the world's failure so far to put itself decisively on a low-carbon development path.

The debate, however, has shifted greatly in recent years. The Stern Review unambiguously demonstrated the global benefits of early action and the high cost of inaction, while the IPCC's assessment reports have illustrated the major cost reductions achievable globally through collective effort.

This report builds on these earlier findings. It reframes the debate in terms of investment benefits rather than mitigation costs. It demonstrates that collaborative international action, involving both developed and developing countries, can greatly lower the cost of CO_2 reductions at both national and global levels. It shows that economic growth and job creation in all major economies can be sustained and even increased under ambitious mitigation scenarios. And it shines a light on the potential benefits from reflating the global economy through a global green 'New Deal' in Copenhagen.

THE CASE FOR COLLECTIVE MITIGATION ACTION

Scientists and economists are clear: cutting greenhouse gas emissions is urgent, and major progress is needed in the next ten years to avoid serious consequences for both the global economy and the environment.

But forging multilateral agreements can be difficult, time consuming and hostage to least-best compromises. Unilateral action is also politically difficult. Concerns about free riders, carbon leakage and the fact that no single country alone can stabilise global emission levels have proven to be critical barriers to action. Implicit in all these problems is an overarching concern with perceived cost, both at the national and global level.

Yet, the economic cost of achieving a given level of emission reduction could be reduced by international cooperation. Previous research has indicated that the establishment of a global carbon price, supported by coordinated research and development, and the adoption of ambitious international standards for low-carbon products could greatly lower the cost of climate change mitigation.

MODELLING THE EFFECTS OF COLLABORATION

This latest report from the Breaking the Climate Deadlock initiative, commissioned from a group of leading econometric researchers at the University of Cambridge, goes further, asking:

- If all nations work together, does it require a higher or lower carbon price per tonne of carbon dioxide to reduce emissions than if some countries or regions go it alone?
- Do some countries gain while others lose, or can all benefit?
- What are the impacts on GDP and employment at global and national levels?

To answer these questions, the research team estimated the mitigation costs and macroeconomic benefits of different unilateral, regional and global emission reduction scenarios using E3MG, a computer model of the global economy developed at the University of Cambridge. The model simulates economic activity under a range of policy scenarios and estimates energy demand and related greenhouse gas emissions. It is able to demonstrate the effect on economies and emissions of specific mitigation policies and capture the economic impacts of interactions between sectors and countries.

The model utilises a two-pronged approach for achieving emission reduction targets: i) carbon pricing and ii) progressive fiscal and taxation policies combined with other direct regulation. This combined approach is essential for addressing the twin market failures of global warming and insufficient technological innovation and development.

In each of the scenarios modelled, countries set the respective emission reduction targets for their economies as a whole. Revenues from carbon taxes or emissions allowances are recycled back into the economy, as reduced employment taxes and incentives for adopting low-carbon behaviours and technologies. Strong regulations are applied by all governments, coordinated internationally depending on the scenario, to rapidly reduce emissions from vehicles, buildings and power generation equipment. The model then establishes the lowest carbon price which will achieve this target and the resulting impact on economic output and employment.

The following emission reduction scenarios were modelled:

- EU-only action
- US-only action
- Joint EU and US action
- All developed countries take action
- All developed countries plus China take action
- Global agreement (all developed and developing countries take action)

For those scenarios that include developing countries, two variant approaches, involving relatively more or less ambitious action in developing countries, were modelled.

The parameters chosen for the model scenarios deliberately cover a range of options, from almost no additional action to cut emissions to a set of targets that probably go well beyond what will be agreed in Copenhagen. While they take into account the global emissions pathways suggested as necessary by the scientific community, they are in no way designed to be a policy recommendation or an indication of what is necessary or possible. Their purpose, instead, is to illustrate how collaboration on cutting emissions, even under stringent mitigation regimes, leads to net positive benefits for developed and developing countries alike.

KEY FINDINGS

The carbon price needed to reach emissions reduction targets drops dramatically as more countries are involved in an agreement.

This is a simple reflection of the larger pool of low-cost carbon reduction opportunities available under a multilateral agreement and the fact that, as markets grow, new technologies become commercially viable. Results show it would take a carbon price of \$65/tCO_2 for the EU to cut its energy related CO_2 emissions by 30% by 2020, operating alone. This falls to \$28/tCO_2 when the US joins in an agreement, and potentially to very low levels (about \$4/tCO_2) in the case of a global agreement. The very low carbon prices, however, are only valid if strong, coordinated, international regulations are in place so that key technologies are rapidly developed to decarbonise vehicles, electricity generation and buildings, in areas where low-carbon 'no regrets' options have been identified as available.[1] This dramatic fall in the required carbon price suggests that levels of ambition are achievable with global collaboration that would be prohibitive if countries acted alone.

Cutting emissions is good for the economy – projected global GDP increases with the coverage of the climate regime.

The modelling shows world GDP increasing slightly, compared to the 'no action' baseline scenario under all the climate mitigation scenarios considered. When there is only action in some regions, such as the EU and the US, these benefits are so small they fall within the margins of error of data and the model; nevertheless the fact that there is no negative impact suggests that possible carbon leakage impacts and loss of competitiveness are likely to be more than compensated by the benefits derived from leadership in a new range of low-carbon technologies and services. Under a global climate agreement, global GDP could increase by 0.8% by 2020 relative to projected GDP with no climate action.

[01] It must be noted that we continue to assume that other mitigation policies (e.g. regulations) are in place in all mitigation scenarios, in contrast to the baseline scenario (where such policies are not applied).

Employment benefits also increase with the coverage of the climate regime.
The greatest benefits for world employment come from a global agreement with more stringent targets adopted by developing countries. This creates in the region of 10 million more jobs worldwide by 2020. This is a small increase in relation to the global problem of falling employment in the current financial crisis, but valuable nonetheless. If only the EU or only the US take climate action, modelling predicts this will create around 1.1 million or 0.7 million more jobs in these regions respectively, and up to 2.89 million globally, by 2020. This is the first estimate of the employment effects at a global level of climate change mitigation policies.

Relatively less ambitious action by developing countries (reducing emissions to 2015 rather than 2010 levels by 2020) reduces the necessary carbon price, but means that the benefits of action, in terms of GDP and jobs, are lower too. This is because climate mitigation involves technological change. For developing countries, enhanced technological change acts as a spur to economic growth.

The electricity sector, heavy users of electricity and sectors with multinational firms such as motor vehicles are likely to benefit most from a global mitigation agreement, relative to a sub-global approach.

The benefits and impacts noted above stem mostly from knowledge sharing, agreed international standards, trading and expanded markets for new technologies, and they amplify the benefits of climate change mitigation when countries work together.

While these figures are striking, it is also important to avoid reading too much into the exact figures that are presented in this report. Policy is not often applied efficiently and the world economy is likely to change substantially in the coming years. In addition, the report does not consider the different ways in which the targets might be achieved. Its choice of emission reduction targets is illustrative and not intended as a recommendation for governments when they meet in Copenhagen. The core purpose of the report is to simply demonstrate the macroeconomic benefits and magnitude of cost savings possible through collective action. And, as we have shown, these benefits and savings are compelling.

CHAPTER 1 REFRAMING THE CLIMATE COST DEBATE

THE CASE FOR COLLABORATIVE ACTION

The scientific evidence is clear: before 2020 global greenhouse gas emissions (GHG) must peak and by 2050 they must be reduced by 50-85% below 2000 levels, in order to avoid a rise in global temperature of 2˚C or more above the preindustrial level.[2] Without ambitious international action, new scientific research[3] predicts close to, or even more than, a metre of sea level rise by the end of this century, due to melting glaciers and expansion of the oceans. These and other changes will have serious economic and human consequences.

As the UN's recent World Economic and Social Survey made clear,[4] effectively combating climate change now requires the active participation of both developed and developing countries. The emission cuts above cannot be met through individual, regional, or developed country-only action – a new global deal is required. But what does such a deal actually entail? Is it simply a portfolio of individual country actions with each nation working on its own or in regional groups? Or is it a truly collaborative and collective effort which creates shared goals, frameworks and institutions?

It may seem intuitive that all the countries should work together, because climate change is a tragedy of the global commons. Despite this, there remain uncertainties amongst decision makers, particularly with respect to the precise costs and benefits of such collective action.

And yet the broad environmental, political and economic benefits of cooperative global action are well known. For a start, multilateral agreements can effectively deal with the three key barriers that limit ambitious unilateral action, namely: i) failure to capture (for the acting nation) any benefits of climate policy accruing to other countries (free riding); ii) ineffectiveness because no single nation acting alone can stabilize GHG concentrations (lack of single strategic actor); and iii) relocation of national polluters with high abatement costs to other places (carbo7n leakage)[5].

Research also shows that collaborative policies, which equalise prices across countries (such as through emissions trading or the use of harmonised taxes), are more cost-effective than unilateral measures. Modelling studies reported by the Intergovernmental Panel on Climate Change (IPCC), in its Fourth Assessment Report on Mitigation[6], for example, typically find that emissions trading amongst industrialised countries halves the macroeconomic costs of meeting the targets in the Kyoto Protocol. International agreements can also provide the necessary framework for large scale financial support, technological cooperation and knowledge sharing.

But given the urgency of the situation, growing domestic appetites for action and the slow pace of international negotiations, countries and regions are increasingly taking action unilaterally. Key examples include the European Union Emissions Trading Scheme, sectoral programmes in Japan and a range of policies in China, India and elsewhere. Domestic emissions trading programmes have also been proposed in the US and Australia.

But does this bottom-up, unilateral action really offer a viable alternative to the collective approach embodied in the UN Framework Convention on Climate Change (UNFCCC) and other multilateral treaties? From an environmental perspective the answer depends on the level of individual ambition and the number of countries taking action. Based on current commitments, the situation is not encouraging, with emission reductions from total unilateral action still far below the level demanded by the climate science.

From an economic perspective the answer is less clear. The IPCC research noted above showed that unilateral action is cost-inefficient within the context of the Kyoto Protocol. But is this inefficiency significant on a global scale? What is the actual level of cost reduction that countries might forego by taking unilateral rather than collaborative action beyond 2012? What other macroeconomic benefits might be missed? Is it really necessary to work together or can the same goals be achieved at comparable cost through individual effort?

In the lead up to Copenhagen, knowing the answers to these questions will be critical if the international community is to choose the least expensive route to a low-carbon future and have the confidence to commit to the emissions path suggested as necessary by the scientific community.

02 IPCC (2007)
03 E.g. Rahmstorf (2007); Pfeffer et (2008)
04 UN (2009)
05 While the issue of carbon leakage carries considerable political weight, the empirical evidence for the so-called pollution-haven hypothesis is in fact poor
06 Metz et al (2007)

THE PURPOSE AND PARAMETERS OF THIS REPORT

This research was commissioned by the Breaking the Climate Deadlock Initiative – a partnership between the Office of Tony Blair and The Climate Group – to investigate the following economic questions, with respect to energy-related CO_2 emissions[7]:

i. If all nations work together does it cost more, or less, per tonne of carbon dioxide to reduce emissions than if some countries or regions go it alone?
ii. How does mitigation affect GDP and employment change, when nations are working together, or independently?

The report is not, however, policy prescriptive. It does not go deeply into answering questions relating to the achievement of climate targets or which policies will be appropriate for individual countries. It does not provide answers to how global financial support and technological cooperation might work or what a fair allocation of the costs of reducing emissions might be. Its choice of emission reduction targets for the modelling exercise is indicative only and based on one possible pathway for avoiding dangerous climate change. The targets should in no way be interpreted as recommendations for the international negotiating process. The report does, however, seek to show that working together is a far better strategy than going it alone.

07 We model CO_2 emissions from energy generation, transportation and industrial processes only. CO_2 emissions from deforestation, other land-use activities, as well as non-CO_2 gases are not included in the modelling.

CHAPTER 2 MODELLING COLLABORATIVE ACTION

THE ECONOMIC MODEL

The research for this report was carried out using a computer model of the global economy developed at the University of Cambridge, by the Cambridge Centre for Climate Change Mitigation and Cambridge Econometrics. The model, known as E3MG, simulates economic activity, energy generation and greenhouse gas emissions. It is able to show the effect on economies and emission levels of policies to cut emissions, such as emissions trading, carbon taxation or efficiency standards.

Box 1. The E3MG model: an overview*

E3MG ('Energy, Environment, Economy, Model: Global') simulates the entire global economy, representing it as 20 interacting regions. For each economic region (many of which are single countries) historical measures of consumer and government spending, production and consumption are collected for each of 42 sectors for every year from 1970 to 2006. Relationships between these quantities are estimated, so that the model can be used to project future economic trends, and to indicate how these quantities might change in response to mitigation policies.

Despite the sophistication of the E3MG model, the overall modelling process can be distilled down to three key steps:

Step 1: A cumulative emissions target is determined (e.g. based on climate science)
Step 2: Policies are defined that will be needed to achieve the targets, e.g.:
- a) Policies and measures such as regulation and the use of carbon revenues to develop new technologies
- b) A carbon price schedule

Step 3: The model is run using the policies and measures defined and the various prices from the carbon schedule. The carbon price is found that ensures the desired emissions target is achieved

Unlike most traditional economic models, E3MG does not assume the economy returns to a state of equilibrium where prices reflect a stable balance between supply and demand. It is built from observed relationships and trading interactions. It reflects the real economic situation, in which prices are unstable and can be different in different places, and resources such as labour are not fully employed.

E3MG also models the development of technology in response to changes in investment and policy represented within the model. This is termed 'induced technological change' and is known to reduce the projected costs of climate policy substantially[8]. In the IPCC's Fourth Assessment Report's comparison of 'induced technology' Models, E3MG is the most detailed and the only macroeconometric model reported.

*For a fuller description of the model please refer to Annex A.

There are three key benefits in using E3MG for modelling climate change mitigation policies. First, the detailed and disaggregated nature of the model allows the representation of fairly complex scenarios. Second, the econometric grounding of the model makes it better able to represent the behaviour in energy-economy systems. And third, a two-way feedback between the economy, energy demand/supply and environmental emissions provides an important advantage over other models which may ignore the interaction completely or only assume a one-way linkage.

The E3MG model can be used to estimate the carbon price that would be required to meet stated emission reduction targets. The carbon price is imposed in the model both through emissions trading in selected industrial sectors (e.g. energy production) and taxes on the carbon content of coal, oil and gas in all other non-trading sectors (e.g. transport). This is one example of a hybrid (tax and trading) approach to mitigation. The model also represents the implementation of other strong mitigation policies in addition to the carbon price, such as regulatory measures and technology incentives (see Box 2. Not by carbon price alone).

[08] Metz et al (2007)

Box 2. Not by carbon price alone

Although the focus in this report is on carbon prices, it is important to note that imposing a carbon price is not the only measure used to achieve the required emission cuts in this study. In addition to mandatory prices on carbon, the revenues from carbon taxes or emissions allowances are put back into the economy as reduced employment taxes and incentives for low-carbon technologies. Also, strong regulations are applied by all governments, to rapidly reduce emissions from vehicles, buildings and power generation equipment.

It is pertinent to include these other measures because research has shown that the G8 targets for greenhouse gas reduction (50% reduction by 2050) are unlikely to be met simply by imposing a carbon price, but will require these additional measures[9].

The scenarios used to compare unilateral with multilateral and global agreements are shown in Figure 1. In each case, the model was set up to create the necessary emission cuts in the acting country or regions only. The scenarios include an increasingly wide range of countries, beginning with the largest developed country emitters – the EU or the US only – and progressing to a global agreement. The most ambitious scenario, 5a, contemplates a global climate agreement with the participation of all countries in mitigation efforts, leading to emission cuts 27% below business-as-usual levels in 2020. For those scenarios that involve developing countries (4a, 4b, 5a, 5b), there are two possible levels of mitigation commitment. The targets are either to reduce to 2010 levels (more stringent) or 2015 levels (less stringent) by 2020.

Figure 1. Eight climate change mitigation regimes compared in the study, plus the reference (baseline) scenario

POLICY SCENARIO	REGION	ANNUAL CO_2 EMISSIONS[10] IN 2020 FOR ACTING REGION	TOTAL EMISSIONS ABATED COMPARED TO BAU ($MtCO_2$)
Reference	World	74 per cent higher than 1990	0
1a	EU	30 per cent less than in 1990	1277
1b	US	30 per cent less than in 1990	2359
2	EU and US	30 per cent less than in 1990	2520
3	Annex I	30 per cent less than in 1990	3898
4a	Annex I and China	Annex I: 30 per cent less than in 1990 China: return to 2010 levels	8853
4b	Annex I and China	Annex I: 30 per cent less than in 1990 China: return to 2015 levels	6096
5a	World	Annex I: 30 per cent less than in 1990 Non-Annex I: return to 2010 levels	10739
5b	World	Annex I: 30 per cent less than in 1990 Non-Annex I: return to 2015 levels	9112

09 Baker, Scrieciu, Fox (2008)

Box 3. Choice of scenario targets and other parameters

The emissions targets and underlying policy mixes modelled in this report are designed to provide a clear indication of the impact of international collaboration on climate change mitigation. They have been chosen to:

a) Illustrate the economic effects of action to reduce emissions that involves ever increasing numbers of countries working together; and,
b) Assess to what extent the results hold with more or less stringent policy regimes.

To achieve this the scenarios are designed to be significantly different from what might be a business-as-usual path, as well as being significantly different from each other. At the same time they fall within the bounds of what, with right political, social and economic conditions, is considered by many to be technically possible.

As such, they could be considered unrepresentative of what is likely to be agreed in Copenhagen in December 2009. For some they will be overly optimistic or stringent while, for others, they may not go far enough. However, the question of what the 'right' targets (for both developed and developing countries) should be is not the issue for this report; the eventual outcome will be the result of political negotiation guided by scientific evidence. The scenarios used here do not purport to represent this outcome or suggest what it should be.

In particular, the targets used to model the participation of developing countries should not be interpreted as either a recommendation for, or reflection of, developing country emissions reductions within UNFCCC negotiations.

It should also be noted that the model only includes energy-related emissions of CO_2. Therefore, the GHG emissions reduction potential from lower black carbon, improved agricultural and livestock practices, halting deforestation and industrial processes is not covered. All things being equal, inclusion of these options would likely reduce the cost of abatement and enable deeper emissions reductions. Finally, the model does not take into account the high costs associated with no action, i.e. the damage caused by unmitigated climate change.

Box 4. Modelling the effects of the financial crisis

The baseline or reference case used in this study includes the impact of the ongoing financial crisis and economic downturn. The downturn itself is depicted according to new economic theory and historical precedent, tracking observed declines in national trade and output as they have been reported. The model includes policy reactions to the crisis, in the form of fiscal stimulus packages that were announced up to the end of March 2009. It also simulates banks cutting back on expenditure, higher savings rates, and reduced access to credit.

[10] Energy-related CO_2 emissions only

CHAPTER 3 KEY FINDINGS

The results from the macroeconomic modelling show significant cost reductions for mitigating CO_2 through collaborative global action, and small but positive increases in global and national GDP and employment levels.

CARBON PRICES

Global collaborative action could significantly cut the carbon price needed to achieve a particular emissions target, potentially by up to a factor of 15, so long as strong climate regulations are also employed globally. Figure 2 shows the carbon prices necessary to achieve the required emissions cuts under each regime, as calculated by the E3MG model. The required price drops dramatically as more countries are included in an agreement, from \$65/tCO_2 for the EU alone or \$45/tCO_2 for the US alone, to about \$4/tCO_2 for a global agreement with relatively less ambitious targets for non-Annex I countries (see also Figure 3).

Figure 2. Carbon prices by 2020 in the scenarios (2000 US\$ / tCO_2)

POLICY SCENARIO	TARGET FOR 2020	CARBON PRICE (2000 \$ / tCO_2)
1a: EU–only action	30% below 1990 CO_2	65
1b: US–only action	30% below 1990 CO_2	44
2: EU and US joint action	30% below 1990 CO_2	28
3: All Annex I Countries	30% below 1990 CO_2	21
4a: Annex I and China (2010)	30% Annex I countries 2010 CO_2 levels for China	13
4b: Annex I and China (2015)	30% Annex I countries 2015 CO_2 levels for China	4
5a: World (Developing 2010)	30% Annex I countries 2010 CO_2 levels for non-Annex I	8
5b: World (Developing 2015)	30% Annex I countries 2015 CO_2 levels for non-Annex I	4

* The uncertainties in the data, estimation and modelling are such that the numbers here and in other places in the report should be interpreted as indicative of orders of magnitude only.

There are three main reasons behind this fall in the carbon price necessary to achieve the given emissions reduction objective:

- Carbon trading creates the opportunity for companies and countries to seek out emission reductions where they are cheapest. This is the logic behind all emissions trading schemes. Rather than each having to make its own uniform cuts, those actors covered by regulation can find the most efficient combination of making reductions at source and financing abatement opportunities elsewhere. Making reductions where it is most efficient to do so lowers the carbon price required, often quite significantly: sulphur dioxide trading in the United States, for example, has reduced the compliance costs for participating firms by as much as 80% and similar cost savings have been modelled for the EU–ETS [11].

- Building on the above, the greater the range of emission reduction opportunities that can be tapped into by countries, the more low cost abatement options there are likely to be. As developing countries – which tend to be less energy- and carbon-efficient, and hence have more low cost abatement potential – enter the agreement, so the carbon price becomes lower still. The various carbon abatement cost curves that have been developed[12] demonstrate the scale of opportunities that exist in developing countries, in some cases accounting for over half the global abatement potential by 2020, in particular from energy efficiency improvements and switching to cleaner fuels. Much of this opportunity exists because designing low carbon transport systems, manufacturing facilities, buildings and energy supplies from scratch is cheaper than retrofitting existing infrastructure, which is more often the case in the developed world. A key point to note here is that supporting mitigation in the developing world should not be seen as a cost but rather as an investment in cutting the cost of putting the world on to a sustainable growth path.

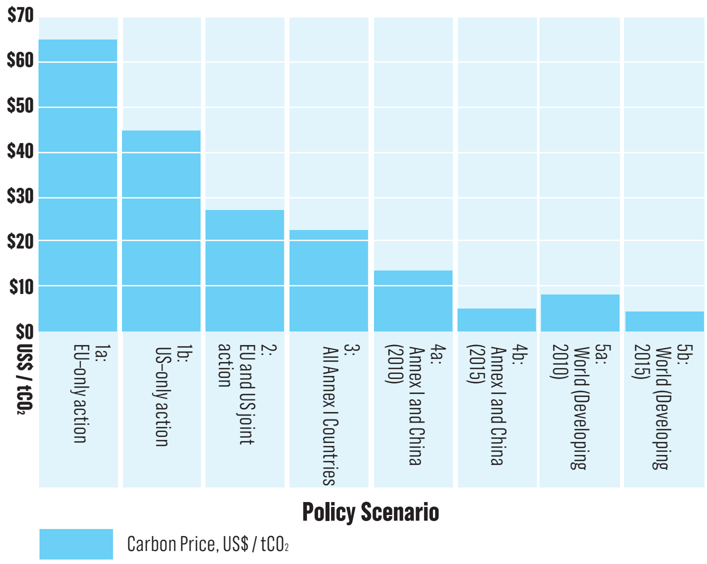
- As the number of countries participating in emission reduction efforts grows – either through taking on targets or by supplying credits to international carbon markets – so the market for low carbon technologies also grows, increasing expertise, driving innovation and bringing down production costs. This can already be seen in the case of both wind and solar energy where increasing demand, driven by direct incentives and the existence of a carbon market has lowered costs by more than half over the last decade[13]. This expansion of markets for new low carbon technologies also contributes to enhanced economic growth and, in particular, increased employment opportunities.

11 Curtis et al (2000)
12 E.g. see McKinsey and Company (2009)
13 NREL (undated)

Carbon prices are also lower when mitigation is less stringent in developing countries (i.e. returning to 2015, rather than 2010 levels). This result is due to simple supply-demand dynamics affecting global carbon markets. As noted above, when developing countries undertake mitigation action, they contribute a large pool of low-cost carbon reduction opportunities to carbon markets. This increase in supply creates a fall in the global cost of carbon. The actual extent to which the required carbon price falls depends on the level of overall demand. If developing countries take on more ambitious action, and hence help support demand, the required carbon price falls less than if developing country action is less ambitious.

All of these carbon prices would be much higher if the model did not assume that a price on carbon is accompanied everywhere by recycling of revenues and strong regulation to accelerate low emission technologies (see Box 2. Not by carbon price alone). It is also worth noting the current economic recession, the effects of which are included in the model[14], has made it relatively easier and cheaper to cut emissions.

Figure 3. Carbon prices by 2020 in the scenarios (2000 US$ / tCO_2)



GDP

The impact of ambitious collective action on global and national GDP is minor but positive: ambitious action increases rather than reduces economic growth.

Nearly all regions increase their GDP by 2020 relative to the baseline, in response to mitigation policy (see Figure 4). Figure 5 shows the growing benefit to total world GDP and employment under progressivley more comprehensive agreements[15]. The effects on GDP are small but need to be taken in context. For example, a key and repeated finding of previous research is that the macroeconomic benefits and costs of climate change mitigation will have a minor impact on global output growth: around -0.12 to +0.08 percent on average[16]. The results shown here support this, but also indicate that the impact could be more positive than earlier research has suggested. The positive results also counter arguments that ambitious mitigation action reduces economic output (see Box 5. Limitations of traditional economic modelling). It is also worth bearing in mind that the results are based on a comparison to a 'business-as-usual' baseline scenario, which does not factor in the negative impacts associated with unmitigated climate change.

[14] Global emission reductions due to the recession are estimated at 1.7 Gt CO_2 over the 3 year period 2007–2009

[15] There is no distinction between domestic and national product at the global level, so sometimes the term Gross World Product (GWP) is used. Gross Domestic Product is a more familiar term, so it is retained here, but is defined exactly equal to GWP.

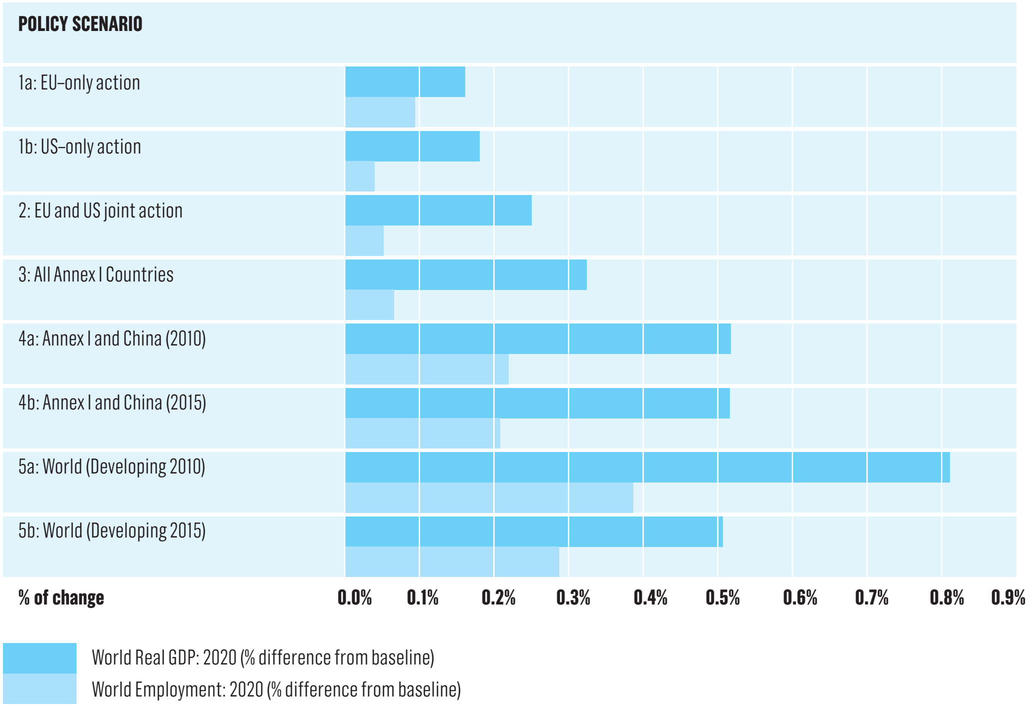
[16] IPCC (2007)

Figure 4. Changes* in GDP in 2020 across the policy scenarios for key countries and regions (% changes from the baseline)

POLICY SCENARIO	EU	US	EU and US	JAPAN	ANNEX I	CHINA	ANNEX I and CHINA	INDIA	MEXICO	WORLD
1a: EU-only action	1.36	-0.31	0.44	-0.10	0.30	-0.38	0.23	-0.09	-0.54	0.15
1b: US-only action	-0.01	0.43	0.23	0.11	0.20	0.02	0.18	0.03	0.18	0.17
2: EU and US joint action	0.59	0.34	0.45	0.02	0.34	-0.07	0.30	0.04	-0.08	0.26
3: All Annex I Countries	0.55	0.32	0.42	0.41	0.44	-0.07	0.39	0.05	0.09	0.33
4a: Annex I and China (2010)	0.50	0.02	0.24	0.35	0.27	4.88	0.75	0.00	0.09	0.63
4b: Annex I and China (2015)	0.97	0.09	0.49	0.53	0.51	2.66	0.73	0.02	-0.29	0.63
5a: World (Developing 2010)	0.75	-0.11	0.28	0.31	0.28	6.04	0.89	0.43	0.36	0.81
5b: World (Developing 2015)	0.77	-0.07	0.31	0.32	0.30	3.68	0.66	0.32	0.51	0.61

*Note that the changes are shown to two decimal places for purposes of comparison. The uncertainties in the data, estimation and modelling are such that the numbers here and in other places in the report should be interpreted as indicative of orders of magnitude only.

Figure 5. Global GDP and employment effects in 2020 (% changes from the baseline for each scenario)



Global GDP benefits increase consistently as the coverage of the regime expands, reaching a nearly 1% increase in GDP with a comprehensive global agreement. This equates to an additional $400 billion in the global economy in 2020[17], (or roughly equal to the total funding that governments set aside for low-carbon investments as part of recent economic stimluls packages)[18].

A less stringent target for developing countries of returning emissions to 2015 CO_2 levels by 2020 (scenarios 4b and 5b) reduces the necessary carbon price, but when there is a global deal it also reduces the benefits in terms of world GDP, by 0.2% or around $100 billion.

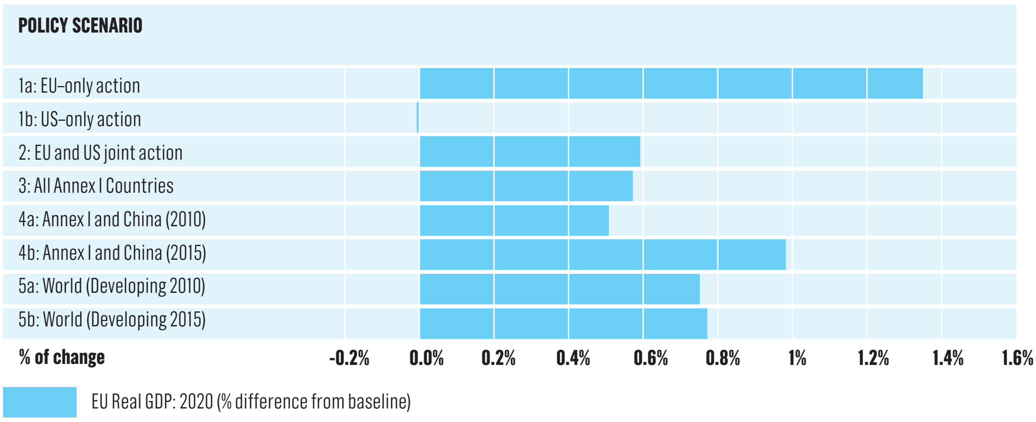
[17] E3MG estimation of global GDP in 2020 under an ambitious global deal (scenario 5a) is $US50.25 trillion at market prices.
[18] HSBC (2009)

Box 5. Limitations of traditional economic modelling

Traditional macroeconomic modelling of climate mitigation has tended to show GDP being reduced as the coverage of the climate-mitigation regime is extended. This is in contrast to the results set out in this report, which show that GDP increases. The most important reason for this difference is that the traditional, equilibrium studies assume that policies, whether global, national or regional, reduce market activity as measured in the models by GDP. Traditional models typically assume that the economy is perfectly efficient and working at full employment, so that any policy such as a carbon tax will shift the economy from this favourable position. The approach used here is more neutral, recognising that we are, in fact, shifting the economy from one development path or trajectory – with existing observed market failures and inefficiencies – to another, thereby allowing GDP to rise or fall, depending on circumstances.

Where mitigation is limited to particular nations or regions, additional GDP growth is strongest in the acting regions. In other words, **there is definite advantage in acting first and acting fast.** The EU, for example, enjoys a 1.36% increase in GDP when it acts unilaterally (Figure 6). This first mover advantage allows it to take the lead in new low-carbon industries, such as renewable energy. In the absence of wider international action, the recycling of carbon taxes and other revenues consolidates its position. This is to the detriment of other major economies such as the US, China and India which see reductions in GDP of 0.31%, 0.38% and 0.09% respectively under this scenario (see Annex B).

Figure 6. Percentage change in EU GDP under different scenarios in 2020



(see Annex B for other country graphs)

When the US acts on its own, it experiences a similar increase in GDP, suggesting that the potential effects of carbon leakage are less than often assumed and outweighed by the benefits of technological change and investment in new sectors. Indeed, ambitious unilateral action provides the US with the greatest GDP boost (0.43%) compared to all other scenarios. When China and developed countries join the US in taking action, the GDP boost for the US actually declines, as first mover advantages are lost. Comprehensive global agreements involving all countries (scenarios 5a and 5b), slightly reduce US GDP growth compared to business-as-usual but only by a little over 0.1% at most.

In nearly all the scenarios in which China does not take part in mitigation efforts, the impact on its GDP is negative, although small. The greatest benefits accrue to China from an ambitious global agreement, which would add just over 6% to GDP in 2020. India, with a smaller industrial base and large service and agricultural sectors, would achieve a 0.43% increase in growth under a comprehensive global deal.

Developing countries in general tend to benefit most from a global agreement in which they take on relatively more ambitious mitigation. The reason for this is that their development is accelerated by a greater technological change towards low-carbon employment-intensive technologies and away from obsolete fossil-fuel combustion.

Looking at the results by sector, the electricity generation industry, heavy users of electricity and industries dominated by large multinational firms (such as motor vehicles) benefit most from multilateral action, relative to action by a single region. For example, the Chinese manufacturing sector is predicted to increase its economic output by 4.7% compared to business-as-usual under a global agreement with relatively ambitious action in developing countries (Scenario 5a). In the scenario where only the EU acts (Scenario 1a), the sector's contribution to Chinese GDP falls by 0.5%. Under the same scenarios similar positive and negative impacts are also seen in the US manufacturing sector, although not to the same extent as in China, reflecting the greater maturity of the overall US economy.

JOBS

The impact of ambitious collective action on global and national employment levels is minor but positive: ambitious action helps fuel net job creation.
Model results show that the number of jobs can increase, relative to the baseline, in response to ambitious climate mitigation. As more countries are included in an agreement, the employment benefits grow. This is linked to the increase in economic output and to the expansion of new sectors, products and services linked to cutting emissions.

The greatest benefits for world employment come from a global agreement in which more ambitious action is undertaken by developing countries (scenario 5a). This creates in the region of 10 million new jobs worldwide by 2020 (Figure 7). This represents a small, but positive, percentage increase of 0.37% in total net global employment (Figure 8). As far as we know, this is the first estimate of the employment effects of climate change mitigation at a global level.

Figure 7. Changes* in employment in 2020 across the policy scenarios for key countries and regions (million persons)

POLICY SCENARIO	EU	US	EU and US	JAPAN	ANNEX I	CHINA	ANNEX I and CHINA	INDIA	MEXICO	WORLD
1a: EU-only action	1.12	-0.03	1.10	0.03	1.28	-0.06	1.22	0.20	-0.25	2.89
1b: US-only action	-0.18	0.68	0.50	0.02	0.52	0.22	0.74	0.03	0.06	1.02
2: EU and US joint action	0.37	0.45	0.82	0.01	0.72	0.18	0.90	0.13	-0.02	1.48
3: All Annex I Countries	0.24	0.37	0.61	0.11	0.82	0.28	1.10	0.12	0.02	1.65
4a: Annex I and China (2010)	0.21	0.19	0.41	0.08	0.53	5.08	5.61	0.20	0.05	6.33
4b: Annex I and China (2015)	1.36	0.12	1.48	0.10	1.54	3.14	4.68	0.17	-0.17	5.44
5a: World (Developing 2010)	0.38	0.17	0.55	0.10	0.92	4.94	5.86	1.14	0.06	10.33
5b: World (Developing 2015)	0.45	0.12	0.57	0.09	0.62	3.40	4.02	0.99	0.07	7.79

*Note that the changes are shown to two decimal places for purposes of comparison. The uncertainties in the data, estimation and modelling are such that the numbers here and in other places in the report should be interpreted as indicative of orders of magnitude only.

If only the EU, or only the US, take climate action, modelling predicts this will create 1.1 million or 0.7 million extra jobs above baseline in these regions, respectively, by 2020. The global figure could be up to 2.89 million (Figure 7). Unilateral action by either the EU or the US provides first mover advantages, and affects employment in other countries, including China, which experiences a small but negative decline in net jobs. China benefits most when it takes part in ambitious and collective mitigation action.

Figure 8. Changes* in employment in 2020 across the policy scenarios for key countries and regions (% changes from the baseline)

POLICY SCENARIO	EU	US	EU and US	JAPAN	ANNEX I	CHINA	ANNEX I and CHINA	INDIA	MEXICO	WORLD
1a: EU-only action	0.46	-0.01	0.25	0.04	0.15	-0.01	0.06	0.05	-0.53	0.10
1b: US-only action	-0.07	0.37	0.12	0.03	0.08	0.03	0.05	0.01	0.14	0.04
2: EU and US joint action	0.15	0.21	0.18	0.02	0.10	0.02	0.06	0.03	-0.05	0.05
3: All Annex I Countries	0.10	0.18	0.13	0.16	0.12	0.03	0.07	0.03	0.04	0.06
4a: Annex I and China (2010)	0.09	0.09	0.09	0.10	0.08	0.61	0.37	0.05	0.12	0.23
4b: Annex I and China (2015)	0.56	0.06	0.35	0.15	0.24	0.38	0.32	0.04	-0.40	0.21
5a: World (Developing 2010)	0.16	0.08	0.12	0.13	0.12	0.59	0.38	0.26	0.17	0.38
5b: World (Developing 2015)	0.18	0.06	0.13	0.12	0.09	0.41	0.27	0.22	0.16	0.29

Box 6. Impact of recent stimulus packages

Preliminary results from baseline modelling indicate that the US and China's current energy policies of green investment-led growth seem to be more advantageous for employment, underlying economic growth, and technological progress than a more carbon-intensive alternative. This is in comparison to earlier policies based almost entirely on coal and exchange of manufacturing exports. The results in this report give weight to calls for some form of coordinated, international, green 'New Deal' in Copenhagen.

The effects on employment are smaller for the industrialised regions. Employment impacts in developing countries are comparable to GDP changes. More ambitious mitigation action in developing countries (scenarios 4a and 5a) has greater benefits in terms of income and employment than less ambitious mitigation (4b and 5b). This is because climate change policies for mitigation are likely to accelerate sustainable development by stimulating industrial and technological change.

Although the absolute and percentage increases at both global and national levels are not large, **the results do show that estimates of significant job losses as a result of ambitious climate mitigation are unfounded.** Where net job losses do occur, this is likely to be due to poorly designed policies and measures.

Box 7. Green jobs revolution

While the changes in economy-wide net employment identified in this report are relatively modest, this hides considerable shifts in sectoral employment. Although a gradual and planned transition to a low-carbon global economy will ensure a minor impact on global economic growth, there will be much larger effects on a few sectors which are disproportionately impacted, both negatively and positively, by the low-carbon shift. However, the critical message for policy makers, which this report clearly demonstrates, is that the net result is an overall increase in employment. Some of the success stories are described below.

The UN Environment Programme identified a range of sectors likely to generate the greatest benefit in terms of economic returns, environmental sustainability and job creation, including clean energy, ecosystem infrastructure and green transport. The US Department of Energy for example, estimates that 260,000 jobs would be generated per year to meet a 20% target for wind electricity generation by 2030[19]. This yearly figure is comparable to the total number of people currently employed in the US coal mining industry[20].

The impact of low-carbon policies have already been demonstrated in a range of countries. In Germany for example, feed-in tariffs have helped established a world leading solar-PV sector. According to the Federal Environment Ministry, around 170,000 people were employed in the renewable energy sector in Germany in 2005 with an industry turnover of €8.7 billion[21]. By 2020, the sector is expected to directly employ 500,000 people[22], – a figure comparable to the German auto industry, which currently employs about 750,000 people.

Low-carbon sector jobs are not limited to developed countries. Suzlon, for example, one of the world's leading wind turbine manufacturers already employs 10,000 skilled workers in India. With 100% year-on-year growth reported in 2008, the scope for increasing job creation is obvious[23]. Other sectors also show great promise. According to the Woods Hole Research Center, India could create some 900,000 jobs in biomass gasification by 2025[24].

CAVEATS AND ASSUMPTIONS

Certain model assumptions are likely to both under– and overestimate the mitigation costs and macroeconomic benefits set out in this report.

For example, assumptions made about 'perfect' policy implementation, low transaction costs and 'unlimited' institutional capacity, are likely to have overestimated the benefits and underestimated the cost of action. Conversely, likely underestimation of the speed of low-carbon technology adoption (a common problem with technological forecasting) will have shifted the results in the other direction i.e. inflating the cost and reducing the benefits.

These assumptions will have led to a degree of uncertainty around the specific numbers presented in this report. However, they are unlikely to have changed the direction or magnitude of cost reduction achievable through collaborative action. In other words, even if the $4/tCO$_2$ carbon price turned out to be double or even treble this value in practice, it would still represent a five to eight fold reduction in the carbon price needed to achieve a certain goal (assuming a constant top carbon price of $65/tCO$_2$).

It is also worth bearing in mind that the model's focus on energy-related CO_2 only, ignores other low-cost abatement opportunities. Large scale emission reductions from lower black carbon, improved agricultural practices, reduced and avoided deforestation, as well as industrial processes, have not been taken into account. It is reasonable to assume that these other opportunities would further reduce the cost of abatement and enable deeper emission reductions.

Finally, the fact that the model's baseline scenario does not factor in the negative impacts of unconstrained climate change on the global economy further underestimates the cost savings and benefits from collaborative action.

19 US Dept Energy (2008)
20 US Bureau of Labor Statistics (2009)
21 Stern (2006)
22 German Renewable Energy Agency (2008)
23 Suzlon (2009)
24 Quoted in: World Watch Institute (2008)

CHAPTER 4 CONCLUSIONS AND RECOMMENDATIONS

The purpose of this report was to answer a relatively simple question: is it better, from the perspectives of mitigation cost, economic growth and employment, for countries to address climate change collectively or individually? As the results presented in the proceeding pages have shown, the answer is unequivocal.

In short, we can conclude the following in confidence:

- New economic modelling shows that the carbon price needed to achieve significant cuts in greenhouse gas emissions is dramatically lower when there is global agreement, rather than independent action by nations or regions. The more countries that join an agreement, the lower the required carbon price.
- Looked at in another way, this shows that the wider the participation in efforts to reduce emissions, the more ambitious the goals set can be for a given carbon price.
- Since a carbon price represents an immediate cost to many businesses, it will be more economically beneficial if more countries cooperate in the transition to a low-carbon economy.
- If all countries act together, cutting greenhouse emissions could have greater benefits for GDP and employment. The new results suggest that it is not necessary to sacrifice social and economic wealth in order to prevent climate change.
- 'First mover' advantages are real and potentially substantive, providing (ironically) an incentive for greater collaboration. Little empirical evidence exists for 'carbon leakage' impacts.
- Climate change mitigation policies in both developed and developing countries are likely to accelerate development because they stimulate global industrial and technological change.
- In effect, these policies contribute to sustainable development goals as much as climate mitigation ones. This is why more ambitious mitigation in developing countries has even greater benefits in terms of income and employment than less ambitious action.
- Developing country growth will of course be contingent on adequate support – technological, institutional and financial – being provided by industrialised countries, but what is clear is that this support is not a "lost" transfer. Indeed, beyond the benefits of increased climate protection, supporting enhanced efforts in developing countries should be seen as an investment in increased GDP and employment growth.
- International cooperation on climate change mitigation generates economic benefits through more information exchange, trading and investment between countries. These amplify the benefits of mitigation.
- There is a long term economic incentive for energy generation companies, heavy users of electricity and motor vehicle manufacturers to back a global or multilateral agreement on climate change, because their economic output is likely to increase under this regime.

The overriding conclusion from these findings is clear. As they approach Copenhagen, policy makers should not fear that making ambitious emissions reductions to prevent dangerous climate change will come at the cost of growth and jobs. Quite the reverse is true: well-designed action on climate change can reinforce their efforts to revive the global economy. And, as governments have found in their response to the global recession, a coordinated international response is more effective and more efficient.

ANNEX A THE E3MG MODELLING APPROACH

E3MG is the latest in a succession of models developed for energy-economy and, later, E3 (energy-economy-environment) interactions at global level. It is very similar in structure to the E3ME model[25], which follows from EXPLOR, built in the 1970s, then HERMES in the 1980s. Each model has required substantial resources from international teams and each model has learned from earlier problems and developed new techniques. Like its predecessors, E3MG is an estimated model, based on OECD, Eursotat, UN, IMF and IEA data; it also includes data sets collected from national sources. It encompasses both long-term behaviour and dynamic year-to-year fluctuations, so that it can be used for dynamic policy simulation and for forecasting and projecting over the medium and long terms. As such, it is a valuable additional tool available for economic, energy and environment policy analysis at the global level.

The model represents a different approach to the modelling of technological change in the literature on the costs of climate stabilisation. It is based upon a 'new economics'[26] view of the long-run, drawing on Post Keynesianism, adopting a 'history' approach of cumulative causation[27] and demand-led growth, and incorporating technological progress in gross investment enhanced by R&D expenditures. Furthermore, E3MG is a hybrid model in the sense that it integrates a bottom-up energy technology sub-model with energy technologies explicitly modelled[28] within a top-down detailed macroeconomic framework. The latter incorporates a dynamic simultaneous system of 22 sets of behavioural time-series equations to explain demand-led growth, as well as prices, energy demand, wages, employment, housing investment and trend output for each industrial sector.

Overall, compared to the existing modelling literature targeted at achieving the same goals, we argue that the advantages of the E3MG model lie in three main areas. First, the detailed and disaggregated nature of the model (estimated on annual data spanning 1970–2006 across 20 regions, 42 sectors, 28 consumer spending categories, 12 fuels and 19 fuel users) allows the representation of fairly complex scenarios[29]. Second, the econometric grounding of the model makes it better able to represent the behaviour of energy-economy systems. And third, by linking the top-down macroeconometric structure of the model with a bottom-up energy technology sub-model (explicitly modelling 28 energy technologies), a two-way feedback between the economy, energy demand/supply and environmental emissions is achieved. This represents an undoubted advantage over other models, which may either ignore the interaction completely, or only assume a one-way causation. The advantages of using the hybrid approach have been reviewed in Grubb et al (2002) and Hoogwijk et al (2008).

Three main mechanisms describe the key features of accounting for endogenous technological change in the version of E3MG we used. First, at the macro-level, sectoral energy-demand, import and export-demand, and employment equations include indicators of technological progress in the form of accumulated investment and R&D. Second, as described below, the ETM incorporates learning-by-doing through regional investment in energy generation technologies that reduce in cost depending on global-scale economies. And third, extra investment in new technologies, in relation to baseline investment, induces further output through a Keynesian multiplier effect and therefore more investment, trade, income, consumption and output in the rest of the world economy.

However, further changes can be induced by policy; hence the term induced technological change[30]. For example, feed-in tariffs for renewables (as used in Germany) will alter relative prices such that investments in renewable technologies are stimulated and, depending on their learning curve characteristics (and Keynesian multiplier effects at the macro level), leading to higher adoption rates. The effects of technological change modelled in this way may turn out to be sufficiently large in a closed global model to account for a substantial proportion of the long-run growth of the system. Further details of the E3MG model are extensively discussed in Barker et al (2005, 2006, 2008) and Barker and Scrieciu (forthcoming)[31].

25 See www.e3me.com

26 'New Economics' is concerned with institutional behaviour, expectations and uncertainty as opposed to traditional economics with its emphasis on equilibrium, mathematical formalism and deterministic solutions. We use the term to include various heterodox approaches including Post Keynesian, evolutionary and institutional economics. This new economics approach is currently being developed for future research and papers. However, some elements of new economics have already been explored in Barker (2008b) and Barker, Scrieciu and Taylor (2008)

27 'Cumulative causation' refers to a dynamic institutional process in which various factors combine to create a vicious or virtual circle to strengthen an initial effect (Berger, 2008). Kaldor (1957, 1972, 1985) developed the economic theory based on increasing returns and agglomeration economies

28 The energy technologies and the equations underpinning the ETM sub-component of E3MG are also extensively discussed in Barker et al (2005, 2006), Köhler et al (2006) and Barker et al (2007) for the E3ME model, the European counterpart of E3MG.

29 The model's regions are linked by trade equations based on bilateral trade matrices, and the sectors are linked by 2000-based input-output tables

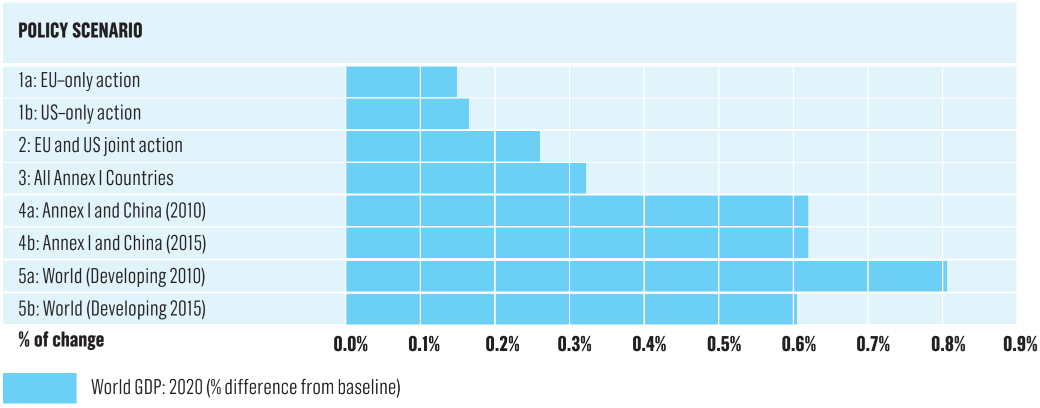
30 The term induced technological change (ITC) refers to further changes in technological progress (i.e. endogenous technological change) that are induced via policy measures (Barker et al, 2006)

31 The model manual used for E3MG is currently under development. However, the manual for the European E3ME model, which is similar in structure and econometric method, is freely available online at www.camecon.com

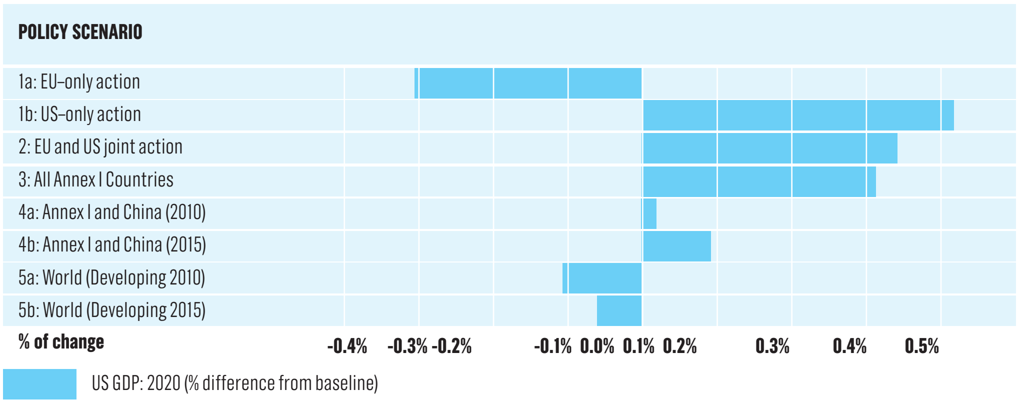
ANNEX B

GDP % CHANGES BY COUNTRY / REGION IN 2020

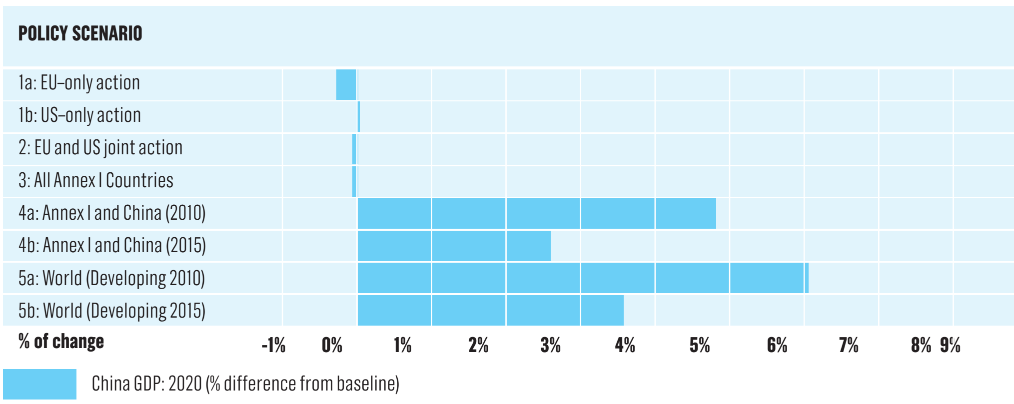
WORLD



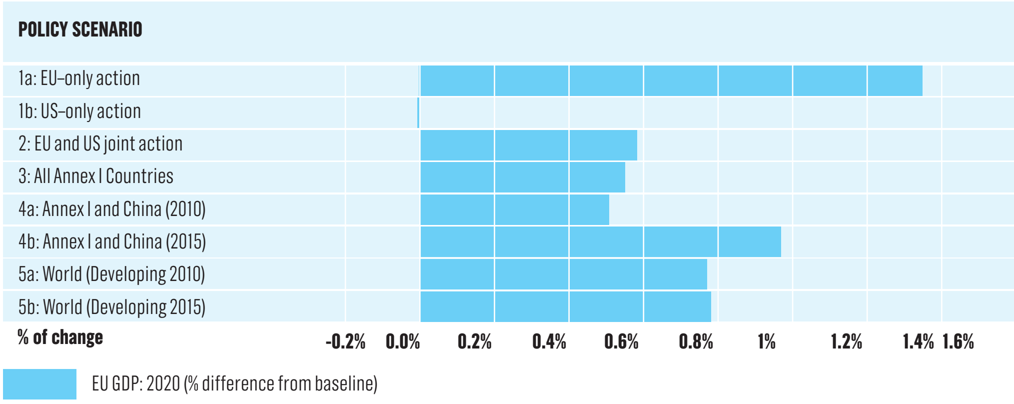
US



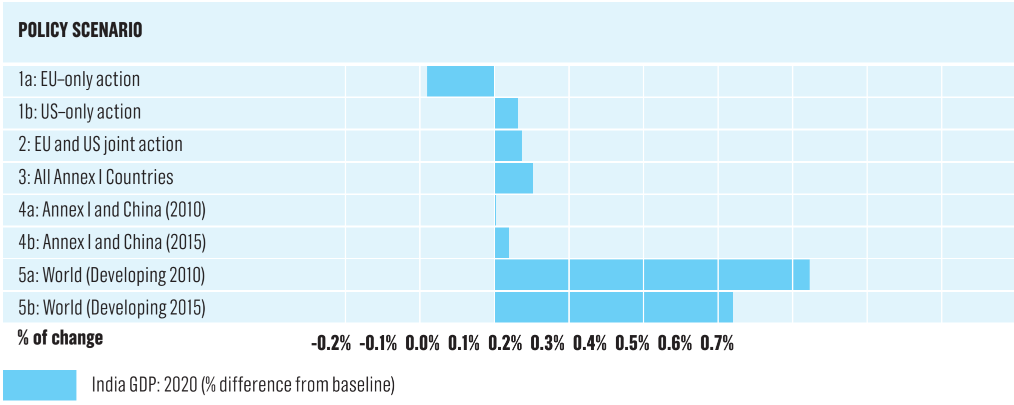
CHINA



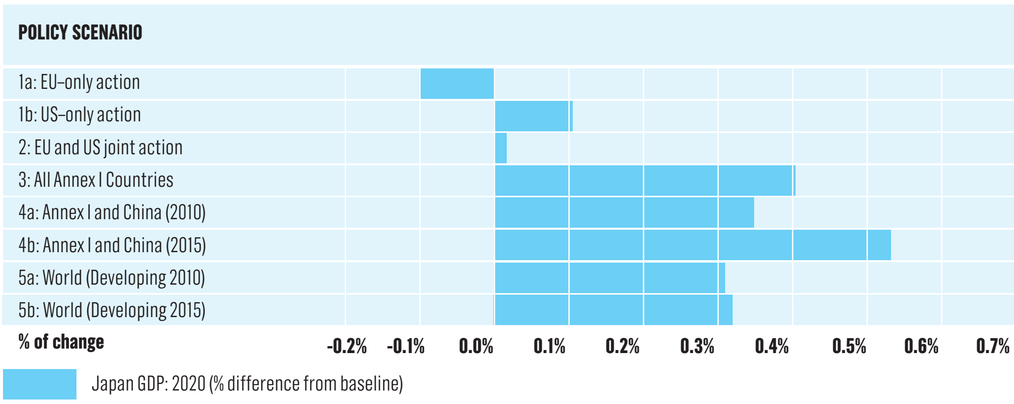
EU



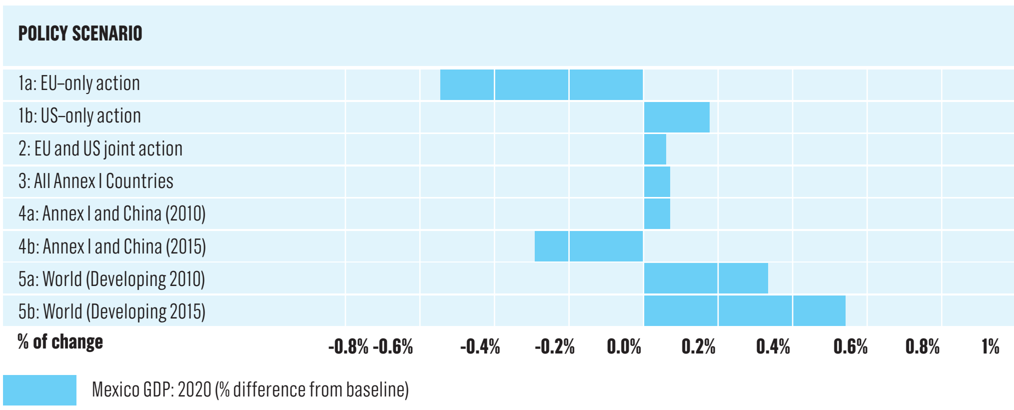
INDIA



JAPAN

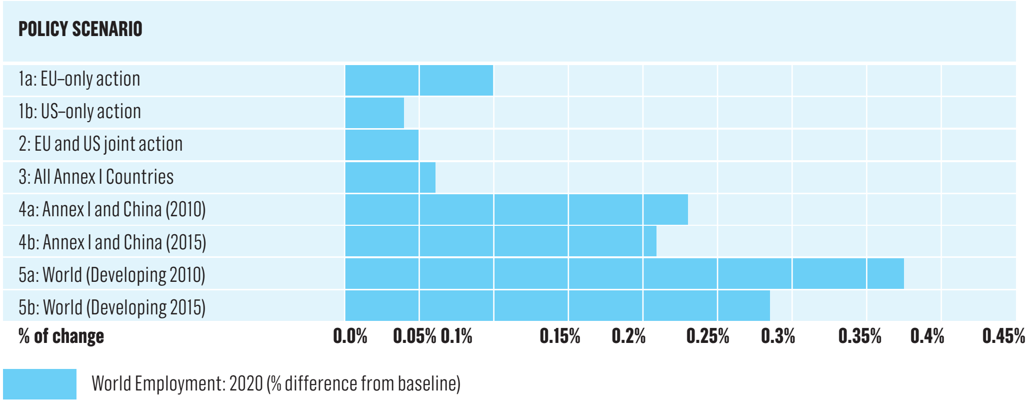


MEXICO

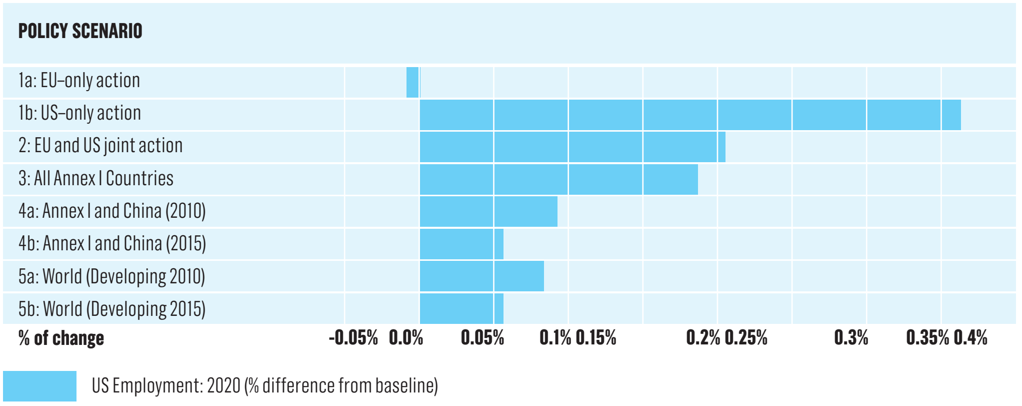


EMPLOYMENT % CHANGES BY COUNTRY / REGION IN 2020

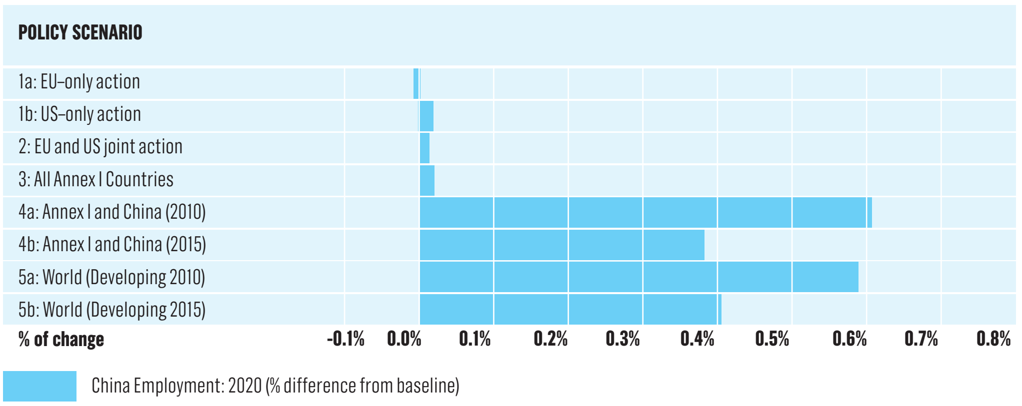
WORLD



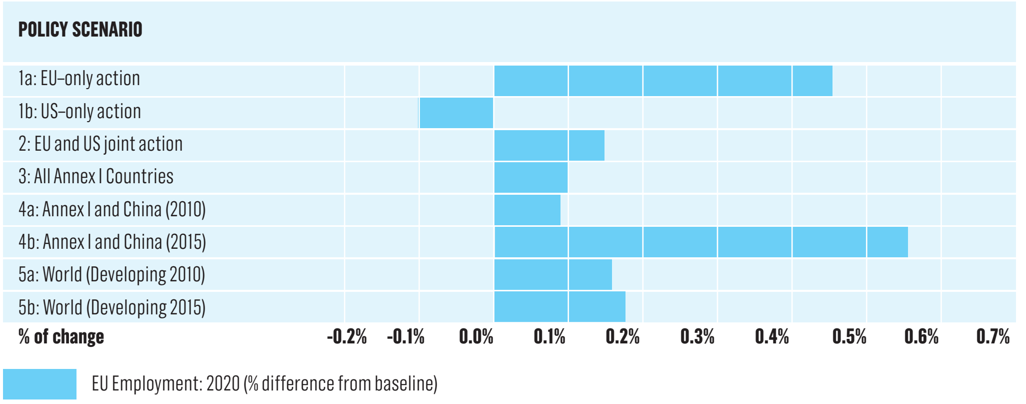
US



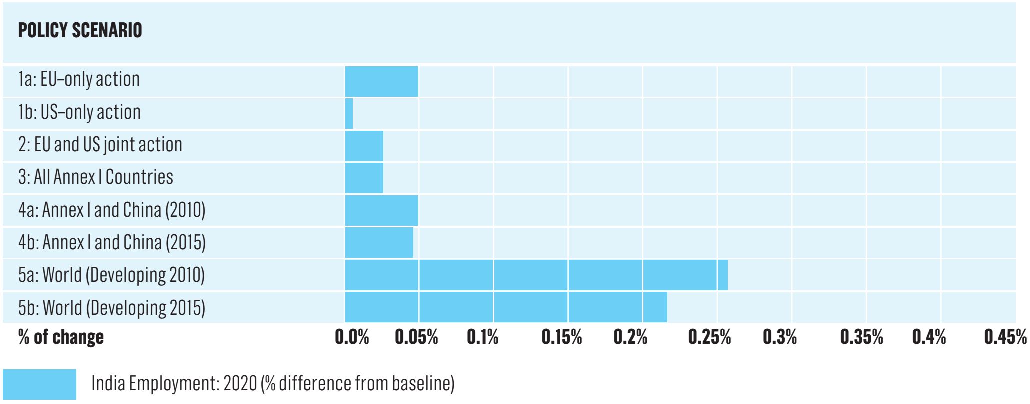
CHINA



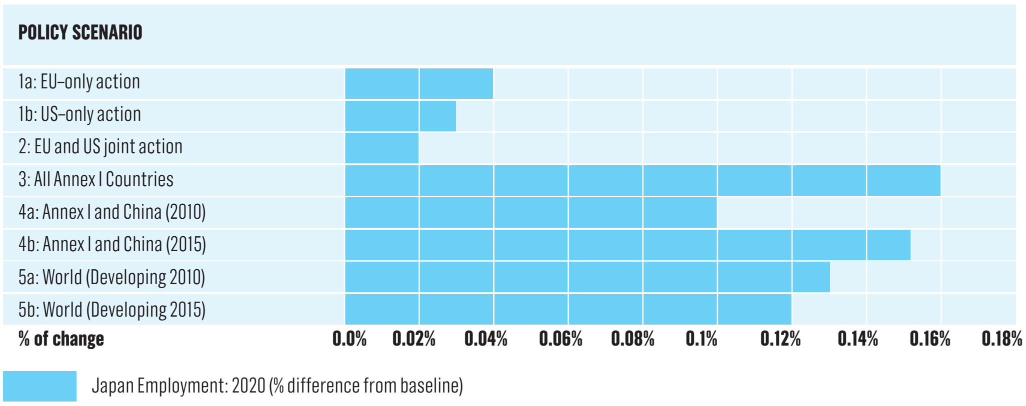
EU



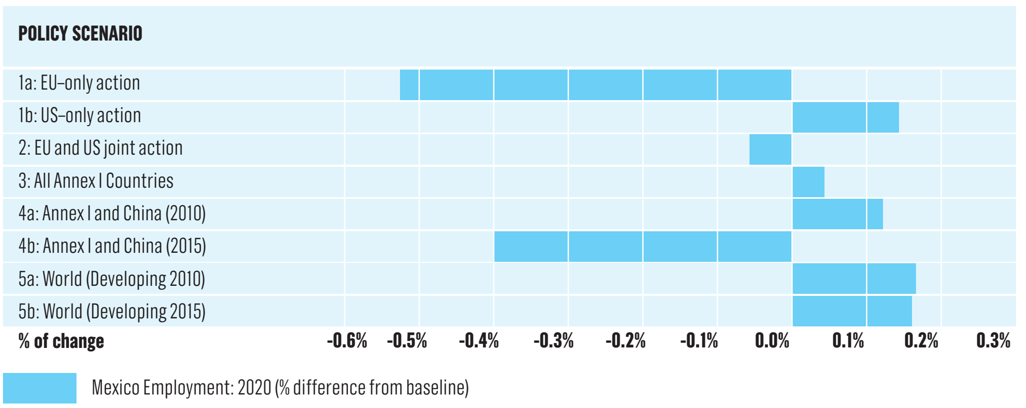
INDIA



JAPAN



MEXICO



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4CMR is hosted by the Department of Land Economy at the University of Cambridge. 4CMR's overarching objective is to foresee strategies, policies and processes to mitigate human induced climate change, including understanding and modelling transitions to low-carbon, energy-environment-economy systems. 4CMR contributes towards the research agenda of the Tyndall Centre for Climate Change Research and the UK Energy Research Centre and was a major contributor to the Stern Review on the economics of climate change and the IPCC's 4th Assessment Report.

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CE specialises in the application of economic modelling and data analysis techniques to the needs of clients in business and government. It is leading independent economic forecasting group with the fullest portfolio of forecasting services available in the UK, and has particular expertise in the analysis of highly disaggregated data sets. The company was established in 1978 to provide commercial access to research in the University of Cambridge.

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