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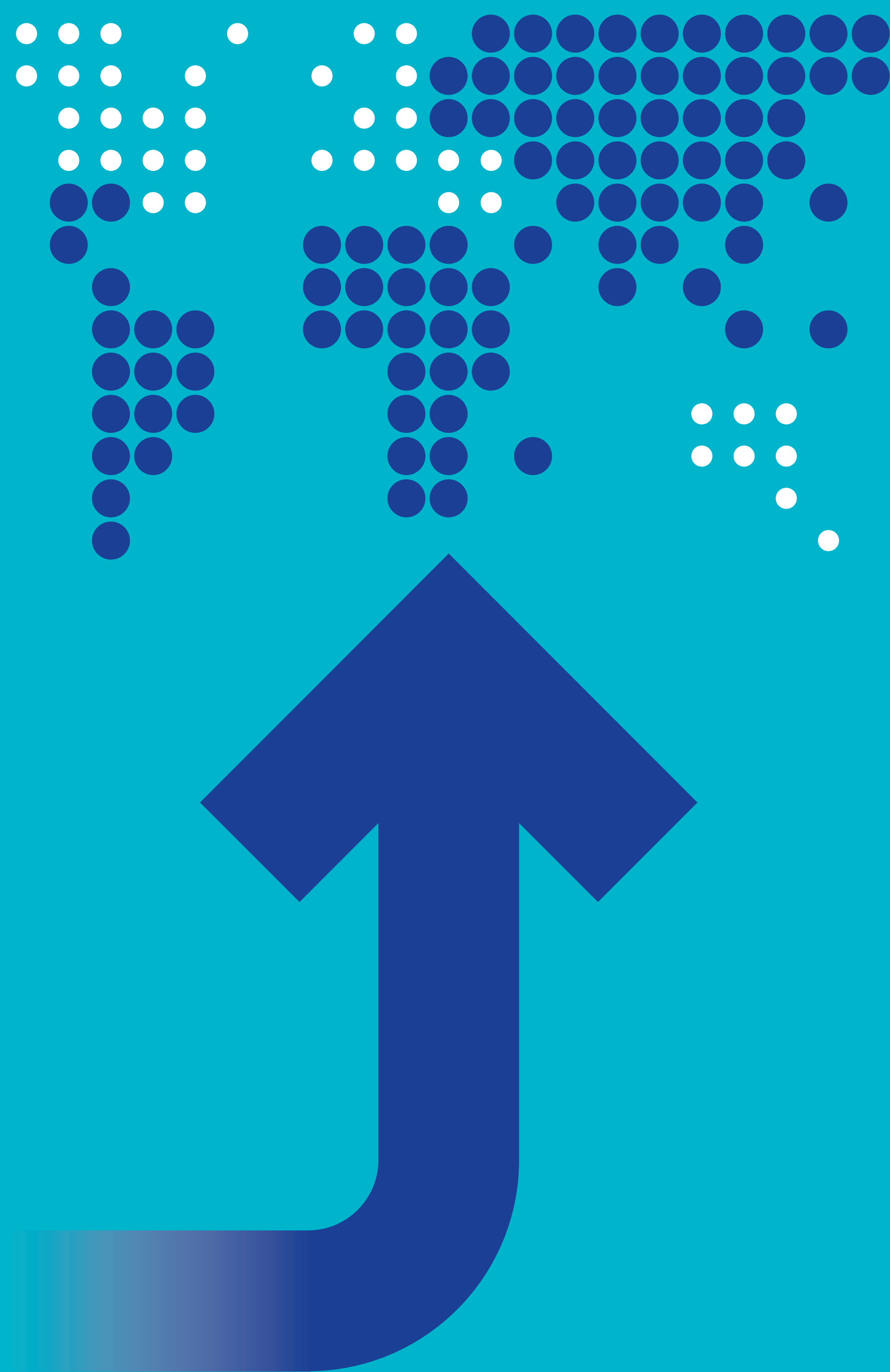

Should Emerging Market Economies Act on Climate Change, or Wait?

Cameron Hepburn
and John Ward

Emerging Markets Forum
A nonprofit initiative of the Centennial Group

Bringing people together to
accelerate growth and
well-being in emerging markets

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Foreword

Climate Change is arguably the single most important issue of our lifetime. It could affect each and every human being on our planet, irrespective of his or her country of residence, income level, race or color. While a universal agreement within the scientific community has yet to be reached, there is certainly a broad consensus by now that the earth is indeed undergoing an unprecedented rise in global temperature as well as unusual changes in weather patterns. Furthermore, it is agreed that these changes are most likely the result of human activity, and that unless this temperature rise is arrested soon, the world as we know it today will face catastrophic consequences.

The global community, including the political and policy leaders of the highest level, has been debating this issue for years and has held a number of summits organized by the United Nations. The last Summit was held in Copenhagen in December 2009, and despite the high hopes of many and the organizers' best efforts, a concrete and binding agreement has so far eluded the global community. A major reason behind the current impasse appears to be the still wide divide between the perspectives of the so-called Annex I (developed economy) countries listed in the Kyoto Protocol and the major emerging markets economies. And yet, the experts still continue to warn us all that urgent action is absolutely essential.

Many prominent participants of the Emerging Market Forum (EMF) are dismayed by this impasse. They have urged the Forum to make an attempt to help bridge the current wide gulf between the perspectives of the developed and developing countries. While we are keen to respond to this request, we are also very aware of the fact that tens of hundreds of highly qualified and well meaning institutions—both public and private—have already produced many outstanding studies and are actively engaged in the ongoing global negotiations on climate change. Therefore, the question we faced was where and how we can add value.

The answer to this question lay in four unique features of the EMF. First, our Forum was created exclusively to debate and tackle major long term issues of direct concern to the emerging market economies. Second, the Forum considers and attempts to address the issues from the perspective of the emerging markets economies. Third, the Forum is ideologically neutral and has no institutional agenda. It commissions analyses by world-class experts who have no personal agenda or ideology. And fourth, the Forum brings together high-level policy makers, senior most executives of multilateral institutions and top business executives, and provides them with an opportunity to discuss the issues in an intimate and informal setting. In our view, these features of the EMF make it uniquely qualified to provide a platform to discuss climate change and to consider what is truly in the best interest of the emerging market countries, well away from the pressures associated the global negotiations.

To provide our participants with a different perspective than they may have encountered before, we commissioned Vivid Economics to prepare fresh analysis that looks at climate change primarily from the economic and social viewpoint of the emerging markets economies. Vivid will be producing their analysis in phases. Under Phase I, they were asked to look at the economic "self interest" of the emerging markets under three scenarios: a) a do nothing scenario—also called the business as usual approach—under which the current trends in climate change go unchecked for the next 40 years; b) a scenario under which the developed countries (Annex I countries listed in the Kyoto Protocol) take steps to reduce their emissions by 80% over the 1995 levels by the end of 2050; and c) a third scenario under which the major emerging market economies (defined as members of the G-20) take parallel actions to restrain their emissions by 2050 to the same levels as their 2005 emissions (as proposed by China in Copenhagen). This Phase I report provides an overview of the effects of global warming based on the actions under each of these three scenarios. It then goes on to estimate the economic implications of each scenario on the major emerging market economies (including impact on agriculture production), with specific references to the impact on the three largest: China, Brazil and India.

This report will be followed up by the Phase II report, which will look at the economic implications of climate change on China, Brazil and India in more detail. We believe that this country level analysis, done in a consistent manner across countries, is essential because, in the end, each country must first determine what is in its own self interest, before deciding how to participate in the global efforts to mitigate and adapt to climate change.

I believe that the enclosed paper offers fascinating new insights as to whether remedial measures taken by Annex I countries alone would be adequate to mitigate the most adverse affects of climate change on the emerging market or, if instead, they must take aggressive proactive actions on their own out of sheer self interest (rather than in response to the outside pressures from the developed countries).

On behalf of the Emerging Markets Forum I would like to acknowledge the generous financial support provided to the EMF by the Japan Bank for International Cooperation (JBIC), Corporacion Andeno Fomento (CAF) and IDFC Foundation, India to make this work possible. I also want to thank Vinod Thomas (Senior Vice President, World Bank), Bindu Lohani (Vice President, Asian Development Bank) and Rajiv Lall (Chief Executive, IDFC) for their continuing intellectual inputs and encouragement throughput the conception and execution of this work.

I do hope that the participants at the forthcoming EMF meeting will find this document as stimulating and thought provoking as my colleagues at EMF and I did.

Harinder Kohli
Founding Director and Chief Executive
Emerging Markets Forum

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Executive Summary

Continued fossil fuel-driven growth could leave Earth around 4.9°C warmer in 2100 than in 1990 and sea levels 0.5m higher. This would have extremely damaging implications for G20 Emerging Markets (GEMs),[1] with economic damages possibly causing annual GDP to be 6.0% lower than it otherwise would be by 2100. The last time global temperatures were this high — the Eocene period, 35-55 million years ago — swampy forests covered much of the world and there were alligators near the North Pole.

Even with ambitious action by Annex 1 countries,[2] GEMs will still experience most of the damaging consequences of climate change. If Annex 1 countries reduce their emissions by 80% from 1990 levels by 2050, temperature increases over 1990 levels might still be 4.4°C in 2100, because over the next decades the GEMs will contribute the lion's share of global emissions growth.

For GEMs to avoid the damaging consequences of climate change, they must take ambitious action alongside Annex 1 countries. GEMs are now responsible for roughly the same amount of emissions as the G20 Annex 1 countries. China has replaced the US as the world's largest emitter. Rapid economic growth to 2050 coupled with population growth implies GEMs will contribute most to future emissions. While Annex 1 countries have contributed the most to historic emissions, it is the GEMs that are expected to be responsible for much of the future warming of the planet. They can control their own destiny – and that of the planet.

If GEMs restrain their emissions to 2005 levels by 2050, and reduce emissions from deforestation by 50 per cent, temperature increases from 1990 levels may be limited to 2.7°C. This would avoid some of the worst impacts. The modelling analysis in this report employs the MAGICC climate model, one of the models used in the latest IPCC report, the RICE damages model created by Professor Nordhaus at Yale University, as well as analysis based on agricultural models and the GLOBIO3 model of biodiversity losses. The report examines three core scenarios: (i) business-as-usual, (ii) action by Annex 1 countries and (iii) action by both Annex 1 and the GEMs. Results are shown in Table 1.

A significant proportion of the benefits generated by GEM action are the result of China, India and Brazil controlling their emissions. If these three GEMs alone were to take action then temperature increases may be restricted to around 3.5°C above 1990 levels. This would reduce the damages experienced by these countries. China's losses are estimated at 2.2% of 2100 GDP, compared with 3.2% if no GEMs act, and India's losses at 4.2% of GDP, compared to 5.9% without any GEM action.

Regardless of whether some or all GEMs act, these temperature increases would still be likely to have serious consequences. Many scientists regard a 2°C increase as a maximum before the risks of dangerous climate change become unacceptable. This position is recognised in the Copenhagen Accord. Limiting temperature increases to 2°C on pre-industrial levels would require more ambitious action by GEMs, Annex 1 and also the rest of the world.

Given this, it is unsurprising that GEMs have already begun to take action. There has already been a rapid and pronounced acceleration in low-carbon innovation activity within the GEMs. China, for instance, is now one of the leading countries in the world in solar, wind and nuclear power, electric cars, and high-speed rail technologies. Brazil has launched a sophisticated real-time deforestation tracking mechanism and committed to reducing deforestation. India's eleventh five year plan (2008-2012) includes measures aiming to increase energy efficiency by 20 percentage points by 2016-17. South Korea and Mexico have put in place absolute emission targets,[3] and it is likely that several GEMs will

1 Argentina, Brazil, China, India, Indonesia, Korea, Mexico, South Africa and Turkey.

2 Defined as an 80% reduction on 1990 levels by 2050 (and no change in land use change emissions), emissions constant thereafter.

3 Although neither target is reported in Appendix II of the Copengahen Accord, South Korea has made a voluntary unilateral pledge to reduce emissions by 4% on 2005 levels by 2020 while Mexico has an aspirational target of reducing emissions

Table 1 **Action by GEM governments is essential if their countries are to avoid the worse consequences of climate change**

Variable		Business-as-usual	Developed country action	Developed country & GEM action
Average global temperature increase in 2100 (on 1990 levels), °C		4.9	4.4	2.7
Atmospheric concentrations of CO_2, parts per million		905	780	550
Economic damages in 2100, % of GDP:	GEMs	-6.0	-5.1	-2.5
	India	-7.0	-5.9	-3.0
	China	-3.9	-3.2	-1.5
Agricultural yield declines in 2050 relative to 2000,%:	Argentina	-19.8	-15.8	-6.2
	Brazil	-22.2	-18.5	-7.3
	China	8.9	9.1	7.2
	India	-14.1	-11.4	-10.7
	Indonesia	-20.5	-19.9	-12.9
	Mexico	-0.7	-0.6	-0.2
	Republic of Korea	-18.5	-18.0	-11.7
	South Africa	-5.6	-5.8	-4.0
	Turkey	-0.7	0.3	-3.1
Sea level rise in 2100, cm above 1990 levels		50.5	45.6	32.1
Decline in biodiversity, km^2 pristine area equivalent loss 1990-2050		2,509,000	2,253,000	1,754,000

Source: Vivid Economics based on sources in text

beat the USA to the introduction of carbon pricing.

Current policies are not enough, however. Accelerated action could trigger a low-carbon race that the GEMs are well positioned to win. As well as reducing the climate damages GEMs may face, coordinated GEM action could prompt Annex 1 countries to ramp up their emission reductions, providing larger markets for GEM low-carbon products. For instance, a recent HSBC report predicted that if governments went beyond the commitments they made during the run up to COP 15 then, even by 2020, the low-carbon market would be worth 2.7 trillion US dollars; 30% larger than if governments simply kept to their COP 15 commitments and 100% larger than in their worst-case scenario.

There is also an opportunity for the GEMs to change the economic and political status quo. Significant technological changes in fundamental technologies have sometimes been associated with countries (or firms in those countries) 'leap-frogging' their counterparts, for example when Great Britain leapfrogged The Netherlands during the Industrial Revolution, or when the US overtook Great Britain through the adoption of mass market production technologies.

There are costs to the transition, but the costs only increase with delay. Fossil fuel intensive growth implies the construction of new, dirty capital stock which is likely to have to be scrapped early once the full cost of

by 50% from 2002 levels by 2050. In Appendix II to the Copenhagen Accord South Africa also reports that its plans will involve emissions peaking between 2020 and 2025, plateauing for approximately a decade and thereafter declining.

dirty production is accounted for. Early action will also speed up the rate of technical progress in low-carbon technologies. Both these factors mean that starting early can allow for a more gradual and planned, and hence less costly, transition. For instance if GEMs start taking action in 2012 to bring emissions back to 2005 levels by 2050 (a potential proposal of China, as reported by the Sustainability Institute (2010)) then they would only have to achieve annual reductions in emissions of 0.4% per annum. If they wait until 2030 before starting to take action (a typical 'delayed action' starting point), with the intention of reaching the same target by 2070, then average reductions of 1.5% per annum might be required. While historical experience shows that reductions of 0.5% per annum are achievable without significant economic consequences, reductions of more than 1.0% per annum have typically only been associated with prolonged economic recessions. All in all, research suggests that costs to emerging economies could be between 25% and 33% lower with early action.

Post transition, GEMs will have more secure energy supplies. Currently, six of the nine GEMs are reliant on imports for more than 20% of their total energy requirements. Fossil fuels provide a small number of countries with disproportionate economic and geopolitical power. In contrast, many low-carbon energy resources (solar, wind, hydro, nuclear, biomass, geothermal) are more readily available in GEM countries.

GEMs will also be healthier and more efficient. Of the ten cities with the worst air pollution in the world, nine are in GEM countries. Fossil fuel combustion is largely to blame for the adverse health consequences for the 50 million people who live in these cities; each year in China alone air pollution is thought to cause 270,0000 cases of chronic bronchitis and 400,000 hospital admissions for respiratory or cardiovascular disease. Air pollution problems are also due to cause an additional $6-10 billion p.a. in crop yield losses in India and China by 2030. These problems are sufficiently great, and alleviating them so important, that one study has suggested that reducing emissions by 15% through a carbon price in China would be desirable on these grounds alone. Moreover, there is the possibility for GEMs to implement measures that both reduce emissions and generate efficiency savings of at least USD 100 billion per annum.

This report suggests that some or all GEMs could seize the climate policy agenda, and open up these broader opportunities, with a co-ordinated, self-interested announcement to exploit the fear of "losing the low-carbon race" in the West. Such a strategy would likely thwart resistance within Annex 1 countries to action on climate change, which would be to the benefit of GEMs. Irrespective of Annex 1 action, however, without early action by the GEMs, they themselves risk bearing the impacts of dangerous climate change.

Introduction

This report examines the economic and strategic implications for the G20 Emerging Markets (or GEMs) of climate change. Building on the work of the Stern Review, which found that the global benefits of taking action to prevent climate change, and the risks associated with failure to act, outweighed the global costs of action, this report addresses similar themes but with explicit focus on the GEMs.4 New modelling examines the benefits if GEMs take early action and the risks and costs if they fail to act. While the GEMs have already undertaken action against climate change to varying degrees, it is found that accelerating these initiatives will yield further economic and social benefits for themselves and the world as a whole.

The GEMs are Argentina, Brazil, China, India, Indonesia, Korea, Mexico, South Africa and Turkey. These are the G20 countries that do not have legally binding commitments to reduce emissions under Annex B of the Kyoto Protocol[5] and that, in 1990, the base year

4 Although many of the themes covered in this report are similar to those covered in the Stern review but with a focus on the GEMs, it has been conducted with much more limited resources and over a much shorter timeframe, so more detailed work on the GEMs remains necessary. As such, three more in depth country reports on China, India and Brazil will follow this report in 2011.

5 Despite the common reference to Annex 1 and non-Annex 1 countries in discussing the Kyoto Protocol, it is countries listed in Annex B that have emission reduction obligations under the treaty. However, for the remainder of this report, given the

for the Kyoto Protocol, had a Gross National Income (on an international dollar Purchasing Power Parity basis) of less than USD 9,000 per capita. All of the other countries of the G20 had a higher GNI per capita in this year.

The report is structured as follows:

- Section 2 sets out three future scenarios for the world's climate, depending on which groups of countries take action. It discusses how action by the GEMs affects their own well-being through avoiding the worst consequences of climate change for their economies and societies.
- Section 3 considers the process of moving to a low-carbon economy and the opportunities for GEMs to build on their recent actions to trigger and win the low-carbon race, to improve their energy security and to establish cleaner, healthier and more productive societies.
- Annex A outlines the current importance of the GEMs to the global economy, their population and contribution to emissions, and how these are projected to grow substantially over the 21st century.
- Annex B provides more detail on the modelling analysis used in the report

This is the first of a series of reports that Vivid Economics is preparing for the Emerging Market Forum on the implications of climate change for the emerging economies. Subsequent reports will look in more detail at Brazil, India and China, examining the risks that climate change may pose to their economies, the challenges and opportunities that it presents to them in the context of their specific development paths, and the policy implications resulting from this.

The economic and social impact of climate change on GEMs

This section develops and analyses three emissions scenarios, and deploys the MAGICC climate model (discussed in Annex 2) to determine the impact of emissions on Earth's levels of atmospheric CO_2, global mean temperature, and sea-levels. It draws out the implications of these scenarios for economic activity using the Regional Integrated Model of Climate and the Economy 2010 model (RICE 2010)[6] and further models from the literature on the economics of climate change.

While these models are among the best of their kind, there remains a high degree of uncertainty around specific estimates concerning the physical impacts and economic damages.[7] In particular, RICE 2010, as with similar models, is calibrated to various 'best estimates' of relevant variables. However, for each of these variables there is a fair degree of uncertainty about what the 'true' value might be, leading to the possibility that both the physical impacts and resulting socio-economic consequences may be more benign or far worse than suggested by the modelling results reported in this paper.[8] The report's findings and conclusions must be considered in this context.

The three scenarios are:

- A business-as-usual scenario, where the recent trends in emissions are projected forward on the basis of GDP forecasts provided by the Centennial Group to 2050 and from 2050-2100 based on forecasts from the climate change modelling literature;
- A developed country action scenario in which developed countries commit to reduce emissions by 80% on 1990 levels by 2050 (consistent with the target set by the EU and very close to the target of the US);

much more familiar language, we contrast the GEMs, as defined above, with G20 Annex 1 countries.

6 Developed by Professor William Nordhaus at Yale University (Nordhaus and Boyer, 2000; Nordhaus, 2010 and the associated supplementary material).

7 Scientific understanding of the climate system continues to improve, but it remains unclear just how sensitive global mean temperature is to emissions forcings. Impacts on precipitation and wind speeds are also not yet fully understood, and there are further challenges in translating these physical changes into socio-economic impacts up to one hundred years into the future. These challenges in assessing socio-economic impacts are particularly acute in relation to large temperature increases.

8 This is compounded by that fact that many of these variables may have probability distributions that are 'fat-tailed' i.e. the probability that they imply catastrophic consequences is higher than would be the case if the variable was normally distributed. See Weitzman (2009).

- A developed country plus GEM action scenario where, in addition to developed countries, GEMs also commit to ensuring that emissions (except from land use change) are at 2005 levels by 2050 (a potential proposal from China, as reported by the Sustainability Institute (2010)) and emissions from land use change fall by 50% on 2005 levels.

The analysis shows that for the GEMs to prosper in a world without dangerous climate change, they must take action — not because they are being urged to by others but simply because they will suffer the worst consequences of climate change if they fail to.

Business-as-usual

Our business-as-usual scenario is based on the recent historic relationship between GDP and emissions for each GEM/G20 Annex 1 country between 1990 and 2005 taking into account improvements in this relationship over this period. Centennial Group (2010) forecasts for economic growth to 2050 (as presented in Annex 1 to this report) have been employed. We note that relative to other long-term macroeconomic forecasts, these forecasts assume higher rates of growth in GEM countries. For the period between 2050 and 2100, which are not covered by Centennial Group forecasts, we assume a steady decline in economic growth rates so that by the end of the century each country is growing at a rate equal to the relevant regional growth rate used in the Nordhaus RICE model.

In this scenario, results from MAGICC show that the world in 2100 will be substantially hotter: in the scenario developed, global mean temperatures are found to be 4.9°C above 1990 levels.[9] These temperature increases are associated with CO_2 concentration levels of more than 900 ppm.

Temperature increases of 5°C would create extremely dangerous changes to the climate. Although, the physical and social impacts in a 5°C+ world are highly uncertain, we do know that the last time temperatures were this high — the Eocene period, 35-55 million years ago — swampy forests covered much of the world and there were alligators near the North Pole (Stern, 2008). The global water cycle would be significantly altered, with billions of people experiencing either very much reduced or very much increased water supply compared to current conditions (Warren et al, 2006). The flow of rivers from the Himalayas, which serve countries accounting for around half the world's current population, would likely be disrupted (Stern, 2008). Ocean acidity would rapidly approach a level not seen for hundreds of thousands of years, with severe, if not yet fully understood, consequences for the natural regulation of ocean chemistry, marine ecosystems and commercial fisheries worldwide (Royal Society, 2005).

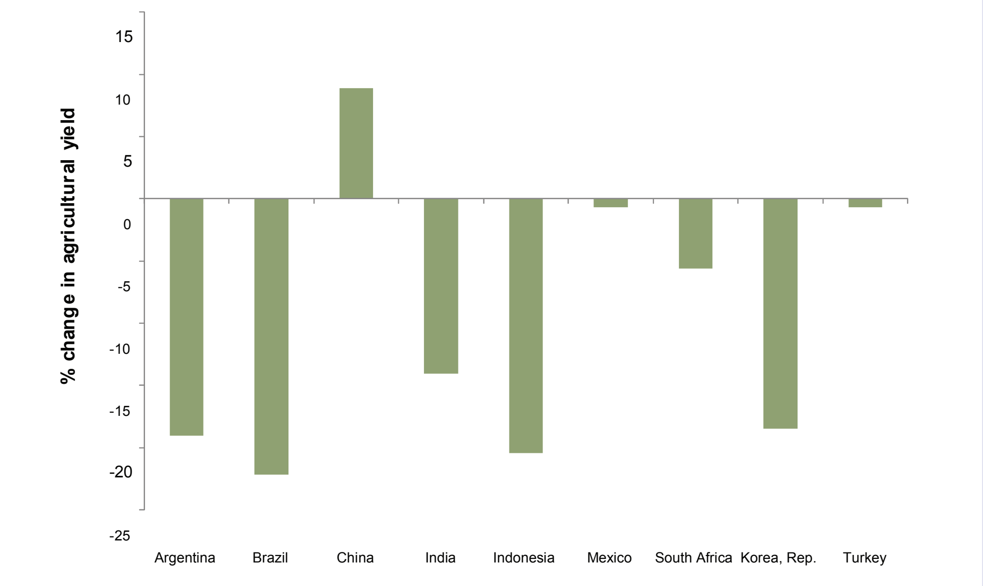
Unsurprisingly, GEM economies will suffer significantly in this world. Economic damage in the GEMs are estimated by the RICE model to be 6.0% of GDP by 2100.[10] This, and all other damage estimates in the report, are reported before the impact of abatement but exclude any loss in GDP from sea level rises. In the same year, the modelling suggests that India might see economic damages of 7.0% of GDP; and China of 3.9%. As shown later in figure 4, the damages experienced by the GEMs, as a proportion of GDP, are greater than those experienced either by G20 Annex 1 countries or by the rest of the world.

Looking behind these aggregate numbers, a number of sectors will bear the brunt of these impacts. Agriculture is one of the most sensitive economic sectors to climate change, and is a relatively important sector in GEM countries currently accounting for about

9 This is approximately 5.3°C above pre-industrial levels. See Annex 2 for a discussion on temperature increases between pre-industrial times and 1990.

10 All of the damage estimates discussed in this report should be interpreted as meaning that the level of GDP in the stated year might be that percentage lower than if there were no increase in average global temperatures above pre-industrial levels. As the gap between pre-industrial temperatures and actual temperatures is expected to grow over time so this percentage loss will become larger the further into the future that damage estimates are projected. In line with other reports we report the impact in one year, 2100. In years before 2100, when temperature increases will be lower, the loss in GDP will be lower. In years after 2100, if global temperatures continue to rise, then the loss in output will correspondingly be higher.

Figure 1 **Four GEMs would see agricultural yields decline by more than 15% under business-as-usual**



Source: Vivid Economics based on Muller et al (2009) and World Bank (2010). Per cent changes relative to a 2000 baseline.

10% of the GEM economy.[11] Significant reductions in crop yields are expected in most GEM countries in the business-as-usual scenario. Figure 1 shows, based on analysis from World Bank (2010) and Muller et al. (2009)[12] that, by 2050, dangerous climate change would be expected to lead to declines in agricultural yields in eight of the nine GEMs and that in the case of India, Argentina, South Korea, Brazil and Indonesia, these declines in yield could be greater than 15%.

China is expected to experience higher yields through more favourable climatic conditions, though the boost to Chinese yields is not sufficient to offset losses elsewhere.

A global temperature increase of 4.9°C may lead to sea-level rises of 0.51m by 2100. This sea-level rise will threaten a large number of GEM cities. For instance Nicholls et al (2007) list the cities most exposed to a 1 in 100 year surge-induced flood event following a 0.5m increase in sea levels and with no further defence measures implemented. Impacts are measured in terms of future population exposure and future economic exposure. As shown in the tables below, seven of the twenty most exposed cities are in the GEMs, with an expected exposed population of almost 50 million people in 2070. In terms of asset exposure, eight of the twenty (and six out of the top ten) most exposed cities are in the GEMs, with a combined expected asset exposure of USD 12.7 trillion.

11 According to UN statistics, which group hunting, forestry and fishing with agriculture. However, agriculture forms the overwhelming bulk of economic activity within this group.

12 These results are calculated by applying the regional change in 2050 yields expected in the A1B scenario as reported in Muller et al (2009) (which is consistent with our business-as-usual scenario, in that Muller et al assume temperature increases of 1.75ºC in 2046-2065 on 1980-1999 levels, while our business-as-usual scenario has 1.76ºC increases in 2050 on 1990 levels) to the country-specific results for yield changes, averaged across a range of future temperature scenarios, reported in the World Bank (2010). These results include some, but limited, adaptation (e.g. optimization amongst existing varieties) and do not assume significant technological progress. In addition, the possibility of higher concentrations of CO_2 aiding plant growth (CO_2 fertilisation) is not included on the basis that it remains controversial (see Muller, 2009). As such, these results should be interpreted as a worst case scenario, consistent with placing a high weight on precaution.

Tables 2a & 2b **GEM cities feature prominently in the list of cities most exposed to half metre sea level rises**

City	Exposed population (2070) (000s)
Kolkata, India	14,014
Mumbai, India	11,418
Dhaka, Bangladesh	11,135
Guangzhou, China	10,333
Ho Chi Minh City, Vietnam	9,216
Shanghai, China	5,451
Bangkok, Thailand	5,138
Rangoon, Myanmar	4,965
Miami, USA	4,795
Hai Phong, Vietnam	4,711
Alexandria, Egypt	4,375
Tianjin, China	3,790
Khulna, Bangladesh	3,641
Ningbo, China	3,305
Lagos, Nigeria	3,229
Abidjan, Côte d'Ivoire	3,110
New York-Newark, USA	2,931
Tokyo, Japan	2,521
Jakarta, Indonesia	2,248

City	Exposed assets (2070) ($bn, 2001)
Miami, USA	3,513
Guangzhou, China	3,357
New York-Newark, USA	2,147
Kolkata, India	1,961
Shanghai, China	1,771
Mumbai, India	1,698
Tianjin, China	1,231
Tokyo, Japan	1,207
Hong Kong, China	1,163
Bangkok, Thailand	1,117
Ningbo, China	1,073
New Orleans, USA	1,013
Osaka-Kobe, Japan	968
Amsterdam, Netherlands	843
Rotterdam, Netherlands	825
Ho Chi Minh City, Vietnam	652
Nagoya, Japan	623
Qingdao, China	601
Virginia Beach, USA	581
Alexandria, Egypt	563

Source: Nicholls et al (2007)

The health of GEM populations may also suffer from such high temperature increases. Predictive studies with results specific to GEM countries for far-future health impacts are rare, but an example is provided by Tanser et al. (2003), which estimates changes in malaria exposure in Africa by 2100. Results suggest that under a no-mitigation scenario, by 2100 South Africa would see the highest increases in malaria exposure in Africa, with a near five-fold increase in person-months of malaria exposure from 28 million person-months per annum to 135 million. This would take it to a degree of exposure greater than present-day Ivory Coast or Cameroon.[13]

Higher temperatures will cause reductions in biodiversity. The GLOBIO3 model of Alkemade et al. (2009) suggests that total biodiversity loss for the GEMs under business-as-usual will be equivalent to a cumulative loss of around 2,500,000 km^2 of pristine habitat by 2050 (compared to 1990). This is equivalent to an average loss of pristine land of 40,000 km^2 per annum. For comparison, the equivalent decline in biodiversity from the loss of natural tropical forest during the 1990s is

13 Although as the risk of malaria is very sensitive to income levels, this may be offset by increases in income levels and hence resilience.

estimated to have been around 150,000 km^2 per year (Shvidenko et al., 2005). China and Brazil would be expected to experience more than 60% of these losses. Within China, the ecosystems most vulnerable to losses would be the North West and Tibetan Plateau, but with significant ecosystem damage also expected among the lower reaches of the Chiangjiang River basin and in South China (Wu et al, 2007). Within Brazil, the risks are concentrated in the Amazon rainforest and the Pantanal wetland, but the coral reefs along the Brazilian coastline are also considered to be vulnerable (La Rovere and Pereira, 2007).

Developed country action

In our second scenario, in which only Annex 1 countries take action, global warming will still be substantial. Even if Annex 1 countries reduce their emissions by 80% of 1990 levels by 2050[14] average global temperature increases of 4.4°C above 1990 levels (4.8°C above pre-industrial levels) may still result by 2100. This would be associated with CO_2 atmospheric concentrations of 780ppm.

A world with this level of warming still implies a radical disruption to the physical and economic geography of Earth. While the current state of knowledge does not allow us to confidently predict how warming of 4-4.5ºC might differ from warming of 5ºC, a number of studies have identified likely physical impacts at around 4ºC.[15] For instance, it is estimated there would be a 40-50% decrease in annual water runoff in South Africa and South America, and at least a 20% increase in South Asia (Arnell, 2006). In semi-arid regions worldwide, the lack of rain would cause frequent wildfires, but particularly in South America and Amazonia (Scholze, 2006). The most affected regions of the world would become too hot and dry to grow crops; for example, some models suggest that the flow of the Nile could decrease by 75% (Strzepek, 2001). It is estimated that 1.5 billion more people would be exposed to dengue fever than in a world with no climate change (Hales, 2002).

Unsurprisingly, therefore, GEMs would still experience material economic losses. The RICE model suggests that aggregate losses for all of the GEMs would be 5.1% of GDP in 2100. For China, losses might be as high as 3.2% of GDP and for India they could reach 5.9% of GDP. These losses are, of course, lower than in the business-as-usual scenario but, strikingly, only by a small amount. Exclusive reliance on action by Annex 1 countries only reduces the losses faced by the GEMs as a whole by 20 per cent (0.9 percentage points). These modest reductions in losses are shown in Figure 2.

With global temperature rises still substantial, potential losses from agricultural yields remain, for many GEMs, striking. As Figure 3 shows, even if Annex 1 countries take action, climate change could lead to Argentina, Brazil, Indonesia and South Korea still all facing yield declines of more than 15% in 2050.

Sea levels would still rise substantially, continuing to threaten many GEM cities. Action by Annex 1 countries is estimated to only reduce sea level rises in 2100 by 5 centimetres (from 51cm to 46cm).

Finally, the GEMs will still suffer from losses in biodiversity. The pristine area equivalent loss would fall only from 2.5 million km^2 to 2.25 million km^2. This is equivalent to an average annual rate of 37,500 km^2 per annum, still equal to 25% of the loss in biodiversity caused by tropical deforestation in the 1990s.

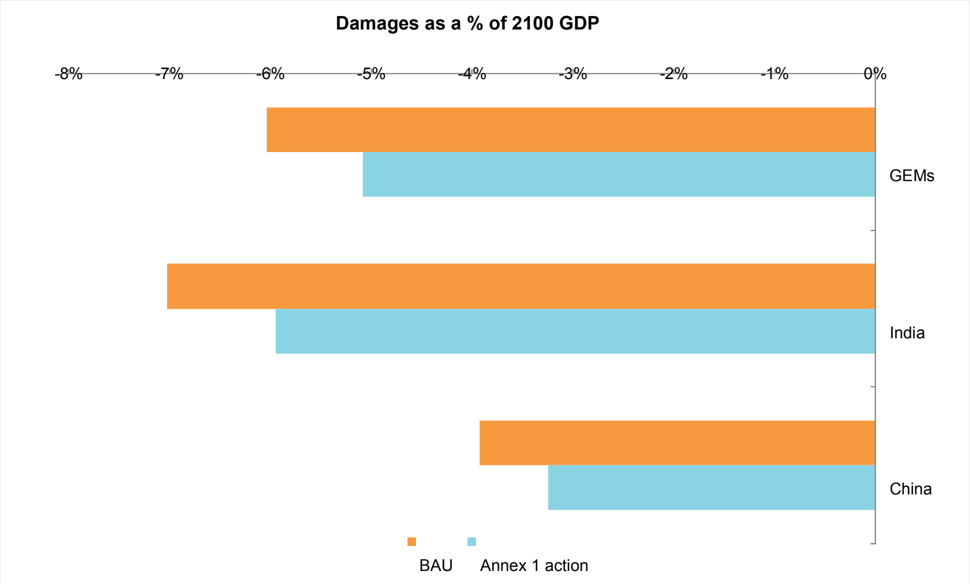
Action by GEMS

At present, only the GEMs or the G20 Annex I countries, with their high emissions, have the scale to make a material impact on climate outcomes. Comparatively, GEMs have the greater incentive to act as the damages they will suffer without action are notably greater.

This unique combination of scale and incentive is illustrated in the two bubble charts below. These figures plot expected damages as a proportion of GDP in 2100 on the horizontal axis so that the further over to the right,

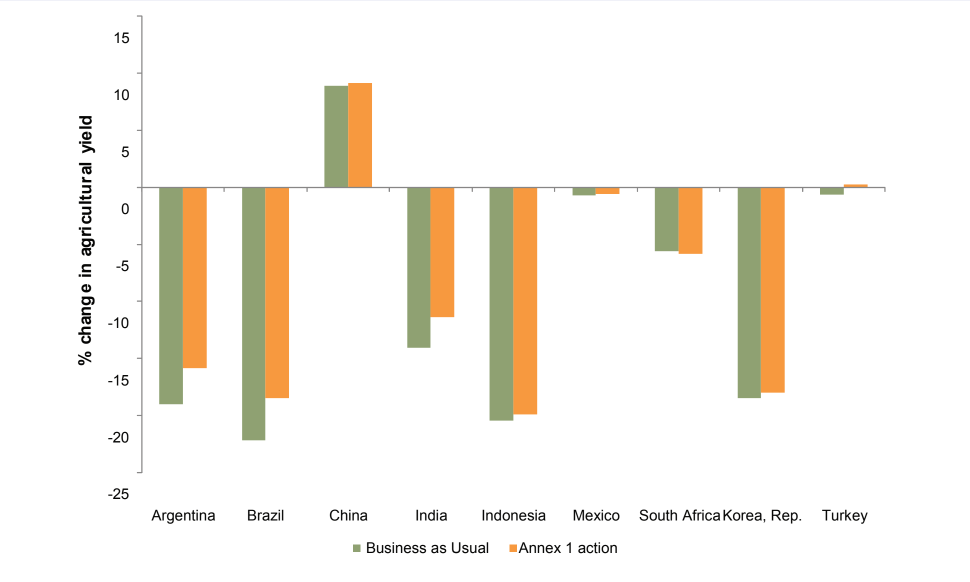
14 This, for instance, is the target that the EU has adopted.
15 Given the lack of a comprehensive assessment of physical impacts and what small differences between different high temperature increases might mean, the precise assumptions underlying these individual assessments may not be entirely consistent.

Figure 2 **Action by Annex 1 countries makes only a small difference to the economic damage from climate change suffered by GEMs**



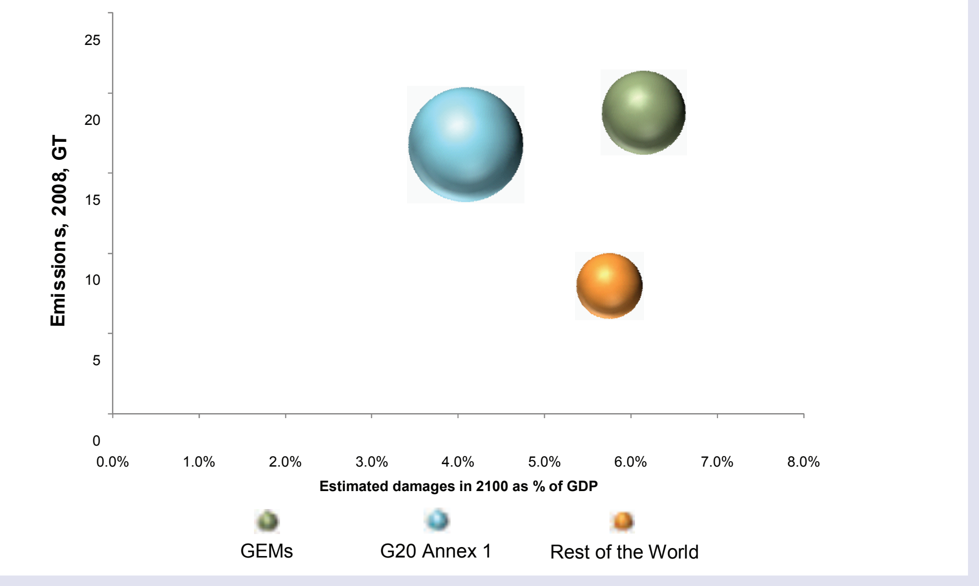
Source: Vivid Economics using RICE (2010) and Centennial Group (2010)

Figure 3 **Action by Annex 1 countries only makes a marginal difference to the agricultural yield reductions faced by the GEMs**



Source: Vivid Economics based on Muller et al (2009) and World Bank (2010)

Figure 4a | **Today, GEMs have both the scale and the incentives to address climate change**



Source: Vivid Economics based on RICE (2010) and Centennial Group (2010). Bubble size proportional to GDP

the more damage climate change does to the economy. The vertical axis shows the scale of the emissions so that the higher up the chart the more material impact the region can have on global emissions. The bubble size is proportional to GDP. The first figure (Figure 4a) shows that even today GEMs are higher and further to the right than either of the other two regions. The second figure (Figure b) shows that, by 2050, under BAU and using Centennial Group (2010) forecasts, this effect is massively accentuated.

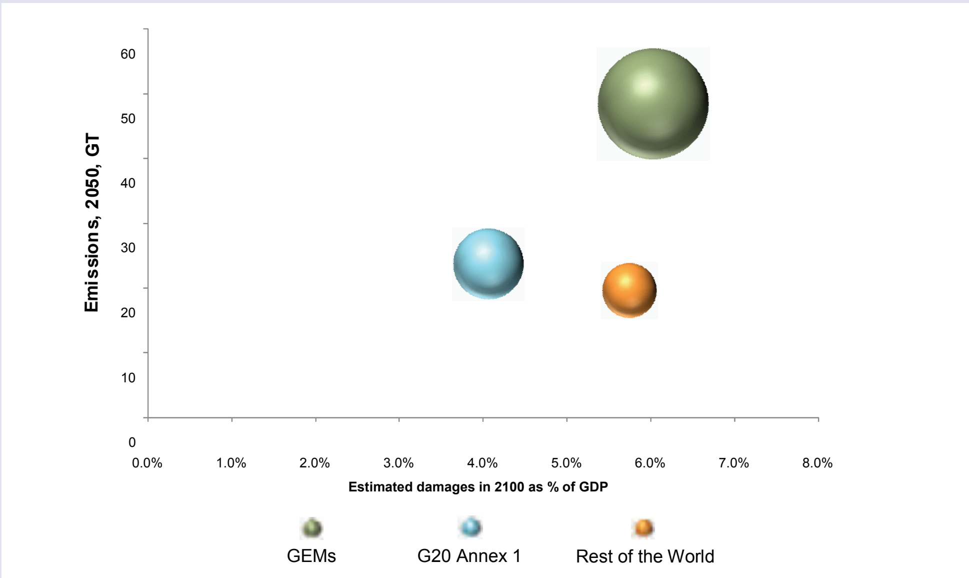
Consistent with their high and growing emissions, the potential for GEMs to make a difference to global temperature increases is materially greater than for Annex 1 countries. Under a scenario in which action by Annex 1 countries to reduce emissions by 80 per cent on 1990 levels is matched by a commitment by the GEMs to ensure that: (i) general emissions in 2050 are no higher than they were in 2005;[16] and (ii) emissions from land use change are 50 per cent lower, then temperature increases are much reduced. Compared to the business-as-usual increase of 4.9°C — and an increase of 4.4°C when only Annex 1 countries take action — global temperature increases are 2.7°C (all on 1990 levels). Atmospheric concentrations of CO_2 in 2100 are 550ppm compared with 905ppm in the business-as-usual scenario (and 780ppm in the Annex 1 action scenario).[17]

The economic damage suffered by GEMs with these temperature increases is significantly smaller, although still not negligible. Economic losses in 2100 fall to 2.5% of GDP; for China and India losses are 1.5% and 3.0% of

16 According to Sustainability Institute (2010), as of April 2010, this is a 'potential' proposal of the Chinese government where potential proposals are defined to include conditional proposals, legislation under consideration, and unofficial government statements.

17 This is likely to underestimate the impact of GEM action on reducing emissions as the premise of GEM action is to reduce fossil fuel imports, GEM action would have positive knock on effects on ROW emissions which our modelling does not capture.

Figure 4b | **By 2050, the difference between GEMs and the other world regions is even greater**



Source: Vivid Economics based on RICE (2010) and Centennial Group (2010). Bubble size proportional to GDP

GDP respectively. Figure 5 compares the losses faced by GEMs depending on the action taken. It clearly illustrates the importance of GEM action in diminishing the economic damage they might face.

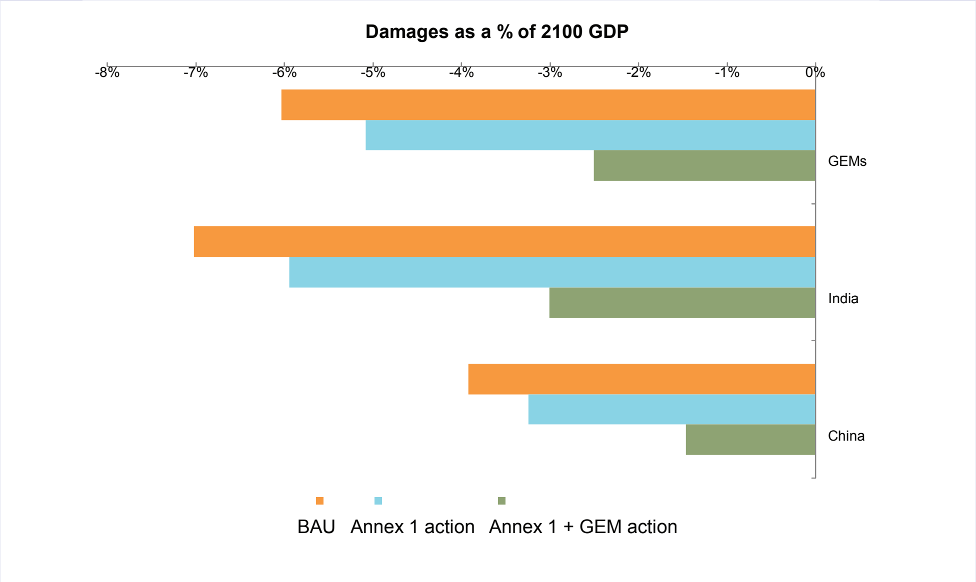
The lower temperature increases resulting from GEM action are, for most GEMs, expected to result in a less damaging impact on agricultural yields. In Argentina and Brazil, where yield declines might be more than 15% if only Annex 1 countries take action, they may instead be only 5%. Declines in yields in India, Indonesia, Mexico, South Africa and Korea are also expected to be mitigated by concerted GEM action.

Sea level rises are much lower in this scenario. Compared to the sea level rises of 51cm in the business-as-usual scenario — and which remain at 46cm in the developed country action case — increases are only 32cm when GEMs take action. In other words, while action by developed countries only generates a reduction in sea level rises of less than 10%, if coupled with GEM action then a reduction of more than 35% is possible.

Biodiversity losses are also curtailed. While action by Annex 1 countries only reduces the biodiversity loss suffered in the GEMs by 10%, complementary action by GEMs boosts this to more than 30%.

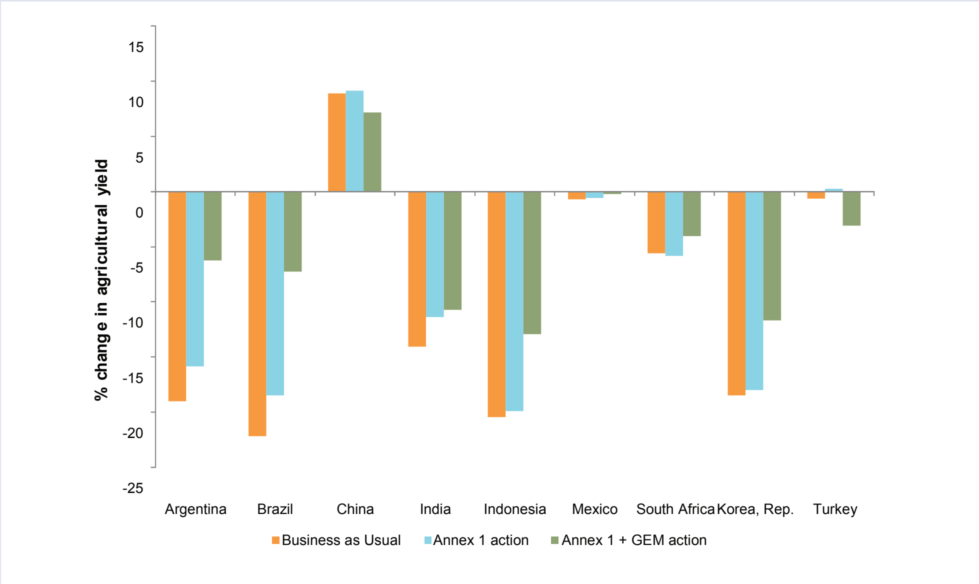
It should be stressed that this scenario is not a recommendation for a 3°C temperature increase. The scientific evidence suggests that temperature increases above 2°C may be dangerous, and this position is recognised in the Copenhagen Accord. For instance, with warming of 3ºC the proportion of the global land surface experiencing severe droughts is still likely to increase from 10% today to up to 40% (Burke et al., 2006) while there will be a loss of glaciers in high altitude regions (including the Tibetan Plateau) affecting water supply to some heavily populated regions. Achieving a 2ºC increase is likely to require even more ambitious reductions from both Annex 1 countries and GEM countries than considered in this report, as well as action from the rest of the world. Reductions in line with 2°C are

Figure 5 | **Only GEM action will prevent climate change seriously affecting their own economies**



Source: Vivid Economics using RICE (2010) and Centennial Group (2010)

Figure 6 | **Concerted GEM action will do much to reduce the negative impact of climate change on agricultural yields in 2050 in their own countries**



Source: Vivid Economics using RICE (2010) and Centennial Group (2010) technologically feasible, but involve significant political challenges.

Action by Brazil, China and India

A significant proportion of the benefits realised by GEM action derive from China, India and Brazil controlling their emissions. If these three countries alone took action alongside developed countries, as defined above, then global temperature increases in 2100 might be 3.5°C above 1990 levels. This compares with 4.4ºC without any GEM action and 2.7°C if all GEMs acted in a coordinated fashion. In other words, these three countries alone account for around 50% of the temperature benefit that the GEMs can achieve collectively. In this scenario, sea levels might rise by around 38cm and atmospheric concentrations of CO_2 would be 640ppm.

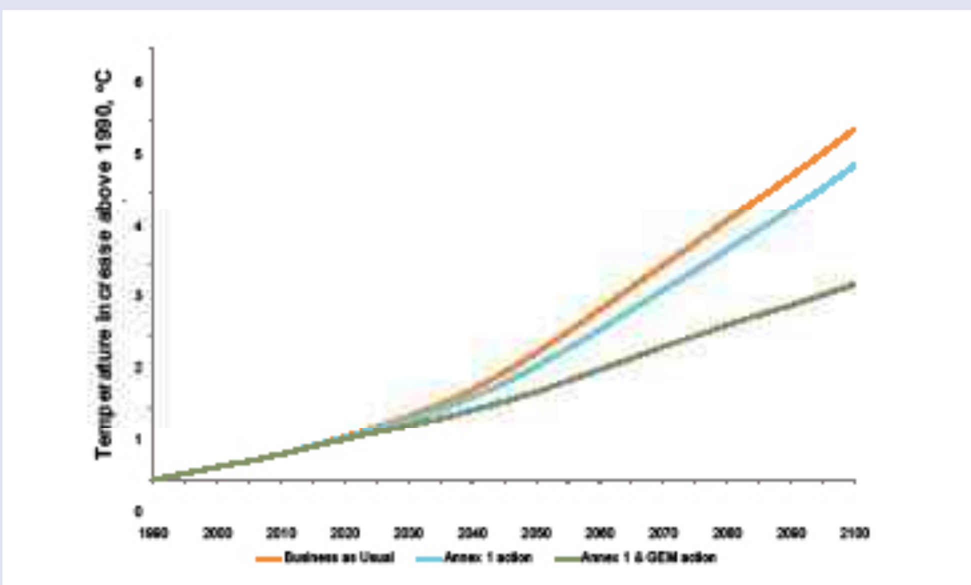
Correspondingly, action by these three countries can achieve important economic benefits. Compared with the developed country action scenario in which India suffers damages amounting to almost 6% of GDP in 2100 and China damages of 3.2% of GDP in 2100, action by these two countries and Brazil would reduce these losses to 4.2% and 2.2% respectively.

Summary: Alternative visions of the future

If GEMs are to experience the strong growth projected in the Centennial Group forecasts then their action or inaction on reducing emissions will determine whether or not the most dangerous changes in the world's climate can be avoided. It will therefore determine whether or not the economic and social consequences of dangerous climate change on GEMs can be significantly reduced.

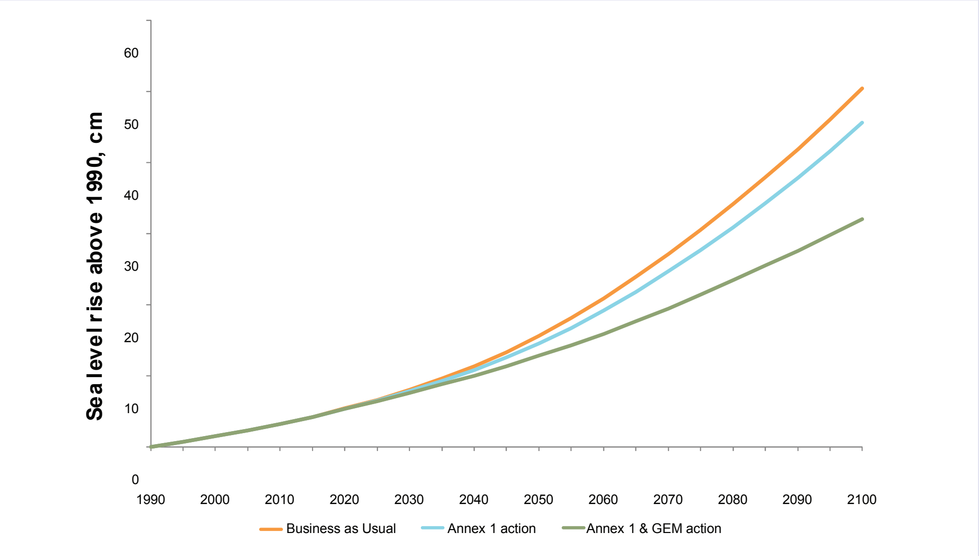
This is summarised in Figures 7 and 8, which show the projected temperature increases and sea level rises in each of the three scenarios, and table 3 which further elaborates on the outcomes expected in each scenario.

Figure 7 **GEM action is indispensable for stabilising global temperatures**



Source: Vivid Economics modelling using MAGICC 5.3 and Centennial Group forecasts

Figure 8 **GEM action significantly reduces sea level rises**



Source: Vivid Economics and MAGICC 5.3 and Centennial Group forecasts

Table 3 **Action by GEM governments is essential if their countries are to avoid the worse consequences of climate change**

Variable		Business-as-usual	Developed country action	Developed country & GEM action
Average global temperature increase in 2100 (on 1990 levels), °C		4.9	4.4	2.7
Atmospheric concentrations of CO_2, parts per million		905	780	550
Economic damages in 2100, % of GDP:	GEMs	-6.0	-5.1	-2.5
	India	-7.0	-5.9	-3.0
	China	-3.9	-3.2	-1.5
Agricultural yield declines in 2050 relative to 2000,%:	Argentina	-19.8	-15.8	-6.2
	Brazil	-22.2	-18.5	-7.3
	China	8.9	9.1	7.2
	India	-14.1	-11.4	-10.7
	Indonesia	-20.5	-19.9	-12.9
	Mexico	-0.7	-0.6	-0.2
	Republic of Korea	-18.5	-18.0	-11.7
	South Africa	-5.6	-5.8	-4.0
	Turkey	-0.7	0.3	-3.1
Sea level rise in 2100, cm above 1990 levels		50.5	45.6	32.1
Decline in biodiversity, km^2 pristine area equivalent loss 1990-2050		2,509,000	2,253,000	1,754,000

Source: Vivid Economics based on sources in text

Accelerating the transition

By making the low-carbon transition, GEMs will transform their economies towards a new technological paradigm. The evidence suggests that this will bring greater energy security, healthier and more productive citizens, cleaner cities, more productive agricultural sectors and more efficient and competitive industrial sectors. These benefits are in addition to avoiding the worst consequences of climate change.

GEMs are already taking action

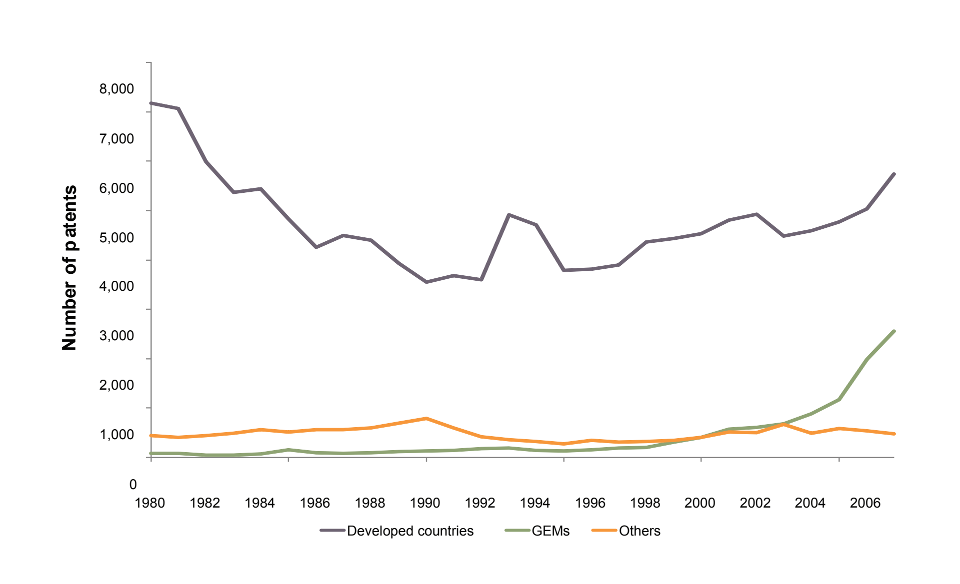
Over the last 2-3 years, GEMs have accelerated their action on climate change and clean energy. China, for instance, is now one of the leading countries in the world in solar and wind, electric cars, and high-speed rail technologies. It is also the leading producer of solar photovoltaic cells, having dramatically gained market share from the United States.[18]

GEMs are also becoming increasingly important locations for low-carbon innovation activity. As the figure below shows, since 2000, low-carbon energy patenting activity has accelerated rapidly within the GEMs.

During the financial crisis, GEM countries led the world in the percentage of economic stimulus devoted to green measures. The economic stimulus plans of South Korea and China were judged to be 38% and 80% "green" respectively (HSBC, 2009), significantly greater than the US or the EU.

Two GEMs have already set emissions reduction targets in absolute terms, mirroring those in Annex 1. In November 2009, South Korea pledged to reduce its emissions by four percent below 2005 levels by 2020. In December 2008, Mexico announced that it will reduce greenhouse gas emissions by 50 percent of 2002 levels

Figure 9 **GEMs are responsible for a rapidly increasing amount of low-carbon energy technology patenting**



Source: Dechezleprêtre et al (2011) and Vivid Economics calculations based on PATSTAT database

18 In 2004, the US accounted for 12% of solar PV production and China 3%; by 2009 Chinese production had risen to 35% and US production only 6%. Earth Policy Institute (2010)

by 2050. China and India will probably put a price on carbon before the US. In July 2010, it was reported that China will begin domestic carbon trading programs during its twelfth five-year plan (2011-2015) to help it meet its target of reducing carbon intensity by 40-45% by 2020. Furthermore, in the same month, India imposed a "domestic carbon tax", in the form of a levy on coal producers, which is expected to raise around US $535 million annually (BusinessWeek, 2010).

Accelerating action could trigger a low-carbon race that the GEMs should win

In the EU, countries and firms are seeking leadership in a "race to compete" in the low-carbon world. In July 2010, a coalition of CEOs of large European companies wrote to support the ministers of the United Kingdom, Germany and France who are pushing for a 30% reduction in emissions by 2020. They argued that without such a target, "Europe might lose the race to compete in the low-carbon world to countries such as China, Japan and the US".

The US President and some Democrat and Republican politicians, believe the USA must "win the clean energy race". President Obama has stated that "the nation that leads the clean energy economy will be the nation that leads the global economy. And America must be that nation." (State of the Union, 2010). To the disappointment of many in the USA, the structure of their legislature has made it impossible for them to pass significant clean energy legislation in 2010.

A large number of jobs are at stake. For instance, in the USA alone, it is estimated that investments of US $80 billion under the Recovery Act will generate over 800,000 jobs in clean energy.[19]

GEMs have a strong self-interested incentive to accelerate the race to a low-carbon global economy; they have the most to lose from a slow transition, and the most to gain from a fast transition. As well as reducing the climate damages GEMs may face, coordinated GEM action could trigger Annex 1 countries to ramp up their emission reductions, providing larger markets for GEM low-carbon products. For instance, a recent HSBC report predicted that if governments went beyond the commitments they made during the run up to COP 15 then, even by 2020, the low-carbon market would be worth 2.7 trillion dollars; 30% larger than if governments simply kept to their COP 15 commitments and a massive 100% larger than in their worst-case scenario (HSBC, 2010).

In the longer-term, they have an opportunity to disrupt the economic and political status quo. Eras of rapid technological progress in core industries such as energy generation have sometimes driven major changes in the relative rankings of countries. For example, Great Britain leapfrogged The Netherlands in the eighteenth century due to being the first movers in the Industrial Revolution and the US overtook Great Britain in the late nineteenth century through the adoption of mass market production technologies. The GEMs already have a strong base from which to seize the clean energy opportunity as evidenced by the rapid increase in low-carbon energy system patenting activity within the GEMs. It is unsurprising that US and EU firms are increasingly fearful of the consequences if GEMs win the clean energy race.

Delaying action increases costs

A recent survey of the literature on cost estimates derived from a wide range of integrated assessment models concluded that these models suggest that the global costs of meeting a 2ºC climate goal are likely to be between 1% and 5% of GDP (Bowen and Ranger, 2009). There is little work to date on what the costs for GEMs specifically might be.[20] The 2ºC goal is more ambitious than the scenarios that have been examined in this report which implies that the costs associated

19 These comprise 722,000 jobs in renewable energy and advanced energy manufacturing (253,000 from direct government spending, and 469,000 from leveraged private investment), and 104,000 in smart grid investment. This does not include jobs from investments in advanced vehicles and batteries or energy efficiency. See White House (2009).

20 Although see section 3.5 below for some qualitative arguments for why it may be towards the lower end of this sort of range.

with realising the benefits discussed in this paper might be towards the lower end of this range. In addition, these cost estimates should be seen in the context of the possibility that, as discussed at the start of section 2, the damages might be much worse than suggested by most modelling assessments. In this light, the costs can be seen as an insurance policy against much more catastrophic damages than reported above.

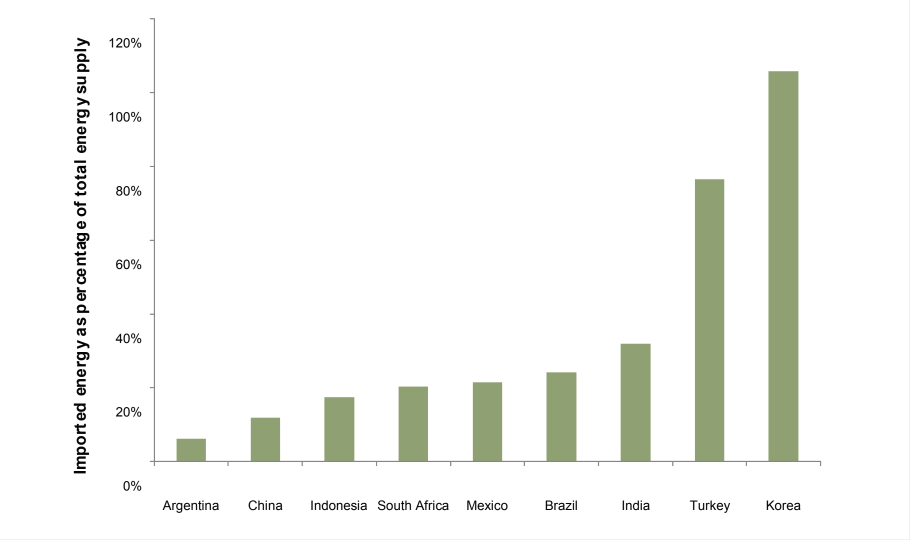
Moreover, costs increase with greater delay to action. Waiting until the future to take action will increase costs as it will lead to the accumulation of capital today that will be inconsistent with the requirements of a low-carbon world and which will have to be scrapped prematurely. Failure to accelerate support towards low-carbon innovation could slow the rate of technical progress in these clean technologies making an eventual switch to these technologies more costly (Acemoglu, 2010). Two recent studies suggest that if the BRIC countries (as a subset of the GEMs) were to begin rational preparation for a low-carbon economy today they could save between 25% and 33% of the eventual costs of that transition (Bosetti et al, 2009; Blanford et al, 2009).

Correspondingly, delay will require steeper annual reductions in order to reach the same goal. For instance if GEMs start taking action in 2012 to bring emissions back to 2005 levels by 2050 then they would have to achieve annual reductions in emissions of 0.4% per annum; if they wait until 2030 before starting to take action, with the intention of reaching the same target by 2070, then average reductions of 1.5% per annum might be required. While historical experience shows that reductions of 0.5% per annum are achievable without significant economic consequences, reductions of more than 1.0% per annum have typically only been associated with prolonged economic recessions.

Greater energy security

Many GEMs are currently reliant on significant imports of

Figure 10 | **Six of the nine GEMs import more than twenty per cent of their total energy needs**



Note: not all imports in one year need be used for supply in that year, allowing imports to exceed 100% as in the case of Korea.

Source: IEA using latest available data (2009 for Mexico, Turkey and Korea; 2008 for all others).

fossil fuels to meet their energy needs. Figure 10 shows that 6 of the 9 GEMs import more than 20% of their total energy needs. Six of the nine GEMs import more energy than they export.[21] Dependency on imports for energy resources leads to concerns that energy supplies and prices may be vulnerable to uncontrollable events and/or political pressures in the exporting country.

Exploiting low-carbon energy sources offers the opportunity of reducing reliance on imported energy. The uneven geographic distribution of fossil fuel resources provides a relatively small number of countries with control of much of the world's current energy supply. By contrast, the wide variety of different low-carbon energy technologies (solar, wind, hydro, nuclear, biomass, geothermal) can provide much greater scope for domestic energy supply according to the prevailing conditions in each country.

Healthier, more productive and more efficient societies

The investments needed to achieve a low-carbon transition will help make GEM societies cleaner, healthier and more productive.

Improved air quality

As well as carbon dioxide, fossil fuel combustion releases locally active air pollutants such as particulate matter, sulphur dioxide and nitrogen dioxide that are damaging to human health. These contribute to a range of cardiovascular and respiratory diseases, including lung cancer, bronchitis and asthma. Particulate matter, small inhalable particles which can penetrate deep into the lungs, is considered particularly problematic.

Nine out of ten of the world's cities with the worst air pollution are situated in the GEMs (Table 4). More than 50 million people live in these cities. All of these cities have annual mean concentrations of PM_{10}[22] that are five to eight times the WHO guideline level of 20 micrograms per cubic metre. Over half of the Chinese urban population lives in cities with concentrations of PM_{10} over five times the guideline level. This level of exposure to PM_{10}

Table 4 **Nine of the ten cities with the worst air pollution (in terms of particulate matter) are located in the GEMs**

City	PM_{10} concentration, (micrograms per m^3)	Population
Cairo, Egypt	169	7,764,000
Delhi, India	**150**	**12,100,000**
Kolkata, India	**128**	**5,100,000**
Tianjin, China	**125**	**7,500,000**
Chongqing, China	**123**	**5,087,000**
Kanpur, India	**109**	**3,100,000**
Lucknow, India	**109**	**2,342,000**
Jakarta, Indonesia	**104**	**10,100,000**
Shenyang, China	**101**	**5,090,000**
Zhengzhou, China	**97**	**2,600,000**

Source: World Bank (2007) World Development Indicators (Table 3.13), City Mayors statistics.
Bold indicates cities in GEM countries

21 These are Argentina, Brazil, China, India, Korea and Turkey.

22 Particulate matter of 10 microns or less in size.

and other pollutants leads, according to World Bank (2007) estimates, to approximately 270,000 cases of chronic bronchitis and 400,000 hospital admissions from respiratory or cardiovascular disease in China each year, and the prematurity of up to 13 per cent of deaths amongst the Chinese urban population. The total cost of air pollution in China is placed at between 1.2% and 3.8% of GDP.[23]

The health benefits of reducing greenhouse gas emissions are considerable, substantially offsetting the costs of abatement. In the most polluted cities, including the health benefits of pollution reduction in cost-benefit analysis of many CO_2 emissions reduction projects would make them cost-beneficial. In China, O' Connor et al (2003) estimate that a tax that reduced emissions by 15 per cent would yield health benefits of 0.14 per cent of GDP, offsetting two thirds of the loss in consumption from the tax.[24] Combined with further benefits from increased agricultural productivity, these benefits can completely offset losses in consumption resulting from mitigation policies (see next section).

Increased agricultural productivity

Fossil fuel combustion leads to the formation of low-level ozone that damages crop yields by reducing photo-synthesis and growth in plants. This is already affecting yields worldwide and, on the basis of current air quality legislation and trends in air pollution, an additional $6-10 billion p.a. in crop yield losses is predicted in India and China by 2030 (Van Dingenen et al, 2009). Some of this could be avoided through mitigation action.

In China it is estimated that a 15% reduction in CO_2 emissions would increase national output of rice by 0.29% (0.5 million tonnes) and wheat by 0.68% (0.8 million tonnes) (O' Connor et al, 2003). In monetary terms, the overall benefit of increased crop productivity in China is placed at 0.1% of GDP (20 billion 1997 yuan, or $3 billion in 2008 $). In conjunction with the health benefits reported above, this would more than offset the consumption losses caused by the tax needed to reduce emissions by this amount. Further, these benefits do not include damage to crops through acid rain, which can also be significant. The World Bank (2007) estimated the economic cost of reduced crop yields due to acid rain in China at $3.6 billion (2003 prices) per annum.

Increased efficiency

Mitigation action can improve efficiency and save money over time, boosting GDP. Energy efficiency improves competitiveness, and the use of waste methane to generate electricity can lower costs. Such opportunities have not always been exploited because of market failures, including information gaps, savings accruing to parties other than those who bear the cost (for example, in property development), and other market failures (e.g. in the capital markets).

Annual savings through such costless mitigation measures could be greater than $100 billion per annum by 2030. Table 5 shows the estimates of potential savings in GEM countries, in absolute terms and as a percentage of GDP for four GEMs: China, Brazil, Indonesia and Mexico.

Although these opportunities are unlikely, by themselves, to completely offset the overall costs of undertaking a low-carbon transition, they are yet another beneficial short-term side effect, and illustrate the value of sensible policy in extracting the short-term benefits of the transition.

23 Depending on whether measured in terms of adjusted foregone earnings (the lower measure) or willingness to pay to avoid (the higher measure).

24 Assuming that the tax revenues are recycled.

Table 5 | **Substantial abatement opportunities that reduce costs are available to the GEMs**

Country	Metric	Value of savings (USD, billion)	% of current GDP	Annual emissions savings in year shown, $MtCO_2e$
China	Annual benefit in 2030	53.5	1.2	~1900
Brazil	**Annual benefit in 2030**	**15.3**	**1.0**	**~200**
Indonesia	**Annual benefit in 2020**	**1.9**	**0.4**	**~180**
Mexico	**NPV of benefit 2009-2030**	**490**	**N/A**	**N/A**

Source: China and Brazil, McKinsey (2009) and (2009); Mexico, World Bank (2009); Indonesia Asian Development Bank (2009). All figures are in $2008.

Annex 1: A key influence on global emissions

This annex outlines the current importance of the GEMs to the global economy, their population and contribution to emissions, and how these are projected to grow substantially over the 21st century.

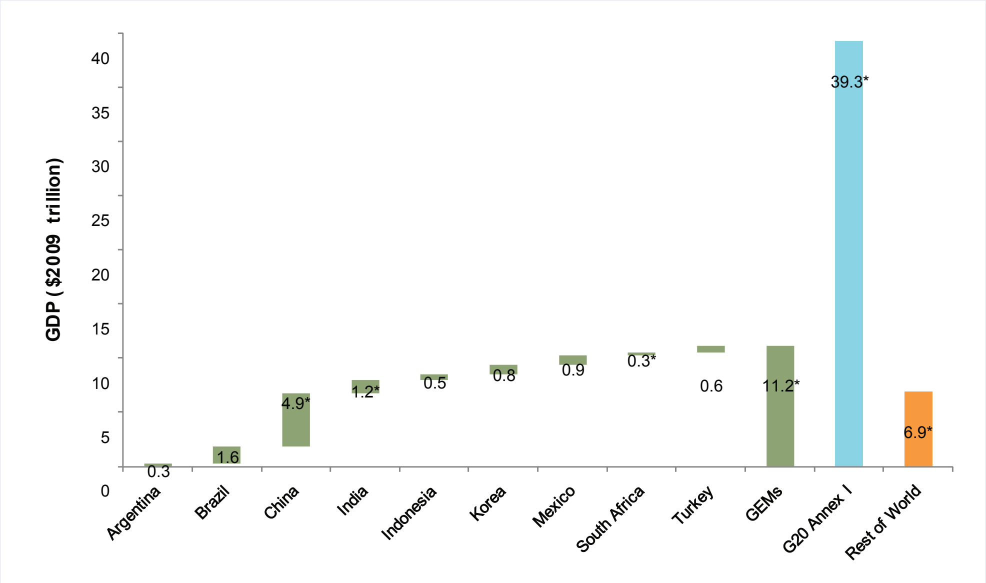
Today's picture: growing in significance

The GEMs are already a major component of the global economic and political architecture. As figure A1 shows, three of the GEMs have economies of over $1 trillion GDP, while collectively the group accounts for almost a fifth of global economic activity. Over the period 2000-2009, GEM countries averaged an annual economic growth rate (6.7%) almost four times that of the G20 Annex 1 countries.[25] Bilateral trade between China, Brazil and India increased by between 4 and 15 times, much greater than the increases in trade between these countries and the United States.[26] There are now twice as many Fortune Global 500 countries originating from GEM countries (74) as there were in only 2005. Such trends have justified the formation of the G20 itself, and it replacing the G7/G8 as the pre-eminent geopolitical forum.

Almost half of the world's population live in GEMs. Figure A2 shows that India and China alone each have a population bigger than that of the G20 Annex 1 countries put together.

GEMs have weathered the global economic recession better than more developed countries. Five out of nine GEMs (Argentina, China, India, Indonesia and South Korea) are thought to have enjoyed positive economic growth during 2009, compared to only one G20 Annex 1 country (Australia).[27] While the Global Credit Crisis led to a global drop in foreign direct investment of 22%

Figure A1 | **GEMs account for around 20 per cent of global economic output**



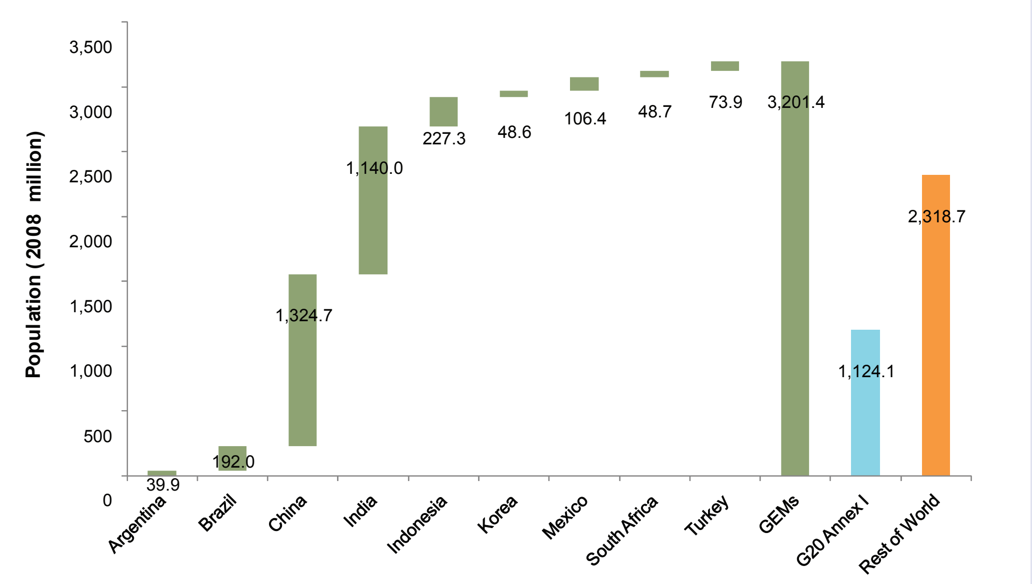
Source: IMF. * indicates IMF estimate

25 Weighted averages based on IMF data

26 International Trade Centre data

27 IMF data; some 2009 figures are based on estimates.

Figure A2 | **Both China and India have populations bigger than the G20 Annex 1 countries put together**



Source: World Bank

in 2008, the GEMs saw an increase of 13%.[28] Such consistently strong performance, and resilience under adverse economic conditions, suggests that the GEM countries will see their economic and geopolitical influence further increase over the coming decades

The major economic powers of tomorrow

GEMs will be a major driver of global population growth in the 21st century. According to the UN Population Division, by 2050, 0.6 billion more people will be living in the GEM countries, two-thirds of them will be in India. Figure A3 shows that, to 2050, GEMs will account for a quarter of the growth in world population, compared to just 2% in the most developed G20 countries.

On some forecasts, India and China will become the world's economic superpowers. By 2050, the central scenario of Centennial Group International (2010) suggests that GEMs may account for more than 60% of global GDP and have accounted for more than two-thirds of the economic growth between today and 2050. As shown in figure A4, their collective output could, in real terms, be 18 times the levels they are achieving today and four times current global economic output. India and China may be the world's largest economies, each accounting for more than the entire economic output of G20 Annex 1 countries.

Current contributions to global emissions

The GEMs already account for just under half of global emissions. Commensurate with their rising economic status, the GEMs have become large emitters. They currently account for 43% of global greenhouse gas emissions, a greater proportion than the G20 Annex 1 countries (Figure A5). Symbolically, China has recently surpassed the United States as the world's largest emitter of carbon dioxide and largest energy consumer (IEA, 2010).

Unsurprisingly given their recent rapid economic

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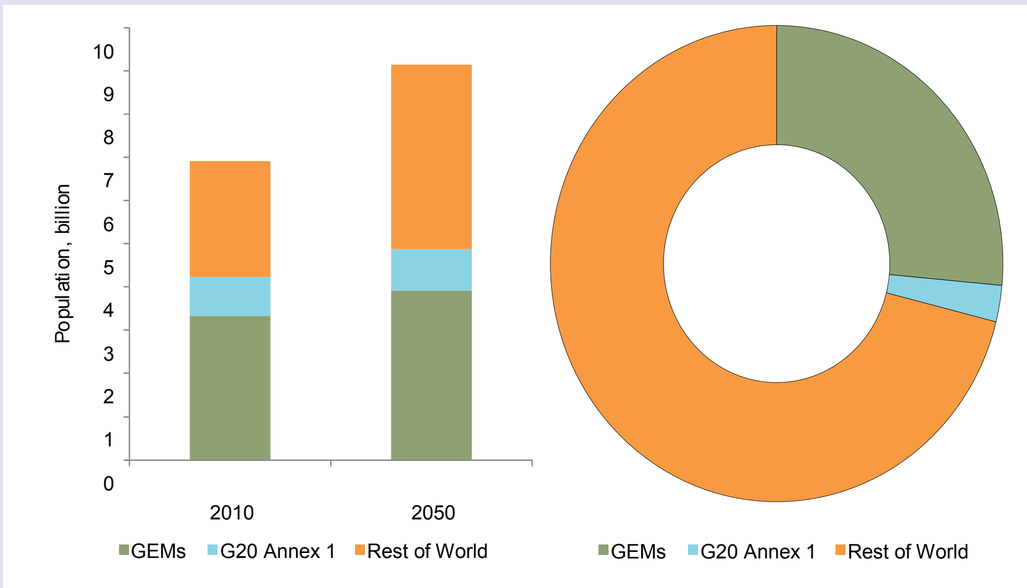
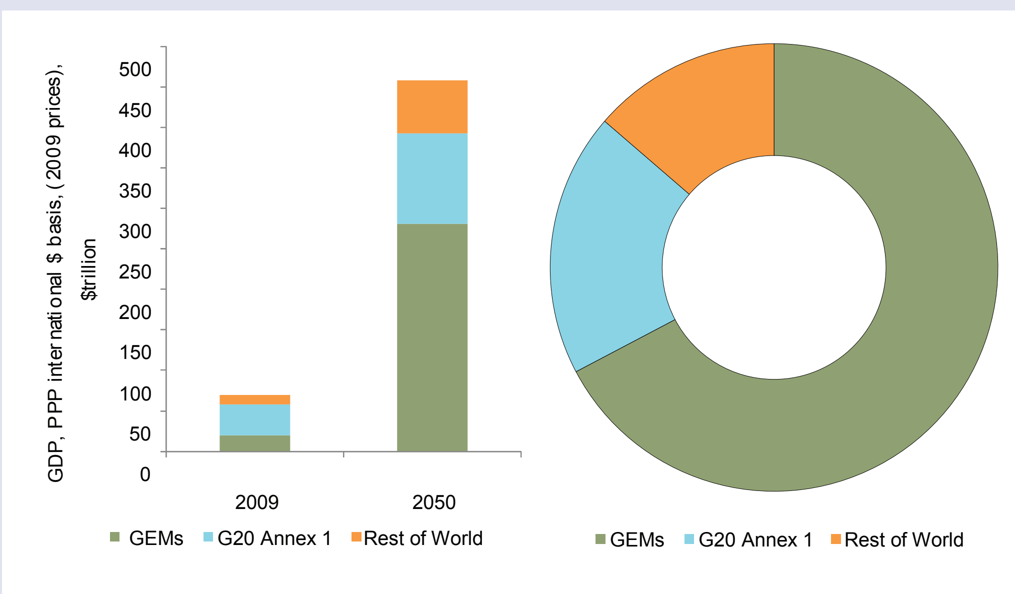
Figure **A3** **GEMs will be responsible for a quarter of the world's population growth between 2010 and 2050**



Source: UN Population Division. 2010 figures are projections.

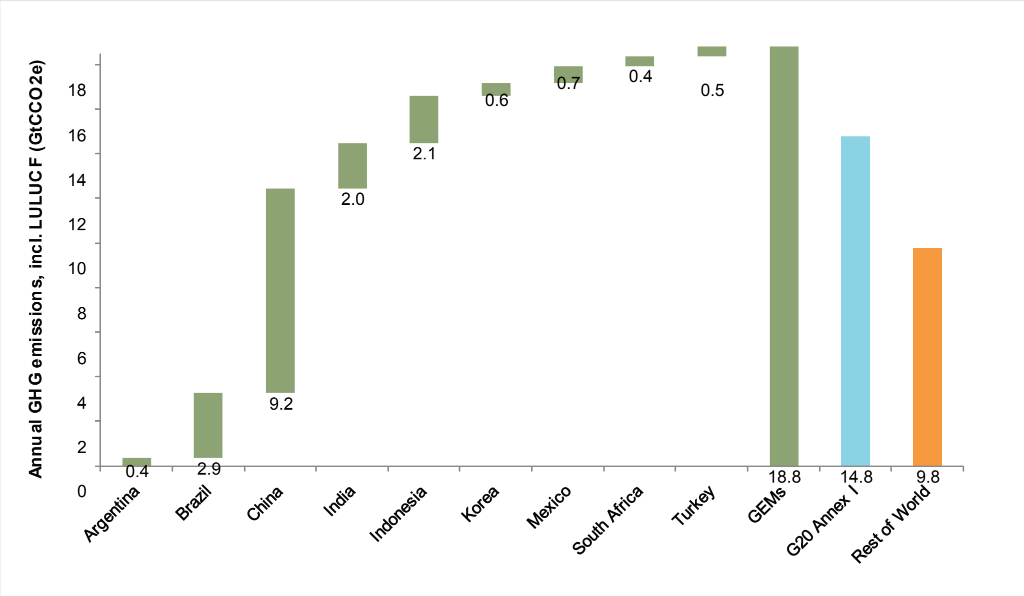
Figure **A4** **By 2050, GEMs may account for more than 50% of global economic activity**



Source: Centennial Group International (2010)

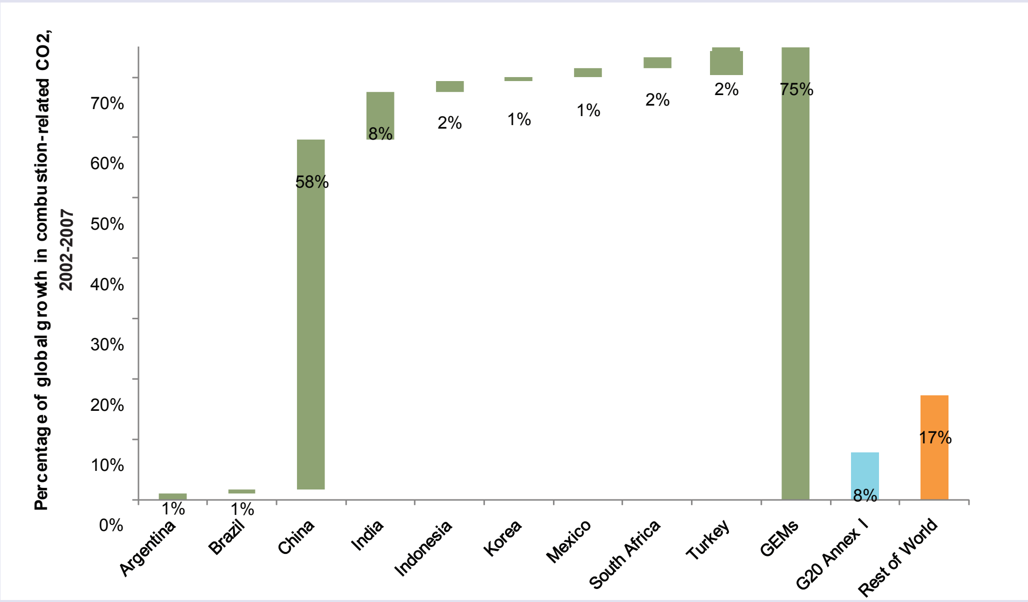
SHOULD EMERGING MARKET ECONOMIES ACT ON CLIMATE CHANGE, OR WAIT?

Figure **A5** **GEMs account for a greater proportion of current emissions than the G20 Annex 1 countries**



Source: (G20 Annex 1) UNFCC; (GEMs and Rest of World) World Resources Institute, projections from 2005 data

Figure **A6** **Three quarters of the growth in combustion related global emissions between 2002 and 2007 came from the GEMs**



Source: Carbon Dioxide Information Analysis Center growth, GEM countries have accounted for the bulk of global growth in combustion CO_2 emissions over recent years. Nearly three-quarters of global growth in fossil fuel-related CO_2 over the period 2002-2007 was driven by GEM countries, with China alone contributing over half (Figure A6). More recent data is expected to further underline and confirm this trend. Just over half of China's increase was attributable to the power sector, with the growth in industrial emissions also accounting for a significant proportion, although much of this was associated with the manufacture of goods exported to Annex 1 countries.

Annex 2: The MAGICC model

The MAGICC model is a simple climate model, described as an "upwelling diffusion energy-balance model" which also incorporates a carbon cycle allowing for system feedbacks (Wigley and Raper, 2001). It is computationally fast, and can represent the output of more complex scientific models, making it suitable for this report.

In our runs using MAGICC, we use a climate sensitivity parameter (which measures the change in temperature for a doubling of CO_2) of 3ºC, based on the most recent IPCC report (Meehl et al., 2007) which concluded that "equilibrium climate sensitivity is likely to lie in the range 2–4.5°C, with a most likely value of about 3°C." For the ocean diffusivity parameter, a parameter of 2.3cm^2/s was used, broadly following Wigley (2005). For the carbon cycle component incorporating positive feedbacks in the carbon cycle, we used the medium option provided by MAGICC.

MAGICC reports expected temperature increases relative to a 1990 baseline. Implicitly, there has been a 0.4°C increase in global average temperatures between pre-industrial times and 1990. This is consistent with the IPCC 4th assessment report which provides a central case increase in global average temperature from pre-industrial times to 2000-2005 of 0.8°C (within a range of 0.6 - 1oC) and the results from Brohan et al (2006) – the most recent relevant study reported in the IPCC report – which estimates that the global average temperature increase per decade from 1979 to 2005 has been 0.268°C. The Brohan et al (2006) results suggest that there was a 0.4°C between 1990 and 2005, implying a further 0.4°C between pre-industrial and 1990.

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