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Anil Markandya, Mikel González-Eguino,
Patrick Criqui and Silvana Mima

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Email(1): ibon.galarraga@bc3research.org

Email (2): mikel.gonzalez@bc3research.org

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Low climate stabilisation under diverse growth and convergence scenarios

Anil Markandya[1], Mikel González-Eguino[2], Patrick Criqui[3], Silvana Mima[4]

In the last decade, a few papers have analysed the consequences of achieving the greenhouse gas concentration levels necessary to maintain global temperature increases below 2 degrees Celsius above preindustrial levels. Most models and scenarios assume that future trends in global GDP will be similar to the growth experienced in the past century, which would imply multiplying current output nineteen-fold in this century. However, natural resource and environmental constraints suggest that future global economic growth may not be so high. Furthermore, the environmental implications of such growth depend on how it is distributed across countries. This paper studies the implications on GHG abatement policies of different assumptions on global GDP growth and convergence levels. A partial equilibrium model (POLES) of the world´s energy system is used to provide detailed projections up to 2050 for the different regions of the world. The results suggest that while low stabilisation is technically feasible and economically viable for the world in all the scenarios considered, it is more likely to occur with more modest global growth. Convergence in living standards on the other hand places greater pressures in terms of the required reduction in emissions. In general we find that there are major differences between regions in terms of the size and the timing of abatement costs and economic impact.

Key words: Climate policy; Economic growth; Convergence; Energy forecasting;

Abatement cost; Partial Equilibrium models; Energy systems.

JEL Classification: O44, Q4, Q47, Q54, C60

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[1] Corresponding author: anil.markandya@bc3research.org
Basque Center for Climate Change, Alameda de Urquijo 4, 4-1. 48008 Bilbao (Spain). Tel: +34944014690.
2 BC3 Basque Center for Climate Change
3 CNRS-Université Pierre Mendès-France, Grenoble
4 CNRS-Université Pierre Mendès-France, Grenoble

1. Introduction

According to the Intergovernmental Panel on Climate Change (IPCC 2007) the objective of stabilising temperatures rise in 2ºC above pre-industrial levels will require global GHG emissions to peak in 2020 and be reduced by around 50% by 2050 (compared to 2000) and more than 80% by 2100. Meeting low climate stabilisation targets requires considerable emission reductions in high-income countries, but also early involvement of developing countries.

Most of the models and scenarios currently in use assume that in next century the pattern of growth will be quite similar to that of the last century. According to Maddison (2001) global GDP increased 19-fold between 1900 and 2001, which means an annual GDP per capita compound growth rate of 1.9%. This spectacular increase shows that during that period technological innovation and capital investment overcame the law of diminishing returns. Natural resources did not become a limiting factor in production. However, this may not hold in the future with the anticipated increase in population and considering the implications for future key resource demands and environmental impacts.

Regarding convergence the differences between studies are much wider, reflecting differences on whether or not existing income gaps are viewed as gradually closing. For example in the IPCC SRES scenarios, developing countries gradually catch up at different speeds. The rapid development and catch-up scenarios remain in dispute as they imply higher productivity growth in the now developing countries than has been experienced in the past. There are also some models that diverge from these findings: for example in the MIT-EPPA model the ratio between developed and developing countries increases slightly, although the gap between some regions widens substantially. Such inequalities may be socially unsustainable and may also be economically infeasible.

This article studies the implications of different global GDP growth levels together with different convergence levels between countries and regions in achieving low stabilisation targets. A global energy model (POLES) is used with a time horizon up to 2050 to analyse the implications of these paths and the consequences of introducing a climate policy (through carbon prices) to cut emissions by half by 2050.

The paper is organized as follows: Section 2 presents an overview of the model used; Section 3 describes the proposed baseline scenarios and the climate policy to be implemented; Section 4 analyses the energy and economic results for the different scenarios aimed at achieving low stabilisation. Section 5 offers some conclusions on the feasibility of low stabilization scenarios.

2. The Model

The **P**rospective **O**utlook for **L**ong-term **E**nergy **S**ystems (POLES) model[5] is a global sectoral simulation model for the development of long term energy supply and demand scenarios (EC 1996, Criqui 2006). The model allows the following to be carried out: i) projections of energy demand and supply by region/country with endogenous international oil/gas/coal prices; ii) simulations of technology development for electricity supply; iii) simulation of CO2 emissions; and iv) assessment of energy and climate policies.

This model therefore provides a consistent framework for studying the dynamics of energy consumption and CO2 emissions worldwide. It takes into account the resource constraints for both oil and natural gas, and enables greenhouse gas emissions from burning fossil fuels to be calculated, along with the marginal

[5] The POLES model has been developed by CNRS (France) since 1990. Currently it is operated, expanded and maintained by the CNRS/UPMF University, Enerdata and IPTS (Spain, European Commission research centre).

cost of reducing emissions in the various countries or regions. It thus makes it possible to simulate various emission constraint scenarios and determine the consequences of introducing a carbon tax or emission constraints with trading systems. Like other sector and technology explicit economic models, its main advantage is in its detailed, robust estimation of the impacts of climate policies on the energy sector, but its main limitation is the absence of macro-economic feedbacks.

3. The Scenarios

The scenarios for this project are based on two main factors: economic growth and convergence between countries. The former determines the level of world GDP growth and the latter the narrowing of the world's output distribution among regions/countries. The four possible scenarios considered are represented in Table 1, where "*Medium Growth-HC*" means medium economic growth and high convergence, "*Low Growth-LC*" means low economic growth and low convergence, and so on. Table 2 shows the regional implications of the scenarios in terms of GDP per capita.

Table 1. Alternative scenarios

	High Convergence	**Low Convergence**
Medium Growth	Medium Growth-HC	Medium Growth-LC
Low Growth	Low Growth-HC	Low Growth-LC

Table 2. GDP per capita (US$ 2005 PPP) and annual average growth rates (2000-2050)

		Medium Growth-HC		Medium Growth-LC		Low Growth-HC		Low Growth-LC	
	2000	2050	(%)	2050	(%)	2050	(%)	2050	(%)
World	7,430	19,144	2.0	19,144	2.0	15,316	1.5	15,316	1.5
Developed Countries	27,865	46,418	1.0	59,683	1.6	37,136	0.6	47,749	1.1
United States	38,746	56,514	0.8	69,475	1.2	45,213	0.3	55,582	0.7
Europe	24,042	40,554	1.1	54,315	1.7	32,444	0.6	43,454	1.2
Japan	28,564	46,804	1.0	60,067	1.5	37,445	0.6	48,055	1.1
Rest of Developed	29,869	45,473	0.9	56,379	1.3	36,380	0.4	45,105	0.8
Developing Countries	2,750	14,735	3.5	12,715	3.2	11,789	3.0	10,173	2.7
India	1,701	14,446	4.5	11,354	4.0	11,557	4.0	9,083	3.5
China	2,641	19,254	4.1	16,279	3.8	15,404	3.7	13,024	3.3
Africa	2,330	9,314	2.9	8,055	2.6	7,452	2.4	6,445	2.1
Rest of Developing	5,300	17,640	2.5	16,111	2.3	14,112	2.0	12,889	1.8
Ratio Developed/Developing	10.1	3.2		4.7		3.2		4.7	

The baseline scenario provides a description of the future world energy system under the different scenarios for growth and convergence. This baseline is developed in a ''business and technical change as usual'' context, and no policies to reduce greenhouse gas emissions are included. The scenario serves as a benchmark for the assessment of alternatives.

Table 3 presents the emission reduction distribution targets we have adopted, in consideration of the targets discussed but not adopted in Copenhagen. To implement these climate policy targets we use three different carbon values for each of the areas considered. We introduce a carbon price that is increased to a level that reduces emissions to the desired level.

Table 3. CO2 emissions targets for different areas/regions and a 2ºC stabilisation path (% of 2000)

	2020	2050
EU-27	-25%	-80%
Rest of Annex 1	-20%	-80%
Non-Annex 1	+73%	-10%
World	**+25%**	**-50%**

4. Results

This section presents a brief outline of some of the results (for full details see Markandya et al 2011). All scenarios show that:

1) Higher energy prices drive technological improvements that lead to energy savings in production but also changes in behaviour in both residential uses and private transportation

2) Setting a price for CO2 dramatically reduces the contribution of fossil fuels, especially coal, to the energy mix.

3) The portfolio of low-carbon technologies is supplemented with an increase in biomass, other renewables and nuclear. This storyline is made feasible by a major change in the power sector (where most of the emission reduction is attained) but also by reductions in the industrial and domestic sectors).

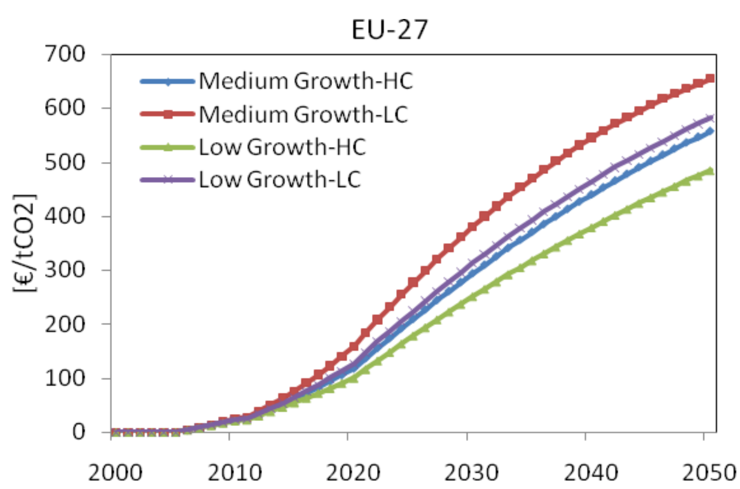


Figure 1. Carbon values (€/tCO2) for different scenarios in EU-27.

Relating to the carbon prices required for the reduction targets, in the case of EU-27 the resulting carbon prices (for a reduction of 25% in 2020 and 80% in 2050) increase from \$100-160/tCO_2 in 2020to \$485-655 in 2050 (Figure 1). The highest carbon prices are obtained in the scenario where baseline emissions for developed countries are highest – the *Medium Growth-LC scenario* –. Conversely, the lowest carbon prices are found when developed countries have the lowest emissions – the *Low Growth-HC scenario*–. It is noteworthy that carbon prices are a little higher in the *Low Growth-LC scenario* than in the *Medium Growth-HC scenario*; this means that for the EU-27 the carbon price is affected more by convergence than by growth assumptions[6].

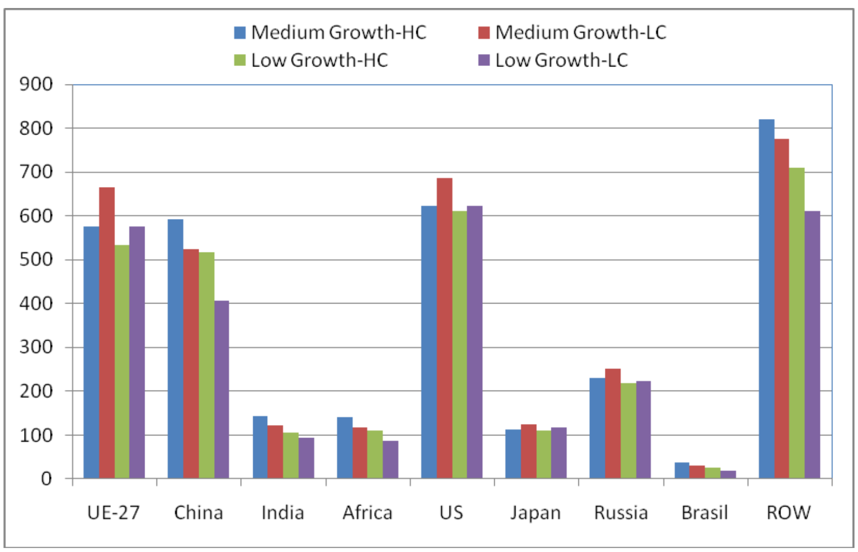
Once the carbon prices and the corresponding emission reductions have been obtained for each region abatement cost can be calculated, reported as a percent of GDP in Table 3:

Table 3. Economic impact (%/GDP) for the world and different scenarios

	2020	2030	2040	2050
Medium Growth-HC	0.12	0.61	1.31	1.81
Medium Growth-LC	0.16	0.61	1.24	1.83
Low Growth-HC	0.09	0.50	1.25	2.09
Low Growth-LC	0.12	0.49	1.07	1.90

An important result of this paper is that low stabilisation targets can be achieved with a cost that is less than 2% of GDP in 2050, which is just around a one year delay in global GDP growth over the period 2000 to 2050. Figure 2 shows the abatement costs for different major regions and different scenarios up to 2050. Most of the abatement costs are supported by the developed world, especially the US (US\$610-685 billion) and the UE-27 (US\$533-665 billion), though China also makes a major contribution (US\$407-592 billion):

Figure 2. Regional abatement cost (Billions US\$ 2005) for different scenarios in 2050



[6] To put these taxes in perspective a tax of US\$500 per ton of CO2 amount to an additional charge of US\$1.3 per liter for a vehicle that generates 2.6kg per liter. The actual increase in the price of motor fuel compared to the baseline, however, will be less, as the price of crude oil is lower with the carbon tax than it is without the tax.

5. Concluding remarks

If a climate policy is introduced, the analysis shows first that it is technically feasible to attain stabilisation consistent with a 2ºC target. This is important as this result implies a full change in the “energy paradigm” and not all the modelling systems reproduce this change. Carbon prices reduce energy consumption per capita by around 33% due to a higher energy efficiency, and electricity consumption per capita by only 15% due to the role of carbon-free electricity. The main increase in power capacity comes from solar, but biomass and nuclear also contribute significantly, as those sources break through even with no carbon price being set. Most of the production with fossil fuels includes CCS.

The effect of growth and convergence may not be so intense in developed countries, but can be crucial in developing countries. In China, for example, depending on the scenario the impact in 2040 may be 0.5% of GDP or 2%. The insights provided on the timing of the impact should be taken into account when designing participatory regimes for countries that have low emissions per capita but that are growing fast.

Overall, the results indicate that lower global growth in GDP does not make it particularly easier to achieve the stabilization target of 2ºC. To be sure, the cost of attaining the target goes up with global growth but it goes up less fast than the increase in GDP and so the percentage costs fall. The results also suggest that while high convergence of GDP across countries increases the cost of attaining the target in global terms, this increase is quite modest. High convergence does, however, imply a higher burden in absolute terms as well as relative to GDP in developing countries. In the developed world abatement costs are higher with low convergence, although the difference between the different convergence scenarios is not as sharp as it is in the case of developing countries. Finally we note that the high convergence scenarios are more dependent on a large scale development of future technologies such as CCS to attain the stabilization goal.

To close we would like to make the important caveat that these results involve a high level of uncertainty and should be treated cautiously. Yet we believe the storyline behind our results should be helpful in understanding the implications for energy and economic systems when decisions are made regarding climate policies that need to look very far into the future.

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