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Towards a cost-effective climate policy. The role of technology, timing and participation.

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ABSTRACT

On the road to Copenhagen, several key issues are under the spotlight. However, the success of any post-Kyoto agreement will depend on its economic acceptability. Three key factors will play a major role in determining the economic performance of any future climate treaty: energy technology development, the participation of developing countries and the timing of a global action. To reduce mitigation costs towards a climate stabilization target, FEEM research findings suggest that post-2012 climate architectures should concurrently encourage the deployment of currently available and future abatement options by means of carbon pricing and policies aimed at fostering innovation. Various options –involving international carbon offsets, technology initiatives– can be used as tools to encourage the participation of developing countries, but the eventual attainment of stringent climate stabilization will rest on a substantial global effort in terms of investment and consumption change. As a first step, the commitment to a moderate transitional target, capitalizing on existing low cost options, may increase the chances of finding an agreement in Copenhagen.

Policy Challenge

In the aftermath of the economic recession, the probability of achieving a consensus on a future global climate agreement in Copenhagen will depend on the economic acceptability and feasibility of a new climate treaty. Which role will key factors such as technology, timing and participation play in the assessment of climate policy costs? And how will they shape the design of a future global agreement?

Introduction

In the forthcoming Copenhagen conference – December 2009 - world Governments will meet to find an agreement on a post-Kyoto climate treaty, with the ultimate aim to fight global warming and its expected impacts worldwide.

Industrialized countries are called to adopt more stringent emission reduction targets, whereas developing countries, and particularly among them the big future emitters such as China, are called to enter a global agreement committing to some (possibly graduated) obligation.

While approaching this important appointment for climate negotiations, the public debate has grown, increasing public awareness on the key issues at stake but often producing enigmatic numbers and confusing evidence on the topic.

From an economics perspective, some key questions are under the spotlight: how much will it cost to mitigate? and which factors will play a crucial role in shaping mitigation costs and policies?

This brief intends to clarify how economics is addressing the assessment of climate mitigation costs, under different technology, timing and participation scenarios, illustrating and comparing methodologies and main results found in the literature.

Climate mitigation policies: the nature of the problem

Climate is changing, and is expected to continue to change, potentially leading to severe impacts on world economies, societies and the environment. Increase in global temperatures, permafrost thawing, sea-level rise, altered precipitation patterns and increased frequency and intensity of extreme events might generate severe impacts on agriculture, tourism, human mobility, and more broadly on the entire ecosystem.

Human activities are ultimately held responsible for these changes, which are increasingly more visible.

Unless the stock of greenhouse gases (GHGs) in the atmosphere is stabilized, global temperatures will continue to rise steadily. Urgent and effective actions are needed to reduce GHG emissions from human activities, limiting the expected damages of global warming. contain

Stabilization efforts require that the growth in world annual emissions be halted, and emissions be brought down to a level compatible with a sustainable living and the right of well-being for future generations. Various long term objectives can be envisaged, though in the recent years the attention has progressively focused on stringent targets such as the + 2 Celsius objective adopted by the European Union and by the Group of Eight at their latest meeting in Aquila, in July 2009. The G8 agreed on an 80% target of emissions reductions by developed countries by 2050 compared to recent years, and proposed a global objective of 50% reductions by 2050, aiming at containing global warming within a + 2 Celsius increase. Given that the current CO_2 emissions from OECD and non-OECD countries are roughly equivalent, such a statement automatically implied that developing countries should aim at reducing their emissions by at least 20% with respect to current levels by the same time frame.

This objective is however largely in contrast with the negotiating positions of essentially all emerging economies and least developed countries, which appeal to the large gaps in per capita emissions that divide the developed and developing worlds, and to their different historical responsibilities. Such a diversity of positions suggests that the long standing logjam that has so far prevented the attainment of a wide ranging agreement might be hardly overcome by the strive for a post-2012 global agreement in Copenhagen. Most likely, a series of national targets will be linked by some sort of international mechanism (probably a market-based one), not necessarily consistent with the 2C objective, which requires immediate cuts in emissions.

What are the challenges of stabilization?

Where do we stand now with respect to the stabilization level advocated by scientists and policy makers?

The current level of GHG concentration in the atmosphere is approximately 430 ppm CO2 eq., extremely close to the 450 ppm CO2 eq. consistent with the 2 Celsius objective. A looser target such as the 450 ppm CO2 only (roughly consistent with 500-550 CO2 eq.) would allow some extra headroom, but would nonetheless be quickly breached in a no climate policy case.

These numbers are particularly alarming if we consider that since pre-industrial levels we have observed an increase of GHG concentrations of 155 ppm CO2 eq., and that under the most recent IPCC 'business as usual' scenarios, i.e. scenarios occurring in the absence of mitigation policies, the concentration of all GHG may increase up to 608-1535 ppm CO2 eq. in the next century.

In his well known report, Stern[1] indicates that 'Stabilizing at or below 550 ppm CO2 eq.[2] would require global emissions to peak in the next 10 - 20 years, and then fall at a rate of at least 1 - 3% per year. By 2050, global emissions would need to be around 25% below current levels'.

FEEM research adds precious input to this literature. FEEM modelling exercises are based on WITCH (Bosetti et al. 2006), a state of the art integrated assessment model, namely a climate-economy-energy hybrid model, extensively used for the economic analysis of climate policy. [3]

WITCH's baseline scenario foresees a persistent growth of emissions due to the continued use of fossil fuels - especially coal - to satisfy the growing energy needs of developing countries and the high standards of living of developed ones. It predicts that energy-related CO2 emissions will double before 2050, and triple by the end of the century, increasing at roughly 24 GtC [4] per year, as shown in Table 1. Under this fossil fuel-led scenario, the CO2 concentration ceiling of 450 ppm, consistent with the target of 550 ppm CO2 eq. previously discussed, would be exceeded in approximately 30 years from now. These results call for a prompt and significant reduction of CO2 emissions.

FEEM research indicates that a scenario compatible with the stabilization of CO2 at 450 ppm would require mitigating world energy-related emissions by almost 40% before 2030, 70% before 2050 and 85% before 2100, as also shown in Table 2.

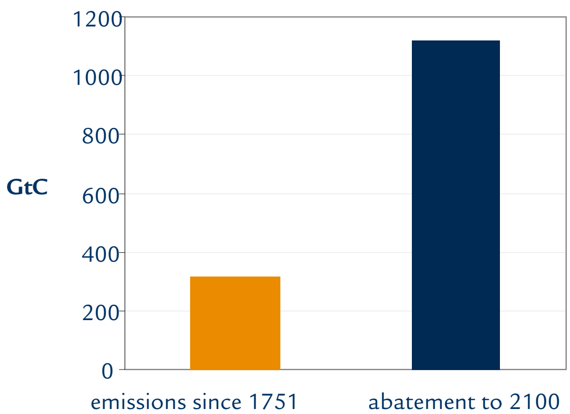
Table 1. Annual fossil fuel emissions (GtC) under different scenarios.

Time horizon	BAU	450 ppm CO2 only	% reduction w.r.t BAU
2005	7.8	7.8	
2030	13.0	8.0	38%
2050	17.0	4.9	71%
2100	23.6	3.6	85%

SOURCE: Bosetti V., C. Carraro, M. Tavoni, 2009

Emission reductions of this sort are challenging, given the expected growth rates of world population and GDP, and the improvement of lifestyles – and energy consumption- in the developing world.

Figure 1. Required mitigation effort in a 450 ppm CO2 only scenario.



SOURCE: Bosetti V., C. Carraro, M. Tavoni, 2009

[1] Stern Review: the Economics of Climate Change, 2007.
[2] Around 440 - 500 ppm CO2 only.
[3] For a comprehensive report, as well as a list of downloadable papers, visit the website: www.feem-web.it/WITCH.
[4] One GTC (gigaton of carbon) is equal to one billion tons of carbon.

As shown in Figure 1, the cumulative emission abatement needed from today until 2100 to achieve the 450 ppm CO2 only stabilization target exceeds the total amount of GHG emitted into the atmosphere since the pre-industrial revolution by almost 3 times. In per capita terms, average world emissions in the second part of this century would have to decline from about 2 to 0.3 tC/cap per year (which is today's average in India).

Three key ingredients for the design of a future global climate treaty: technology, timing and participation_

In order to achieve the safe stabilization target identified, a significant carbon price signal is needed to decrease energy consumption and increase the relative competitiveness of carbon-free technologies. Major investments in the energy sector would be needed to make this happen.[5] Currently available technologies can significantly contribute to the mitigation challenge, mainly through renewables, carbon capture and storage (CCS), nuclear and biomass, as well as energy savings and efficiency improvements.[6] Nonetheless, the development of innovative technologies may prove to be indispensable if we are to meet the increasingly stringent targets.[7]

In addition to the work undertaken by many researchers in the Working Group III of the IPCC, a number of studies have investigated the effect of a stabilization policy on the energy sector, and on the economy as a whole.

In a FEEM study, Bosetti et al. (2007) conclude that investments in mitigation technologies in the power sector should be increased significantly; yearly capacity additions of at least 20-30 GW should be planned for each of the three main abatement technologies - renewable, nuclear and CCS - and be implemented starting from 2015. At the same time, public energy R&D investments should be increased four times with respect to today's expenditure to allow for the development and commercialization of innovative carbon-free technologies.

Yet, the competitiveness of technology is difficult to predict. In the case of the energy technologies mentioned above, additional factors such as public acceptance, reliability as well as international security might put their competitive deployment at risk. Furthermore, innovation is inherently uncertain, as testified by the scattered outcomes of public energy R&D programs carried out in the 1980s.

Generally, carbon free technologies, particularly in the energy sector, are likely to play a major role in the effectiveness of future climate control policies. The speed and effectiveness of technological change will depend on climate, energy and economic policies, and will vary across countries according to their specific endowment and development capacity.

In addition to technology, being a global and urgent problem, climate change mitigation needs a coordinated effort to be effective. Firstly, climate change is a global challenge and therefore unilateral action by a subgroup of countries may bring about little result, especially if free-riders have a growing role in the global economy. Secondly, substantial disparities exist in population lifestyles in different parts of the world, and the right to develop should not be compromised.

Developing countries are not responsible for the bulk of historical emissions produced by the richer industrialized world, but they are growing –some of them at a very rapid pace- and becoming the big emitters of the future.

Table 2. China versus United States

	China/US ratio	
	Total Emissions	Per Capita Emissions
1992	0.48	0.10
1997	0.55	0.12
2007	1.13	0.26
2030	1.75	0.44

SOURCE: Bosetti V., C. Carraro, M. Tavoni, 2009

At the Rio Conference in 1992, when the UNFCC was established, China's total emissions were less than half of those of the US. Five years later, when the Kyoto Protocol was signed, the ratio increased only to 0.55. However, the following 10 years have changed the picture radically. Today, China is the largest emitter in the world,

[5] Cf. Bosetti, Carraro et al., 2007.
[6] Pacala and Socolow, 2004.
[7] See for example Nemet and Kammen, 2007, and Bosetti and Tavoni, 2008.

with emissions 10% higher than those of the US. Quite frighteningly, future projections show a growing gap between the two countries.[8]

Looking at per capita figures offers a different perspective. An average Chinese citizen emitted 10% of the emissions produced by an average US citizen in 1992. Despite its fast economic growth and a stable population, today China's per capita emissions are about one quarter those of the US. Projections indicate that the difference will remain relevant also in the next decades.

These figures suggest that developing countries, even the fast growing ones, would wait for the developed ones to take action before joining an international climate coalition.

Technology development, the degree and timing of participation of the different world regions in an international agreement will thus be essential in determining its economic and environmental effectiveness. Understanding the role of these three key factors in the design of future mitigation policies is crucial to the success of climate negotiations.

FEEM findings on the role of technology, timing and participation in shaping the costs of mitigation

FEEM modeling research is comprehensively investigating the role of technology, timing and participation, in the quantitative assessment of the costs of stabilization, with the aim to provide useful input to the policy debate on post-Kyoto commitments.

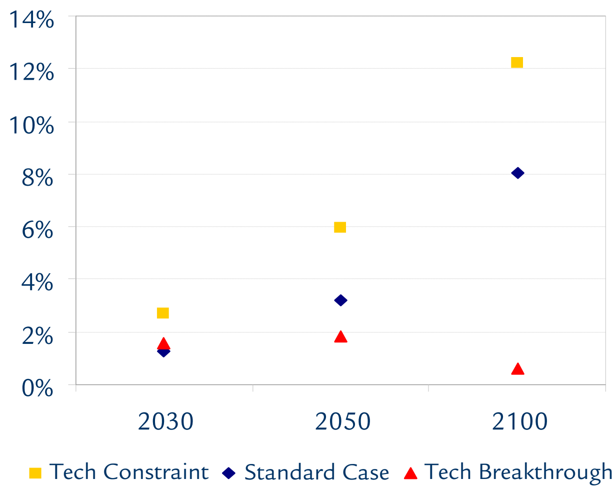
Crucial technologies may not be implemented....

In a recent paper, V. Bosetti , C. Carraro and M. Tavoni[9] investigate the impact of technology availability on the economic feasibility of a safe stabilization scenario – at 450ppm CO2 only - comparing three different cases. In addition to the baseline scenario in which GHG stabilization can be achieved using all available technologies, two other scenarios are considered: one scenario of limited technology development for power sector technologies such as CCS, nuclear and renewables - specifically, nuclear energy is constrained at current generation levels, CCS is not allowed, and Wind and Solar can provide at most 35% of total electricity- and a more optimistic scenario, of technology breakthrough, in which innovative technologies become available in a few decades from now, pending sufficient R&D investments.

Figure 2 reports the aggregate global economic loss in the three scenarios. This is measured by the undiscounted Gross World Product (GWP) undergone with respect to the baseline in 2030, 2050 and 2100.

Figure 2 shows that, in a world of constrained technology, a 450ppm CO2 only policy might become very expensive. For example, GWP losses would increase from 1.3% to 2.7% in 2030 and from 3.2% to 6% in 2050. On the other hand, the optimistic technology scenario shows that innovative technologies, if developed through sufficient R&D investments, decrease the policy bill to almost zero costs in 2100, thus confirming that innovation is the key to decoupling GHG emissions from economic activity.

Figure 2. GWP losses induced by a 450 ppm CO2 only stabilization target under different technology scenarios, in 2030, 2050 and 2100.



SOURCE: Bosetti V., C. Carraro, M. Tavoni, 2009

It should nonetheless be noted that such benefits would materialize only in the long-run, and that in the short-run economic losses would actually increase because of the necessary R&D effort. For example, in 2030, in the technology optimistic scenario, GWP losses would be 24% higher than in the standard technology scenario

[8] Blanford et al., 2008.

[9] Bosetti, V., C. Carraro and M.Tavoni, "Climate policy after 2012. Technology, Timing, Participation", CESifo Economic Studies, 55(2): 235-254, 2009.

(from 1.3% to 1.6%), but this extra effort would be more than offset by the benefits of the availability of an affordable and widely deployable mitigation option in the second half of the century.

Given the existence of innovation market failures, the coupling of a carbon price with an energy R&D policy can in principle achieve additional economic efficiency by internalizing the positive externality of technological change. FEEM estimates suggest that such efficiency gains would be of the order of 10-15%.[10]

Developing countries may delay their participation...

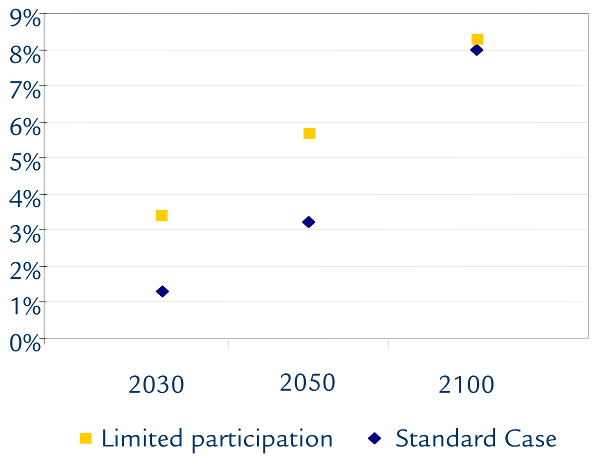
Most estimates of the economic cost of climate policies - such as the ones in the latest IPCC report and the Stern Review - assume the complete participation of major economies. That is, they compute the cost of climate policy in a 'first best' case in which all countries participate in the cooperative effort to curb GHG emissions. Reality may be quite different.

FEEM research shows that if developing countries' participation were delayed, in order to comply with the target of stabilizing CO2 only concentrations at 450 ppm, the world would need to pay a significantly higher economic cost. GWP losses would increase by 160% (from 1.3% to 3.4%) in 2030 and by 77% in 2050 (from 3.2% to 5.6%), realigning only at the very end of the century, as shown in Figure 3.

The intuition for this significant gap is that cheap abatement opportunities are more abundant in developing regions. Also, given the long lifetime of energy infrastructure, allowing developing regions to build capital in the next two decades without accounting for future climate policies would result in prolonged economic penalties.

Therefore, as many regions as possible, and particularly fast growing ones like China, India, Brazil and Russia, should be given incentives to join a post-2012 global climate policy agreement. Accession deals could be provided through international offsets of carbon permits, though that could potentially entail significant monetary transfers. Or via technology transfers or the creation of adaptation funds. A commitment to future emission reduction obligations could also provide the incentives to invest in low carbon options to avoid technology lock in.[11]

Figure 3. GWP losses for a 450ppm CO2 stabilization target under different participation scenarios, in 2030, 2050 and 2100.



SOURCE: Bosetti V., C. Carraro, M. Tavoni, 2009

Lack of agreement may delay action in developed countries as well ...

Beside technology and participation- issue which has lead to a stall in the negotiation process and which will hopefully see some progress in Copenhagen- time is the other crucial factor able to affect the effectiveness and the cost of climate policy in a significant way. The persistence of CO2 molecules in the atmosphere, the long lifetime of energy capital, and the time need to induce change in consumption habits, are such that the actions taken today and in the near future will have long lasting consequences over the whole century. Therefore, any delay in adopting effective measures to control climate change may reduce the effectiveness of these measures and/or increase their negative impacts on economic systems.

FEEM research also investigates the costs of a delayed global action, comparing the standard policy case (global cooperation and no delay) with two other scenarios, aiming at the 450 ppm CO2 only stabilization target. The first alternative scenario assumes that no action to control climate change is taken for the next 20

[10] Bosetti et al, 2009b.

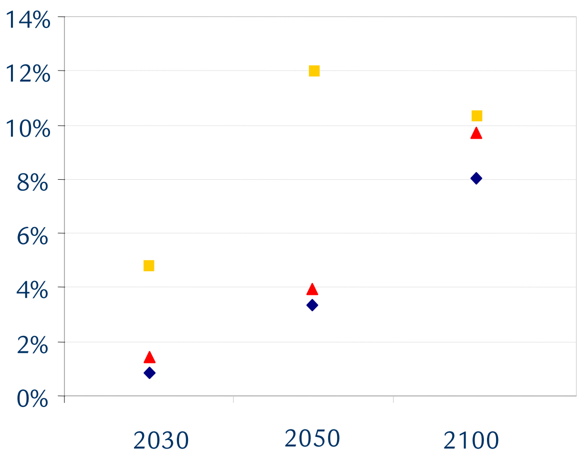
[11] Bosetti, Carraro and Tavoni, 2008.

years, and all countries continue on their business as usual path (Delayed action on BAU). After 20 years they move to a 450 ppm stabilization path. In the second one, all world countries are assumed to adopt a mild climate policy for the next 20 years (Delayed action on milder policy) and eventually revert back to a policy directed to attain the 450 ppm stabilization target.

Figure 4 shows the detrimental consequences of a delay in global action on the cost of meeting the 450 ppm target. Costs increase by almost 3 times, from 1.3% to 4.8% of GWP loss in 2030, and from 3.2% to 12% in 2050, and are quantified in the range of 2.2–5.7 trillion USD per year of delay (assuming a 5% and 3% discount rate, respectively).[12]

Negative consequences are perceived till 2100, when costs are still higher by 30%. A further delay of 5-10 years would make the target unattainable.

Figure 4. GWP losses in a 450 ppm CO2 only target under different timing scenarios, in 2030, 2050 and 2100.



SOURCE: Bosetti V., C. Carraro, M. Tavoni, 2009

A potential escape is offered by pursuing a milder target, for which a broader international consensus could be found. FEEM research[13] shows that a policy strategy aiming at a milder target- i.e. stabilization at 550 ppmv CO2 only - that immediately begins to undertake some emissions reductions and in 20 years reverts to the business-as- usual scenario, does not harm global welfare. The same mild mitigation policy can be tightened at costs still lower than those faced in the case of 20 years of inaction followed by the adoption of a stringent climate policy.

The policy implications of these findings support the arguments that call for immediate action to tackle climate change[14]: if we continue doing nothing for 20 years, the costs of shifting from a business-as-usual to a stringent climate policy are extremely high. On the other hand, undertaking some form of mild stabilizations policy seems to be a hedging strategy which, at virtually no cost, would allow us to revert to business-as-usual and, at relatively modest cost, to undertake more decisive action whenever a more stringent stabilization policy were agreed upon.

FEEM research results point clearly to a precautionary behavior in which emissions are considerably reduced even before an agreement is signed.

Eventually, the looser-to-more-stringent strategy would not be optimal, but its short term dominance could work as a hedging strategy to avoid the risk of a complete stall in negotiations.

Policy insights on the road to Copenhagen

Technology, participation and timing are shown to affect considerably stabilization costs. Figure 5 summarizes the cost differentials induced by each of the three factors. Limited mitigation technology availability in the power sector is estimated to increase policy costs by roughly 70%. Developing countries delaying their participation in an international climate agreement until 2035 would impose a slightly higher penalty (76%). Finally, a 20-year delay in global action would induce a cost increase of up to 160%.

These results suggest that post-2012 climate architectures should incorporate measures that make sure that the deployment of known technological options is not restricted, the major emitting economies are induced to participate in

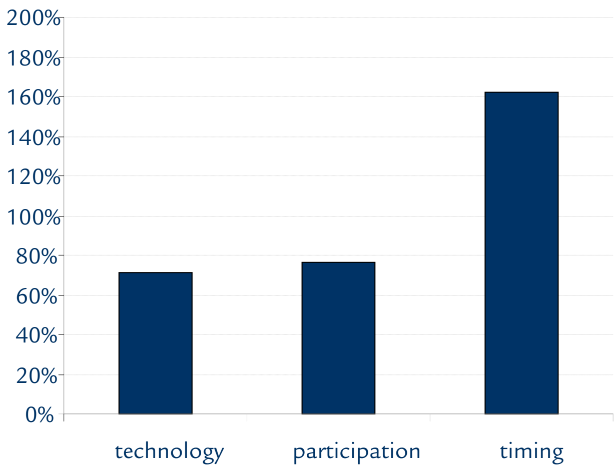
[12] Bosetti et. al 2009c.

[13] For detailed results see Bosetti et. al 2009c.

[14] See Stern 2007.

a climate agreement, and action to control climate change is not delayed.

Figure 5. Potential additional economic losses (% increase with respect to the base policy case)



SOURCE: Bosetti V., C. Carraro, M. Tavoni, 2009

As for the technology challenge, the investment paths in the energy sector in the 1980s provide a useful reference point for the needs that lie ahead of us. For example, if the size of investments in nuclear power plants needs to return to its peak year levels, institutional capacity building and innovation programs need to be put into place soon. Similarly, public energy R&D expenditures should be increased significantly, with a specific focus on low carbon transport technologies, such as vehicle electrification.

The establishment of a well functioning global carbon market that would allow developing regions to join an agreement could provide economic incentives for a wider participation that can bring down total costs. However, given the political constraints related to large international monetary transfers, the extent of international offsets might be restrained. Additional domestic action might nonetheless spur more international spillovers in low carbon technologies which could partially compensate developing countries for the lower revenues from the carbon market. The chances of finding an agreement in Copenhagen could be increased by a commitment to a mild target capitalizing on existing low cost options. For example, reduction of emissions from avoided deforestation is believed to bear the potential for substantial mitigation at low costs, and to thus offer a valuable alternative to the risk of a complete stall in climate negotiations. Indeed, the Bali action plan has given priority to such a provision, which will also be under the spotlight in Copenhagen. Domestic measures aimed at improving energy security and limiting local pollution could also be exploited to limit greenhouse gases. However, to achieve climate stabilization more drastic measures will eventually be needed. Such policies will most likely come at an economic cost; though the seriousness of the climate problem might well justify them, we should not underestimate the effort required to solve it, and we should employ the right policies to minimize such costs. This brief has put forward some suggestions on how we can move forward in this direction.

This Policy Brief builds upon the paper by Bosetti, V., C. Carraro and M.Tavoni, *Climate policy after 2012. Technology, Timing, Participation*, CESifo Economic Studies, 2009, and the WITCH –team FEEM modelling work.

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