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To cite this version:

Olivia Ricci, Sandrine Selosse. A cost analysis of the Copenhagen emission reduction pledges. Economics Bulletin, 2013, 33 (1), pp.764-771. hal-00802087

HAL Id: hal-00802087
https://hal-mines-paristech.archives-ouvertes.fr/hal-00802087
Submitted on 10 Apr 2013

Economics Bulletin

Volume 33, Issue 1

A cost analysis of the Copenhagen emission reduction pledges

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Abstract

As part of the Copenhagen Accord, countries have submitted emission reduction pledges for 2020. Using a long term optimisation model (TIAM-FR), we evaluate the implications of these submissions for emission reductions, carbon prices and total cost of the energy system. Our study finds that the pledges are not sufficient to meet the global recommended 2-2.4°C objective. Furthermore, reaching the overall 2°-2.4C objective would involve significant costs for China and India that explains the difficulty of international negotiations.

This research was supported by the Chair Modeling for sustainable development, driven by MINES ParisTech, Ecole des Ponts ParisTech, AgroParisTech, and ParisTech, supported by ADEME, EDF, RENAULT, SCHNEIDER ELECTRIC and TOTAL.
Citation: Olivia Ricci and Sandrine Selosse, (2013) "A cost analysis of the Copenhagen emission reduction pledges", *Economics Bulletin*, Vol. 33 No. 1 pp. 764-771.
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Submitted: December 27, 2012. **Published:** March 15, 2013.

1. Introduction

Global warming is essentially an economic and political problem. The atmosphere is a global public good. Greenhouse gas (GHG) emissions that contribute to global warming have the same damaging impact, whatever country they originate from. All regions of the world are affected, regardless of whether and to what extent they contribute to the problem. Protecting the atmosphere and therefore preventing global warming implies a drastic reduction in total greenhouse gas emissions. However, in the absence of an international agreement on emissions control, countries tend to adopt free-riding behavior, whereby they rely on other countries to reduce emissions and incur the resulting abatement cost. The Kyoto Protocol was the first international agreement in which some countries committed to emission reduction targets for the period 2008-2012 (in Annex I to the protocol). A cap-and-trade system was introduced to enable the emergence of an international carbon price in order to efficiently attain the overall objective. The protocol's impact has, however, been limited, due to the lack of commitment from fast-growing emerging countries such as China, India and Brazil, and the non-ratification of the United States. The challenge of the Copenhagen summit in 2009 was to determine the rules for the post-Kyoto period. Its crucial focus was therefore to ensure the ratification of a global agreement on emission reduction targets including all major industrialized and emerging countries. Despite the fact that negotiations during the summit failed to reach a global consensus, in late January 2010 some countries, including major emerging nations, pledged their commitment to the United Nations Framework Convention on Climate Change (UNFCCC) as part of the Copenhagen Agreement. Emissions control commitments now cover 80% of 2005 global GHG emissions compared to barely more than a quarter for the Kyoto Protocol.

These commitments, which have very different terms and conditions, have yet to be evaluated. In fact, the Copenhagen Accord adopted a different approach to the Kyoto Protocol by allowing "variable geometry" commitments depending on the country (Casella et al. 2010). Annex I countries committed to reducing emissions on an absolute basis, while all major emerging counties made commitments in relative terms. For instance, China and India pledged to reduce emissions per unit of GDP relative to 2005. Published analyses of the Copenhagen pledges reach the same conclusion: although the national commitments made in Copenhagen reflect a significant shift relative to trend scenarios, this shift is a long way from the IPCC recommendations for limiting a global temperature increase to 2°C (Dellink et al. 2010; Den Elzen et al. 2011a, Casella et al. 2010; Peterson et al. 2011; Criqui and Ilasca 2010; Stern and Taylor 2010; van Vliet et al. 2012). Peterson et al. (2011) also showed that the pledges are not costly in either GDP or welfare terms. Taking a partial and general equilibrium approach, empirical studies have found that the cost for developed countries was less than 0.5% of GDP in 2020, and that the effects are more heterogeneous in developing countries (Saveyn 2011; den Elzen et al. 2011b; Peterson et al.2011).

We contribute to the growing body of literature on the environmental and economic impact of the Copenhagen commitments by introducing these pledges into the bottom-up optimization model, TIAM-FR. The model depicts the energy system over the period 2005-2050 in such a way as to minimize the net total cost of the system under a number of environmental, technological and demand constraints. To evaluate these commitments, we considered the most optimistic pledges for 2020 and made assumptions on the 2050 targets based on the policy ambitions announced by each country. We then compared these pledges to a business-as-usual scenario and to a global scenario compatible with the IPCC consensual

2-2.4°C objective (IPCC, 2007) where all countries are constrained by a global mitigation target.

We aim to answer the following questions:

- Can we limit temperatures to 2°C with the most favorable pledges announced by countries?
- What are the regional energy system costs that result from these two climate scenarios?

2. Model and climate policies

2.1 TIAM-FR model

This analysis is based on the TIAM-FR model (the French version of the TIMES Integrated Assessment Model), a bottom-up optimization model developed under the Energy Technology Systems Analysis Program (ETSAP). It depicts the world energy system with a detailed description of different energy forms, resources, technologies and end-uses (Ricci and Selosse 2012). End-use demands (i.e. energy services) are based on socio-economic assumptions and are exogenous over the planning horizon (2005-2050). The basic principle of the model is a broad linear optimization of substitution possibilities in the energy system between explicit technologies and commodity flows under constraints. The model assumes perfect markets and foresight and is therefore suitable for normative analysis. The model minimizes the total discounted cost of the energy system over the entire model horizon.

The model is geographically integrated into 15 global regions (Industrialized countries: Australia-New Zealand (AUS); Canada (CAN), United-States of America (USA), Western Europe (EU-15, Iceland, Malta, Norway and Switzerland, WEU), Eastern Europe (EEU), Japan (JPN); Fast developing countries: India (IND), China (includes Hong Kong excludes Chinese Taipei, CHI); Developing countries: Africa (AFR), Central and South America (CSA), Middle-East (includes Turkey, MEA), Mexico (MEX), South-Korea (SKO), Other developing Asian countries (includes Chinese Taipei and Pacific Islands, ODA), Former Soviet Union (include the Baltic states, FSU)). The regions are linked by energy trading variables. These trade variables transform the set of regional modules into a single multiregional energy model, where actions taken in one region may affect all other regions. This feature is essential when global as well as regional energy and emission policies are simulated. For each region, a total net present value of the stream of annual costs is computed, discounted to the year 2005. These regional discounted costs are then aggregated into a single total cost, which is the objective function to be minimized by the model. Annual costs include investment costs, operation and maintenance costs, fuel costs (mining and imports), the cost of trade and the residual value of technologies at the end of the horizon.

The objective function is:

$$NPV = \sum_{r=1}^{R} \sum_{y \in years} (1 + d_{r,y})^{refy-y} * ANNcost(r, y)$$

where NPV is the net present value of the total cost; ANNcost(r,y) is the total annual cost in region r and year y; d(r,y) is the discount rate, refy is the reference year for discounting, years is the set of years and R the set of regions (Loulou, 2008).

Through its integrated climate module, the model makes it possible to analyze and make assumptions on atmospheric GHG concentrations and temperature changes. It integrates CO_2, CH_4 and N_2O greenhouse gases.

2.2 Climate policies

Two climate scenarios and a business-as-usual (BAU) scenario are simulated in the model:

- **BAU scenario**: In the BAU scenario, no climate policy is assumed.

- **Glob_50 scenario:** The Glob_50 scenario assumes that global CO_2 emissions are reduced by 50% in 2050 compared to the 2000 level. This scenario is compatible with the UNFCCC consensual 2-2.4°C objective (as specified by IPCC, 2007). All regions are bound by the global climate constraint.

- **Cop_15 scenario:** This scenario represents the most optimistic CO_2 mitigation targets by 2020, as expressed in the Copenhagen Agreement by Europe, the United States, Australia, Canada, Japan, China and India. Targets for 2050 were assumed according to the policy ambitions of each country as published in literature. This is a regional scenario in which only these countries are bound by the climate constraint. Table I presents the Copenhagen pledges.

Table I: Cop 15 targets and 2050 assumptions for CO_2 emissions

Regions	Year ref.	Year target	Targets	Reduc. type
WEU-EEU	1990	2020	Pessimistic: 20%	Emissions reduction
			Optimistic: 30%	
		2050*	**80%**	
USA	2005	2020	**17%**	Emissions reduction
		2050	**83%**	
AUS	2000	2020	Pessimistic: 5%	Emissions reduction
			Optimistic: 25%	
		2050	**80%**	
CAN	2005	2020	**17%**	Emissions reduction
		2050	**83%**	
JPN	1990	2020	**25%**	Emissions reduction
		2050	**80%**	
CHI	2005	2020	Pessimistic: 40%	CO_2 intensity reduction
			Optimistic: 45%	
		2050	**10%**	Emissions reduction
IND	2005	2020	Pessimistic: 20%	CO_2 intensity reduction
			Optimistic: 25%	
		2050	**10%**	Emissions reduction

* 2050 values are assumptions based on the policy ambitions announced for each country except China and India for which we have purposely chosen a stringent emissions reduction target

3. Results

The results focus on the impact of climate policies on CO_2 emissions and energy system costs.

3.1 Environmental impact of climate policies

In the BAU scenario, the atmospheric concentration of CO_2 reaches 472 ppm in 2050, while beyond 400 ppm CO_2, it is impossible to stabilize global warming below 2-2.4°C (IPCC, 2007). In Cop_15 atmospheric CO_2 concentration continues growing to reach 433 ppm in 2050. Meanwhile, the global constraint (Glob_50) that consists in reducing CO_2 emissions by 50% compared to the year 2000 allows a stabilization of the atmospheric concentration of CO_2 at 403 ppm in our model. To meet the 2-2.4°C target (Glob_50), global CO_2 emissions should decrease by 4.47 Gt in 2020 and by 40.99 Gt in 2050 compared to the BAU pathway. However, in Cop_15 global emissions are only reduced by 2.23 Gt in 2020 and by 28.46 Gt in 2050 compared to BAU. Table II shows how the emissions reduction effort is shared out between countries in the two target scenarios.

Table II: CO_2 emissions reductions compare the BAU (Gt CO_2)

Regions	2020		2050	
	Glob_50	Cop_15	Glob_50	Cop_15
Industrialized countries	-1.138	-2.174	-11.54	-13.58
Fast developing countries	-1.405	-0.135	-17.87	-15.067
Developing countries	-1.927	+0.072	-11.57	+0.181
World	-4.47	-2.237	-40.99	-28.46

In Cop_15, CO_2 emissions are primarily led by industrialized countries in 2020. In 2050, ambitious assumptions for China and India (10% emissions reductions) lead to a reduction of 15 Gt of CO_2 emissions compared to BAU. India and China contribute more than 50% of the overall objective. Glob_50 benefits industrialized countries in 2020 and 2050 compared to Cop_15, while developing countries are heavily constrained in 2020 and 2050. The contribution of fast developing countries is also higher in this scenario.

We find that the optimistic commitments pledged by countries in Cop_15 do not reduce emissions enough in 2020 and that even favorable assumptions for 2050 are not sufficient to meet the global 2-2.4°C objective. Moreover, to achieve the expected global objective, we show that fast-developing countries must reduce their emissions further and that developing countries need to participate in efforts to reduce CO_2 emissions.

3.2 Economic impact of climate policies

This section evaluates the energy system cost implications of the two climate scenarios. The total system cost resulting from the Copenhagen pledges (Cop_15) and the global constraint (Glob_50) consists of investment costs, variable costs, fuel costs (mining, import), fixed annual operation and maintenance costs, and the cost of trade (import-export). Table III shows the abatement costs and carbon marginal cost (carbon price) per region.

In Cop_15, the total system abatement cost, expressed as the cost of additional mitigation expenditure compared to the BAU scenario in 2020, is estimated at USD 61 billion (increase of 0.5% compared to BAU). The largest share of this cost is incurred by industrialized countries (92% of the global cost). The abatement cost is relatively high for Europe, Australia and Japan. These are also the countries with the highest emissions reduction constraint for 2020 (table I). The carbon marginal costs are also the highest for these regions, reflecting the severity of the constraint (34 USD/tCO_2 for Australia, 58 USD/tCO_2 for Europe and 92 USD/tCO_2 for Japan). In 2050, fast-developing countries (India and China) are more constrained by our emissions reductions assumptions than they are by their commitments for 2020, therefore additional abatement costs (compared to BAU 2050) are higher for these regions (about USD 600 billion). In 2050, the marginal carbon cost reaches 447 USD/tCO_2 in Japan, 245 USD/tCO_2 in Europe, 86 USD/tCO_2 in China and 75 USD/tCO_2 in India.

In Glob_50, the model minimizes the global cost of the system. The abatement cost is higher than Cop_15 for almost all developing countries and it increases sharply for China and India from 2020. In 2050, 45% of the total abatement cost is incurred by China and 10% by India. Developing and industrialized countries contribute to the global abatement cost at respectively 22% and 23%. Japan and Europe, where marginal abatement costs are high, benefit from this policy. In 2050, abatement costs in these countries are 60% lower than in Cop_15. The carbon price in Glob_50 for all regions is 11 USD/tCO_2 in 2020, 48 USD/tCO_2 in 2030, 74 USD/tCO_2 in 2040 and 94 USD/tCO_2 in 2050.

Table III: Annual abatement costs and carbon prices per region

Regions	**Regional abatement cost (M US$)***				**Carbon marginal cost in Cop_15 (USD/tCO_2)**	
	Glob_50		**Cop_15**			
	2020	**2050**	**2020**	**2050**	**2020**	**2050**
AFR	3,542	40,412	259	13,585	-	-
AUS	3,700	6,114	2,877	660	34	41
CAN	-886	6,784	727	4,443	12	16
CHI	**24,676**	**639,203**	2,353	**493,888**	-	86
CSA	5,203	39,885	3,523	6,533	-	-
EEU	1,345	35,195	**18,616**	**49,629**	58	245
FSU	1,897	75,136	-1,553	4,608	-	-
IND	**6,207**	**147,698**	-97	**81,294**	-	70
JPN	31	24,424	**17,842**	**88,034**	92	447
MEA	-462	36,374	3,879	-9427	-	-
MEX	847	12,518	1,014	2,103	-	-
ODA	657	87,752	-4,112	2,599	-	-
SKO	2,834	30,722	-503	-1,453	-	-
USA	-1,658	181,594	75	**251,722**	-	183
WEU	3,521	87,561	**16,575**	**226,091**	58	245

* The regional abatement cost is the cost of additional mitigation expenditure compared to the BAU scenario for each region. A negative sign indicates advantages due to exports.

The additional global discounted cost on the period 2005-2050 with a discount rate of 5%[1] (in absolute terms, compared to BAU) is USD 3,610 billion in Glob_50 and USD 3,050 billion in Cop_15. In relative terms, this represents an increase of 2% in the global scenario and 1.6% in Cop_15. In Glob_50, the countries with the lowest discounted cost are industrialized countries. Although this last scenario minimizes the global discounted cost of the system, it appears to be costly for fast-developing. For instance, the discounted cost of the

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[1] This discount rate is in line with the literature on the cost of climatic targets, particularly integrated models like the one used in this study (van Vuuren et al. 2010; van Vliet et al. 2012; Krey and Riahi 2009; den Elzen et al., 2011a, 2011b).

system increases by 6.3% for China compared to BAU and 5.8% for India. We have conducted a sensitivity analysis on the discount rate because the long term costs of GHG abatement are highly affected by the choice of this parameter. A discount rate of 3% and 7% was simulated in the model. A higher discount rate give an incentive for delaying mitigation actions therefore, the global additional discounted cost is lower with a 7% discount rate and higher with a 3% discount rate (Glob_50_DR3%: USD 6,120 billion; Glob_50_DR7%: USD 1,565 billion; Cop_15_DR3%: USD 6,120 billion; Cop_15_DR7%: USD 1,565 billion). At a regional level, the conclusion that the Glob_50 scenario is more costly for fast developing than for industrialized countries is robust regardless of the discount rate.

4. Conclusion

This paper assesses the environmental and economic effects of the Copenhagen Accord through a specific analysis of the pledges announced by countries in 2010. It compares it with the least cost option of a global agreement compatible with the 2°C target. Even when applying the most ambitious Copenhagen pledges for 2020 and favorable assumptions for 2050, the emissions trend remains incompatible with the 2°C recommendation. Furthermore, reaching the overall 2°C target involves significant costs for China and India, which explains the difficulty of international negotiations. The 2°C objective seems very unlikely unless significant financial transfers are considered to fund the abatement cost to emerging countries.

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