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Abstract

This paper examines compromise spaces between competing perspectives on four key climate change issues: costs, level of domestic action, environmental integrity, and developing world involvement. Based on extensive simulations of a model integration tool, SAP12 (Stochastic Assessment of Climate Policies, 12 models), the analysis considers options for fine-tuning the Kyoto Protocol, such as concrete ceilings or levies on carbon imports; restoration payments to be made on excess emissions; credits for sequestration activities in Annex B countries; and others. It shows the critical importance of the baseline against which the performance of each tool has to be assessed in the absence of direct economic penalties for noncompliance. The restoration payment option (also known as a safety valve) emerges as a superior means of addressing the core policy issues, including environmental integrity, and provides a large compromise space between payments of $35 to $100 per ton of carbon.

Key Words: climate negotiations, 2010 carbon markets, uncertainty about abatement costs

JEL Classification Numbers: Q25; D74; D78; D80

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Introduction

Many explanations can be given for the inconclusive outcome of the Sixth Conference of the Parties (COP6) to the United Nations Framework Convention on Climate Change (UNFCCC): diplomatic misconduct, cumbersome negotiation machinery, lack of political will,[1] or intrinsic defects of the Kyoto Protocol (Victor 2001). This paper builds on the intuition that besides such factors and obvious divergences in interests, uncertainty about the costs of meeting predefined targets is the principal issue fueling doubts that risk undoing "Kyoto's unfinished business" (Jacoby et al. 1998).

The doubts come from opposite directions. The European insistence that flexibility mechanisms be supplemental to domestic action stems from the fear that because of low abatement costs and the excess emissions quotas assigned to Russia and Ukraine, carbon prices may not reflect the long-term value of a significant carbon constraint (Ha-Duong et al. 1999), while carbon trading may become a way of escaping real reductions. A symmetrical concern is shared by Japan, the United States, Canada, Australia, and New Zealand (JUSCANZ): that the costs of meeting the Kyoto commitments could be high enough to undermine the economic and political viability of the system, leading these countries to question, at least implicitly, the Kyoto targets and timetables and to consider options for hedging against the risks of excessive costs.

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[1] For an overview of a European Union perspective on the process, see Gupta and Grubb (2000) and Metz and Gupta (2001).

To analyze the central uncertainties in this debate, we developed a model integration tool, the Stochastic Assessment of Climate Policies, 12 models (SAP12), incorporating harmonized reduced forms of a dozen global climate-economy models that encompass various degrees of optimism and pessimism behind negotiation stances (see Box 1). This enables us to analyze negotiation packages under different values of such parameters as compliance payments, supplementarity constraints (following Article 17), share of the proceeds, and carbon sequestration, with a view to delineating a compromise space between competing interests and world views. The larger this space for a given negotiation package, the more likely an agreement is, at least from a purely economic perspective.

Although they come from a cross-section study of 12 models, we deliberately sum up SAP12 results in the synthetic form of "likelihood spaces." Such a probabilistic interpretation is grounded in the fact that despite some form of Delphi process in the runs used to produce our reduced forms, the underlying models encompass a large scope of values for abatement costs and requirements: the 2010 cost projections vary by almost an order of magnitude. Policymakers may therefore regard the distribution of modeling results as representing uncertainties in the real world and attach to these results subjective probabilities reflecting their own beliefs. Unless otherwise stated, the reported likelihood intervals assume equiprobability between models.

First, we clarify some conceptual ambiguities about compliance costs; this may lead to rethinking the supplementarity quarrel in light of the impact of compliance systems on the level of domestic action. The second section, focusing on environmental performance and costs, delineates compromise spaces within the proposals of Annex B (developed) countries, excluding extended activities under Article 3.4. In our third section we compare such compromises with those including the latter option. A final section closes the triangle of the European Union, JUSCANZ, and the G77 by examining how the alternative Annex B compromises may create a strong incentive for the developing world to join international climate control regimes.

Conceptual Ambiguities Behind the Negotiations

The post-Kyoto process was shaped by divergences among Annex B countries on compliance costs and supplementarity. Ironically, these differences overshadowed what are probably more fundamental long-run conflicts between the Annex B and G77 nations. The failure to reach agreement among Annex B nations was due, in part, to the very negotiation language—casual rhetorical compromises that blurred critical points of contention. To minimize further misinterpretation, we begin with some conceptual clarification.

The model integration tool SAP12 (Stochastic Assessment of Policy, 12 models) incorporates reduced forms of the marginal abatement cost curves of 12 major climate-economy models. The curves are constructed by backward calibration from data published in *The Energy Journal* Kyoto Special Issue (Weyant and Hill 1999) for 10 of them and from the modelers themselves for POLES and WAGEM. Five of these models are American (MERGE 3.0, MIT-EPPA, MS-MRT, RICE and SGM), two Australian (ABARE-GTEM and G-Cubed), one Japanese (AIM) and four European (Oxford Model, POLES, WAGEM and Worldscan). All models were peer-reviewed either by members of the Stanford Energy Modeling Forum or by the International Panel on Climate Change for its *Third Assessment Report*.

Given the available data, calibration has been made in a consistent manner for four zones—the European Union, the United States, Japan, and the remaining non-Eastern European Annex B countries in the CANZ group. With simple assumptions, curves were then derived for the Economies in Transition (EIT) and the Clean Development Mechanism (CDM) potential from the Annex B and global trading equilibria. For a given model, the resulting set of six curves allows the computation of a market equilibrium under various assumptions regarding the implementation of the flexibility mechanisms.

Note that the resulting marginal costs correspond to levels of lump-sum recycled carbon taxes inducing a given abatement. Thus, they embody not only assumptions about technical costs but also the macroeconomic feedbacks as described in each model. Accordingly, “total costs” are derived by integrating below the curves for domestic costs and adding the volume of imports priced at the international equilibrium price (all runs suppose an international market of emissions credits resulting from the three flexibility mechanisms).

The underlying methodology is grounded in the premise that policymakers can interpret the variance in results from the 12 models as revealing uncertainty in the real world regarding key parameters of cost assessment, such as technical change and behavioral reactions to policy signals. A conventional stochastic treatment is thus applied:
SAP12 runs each of the models separately and provides an expected value of basic economic and environmental indicators for the policy packages tested. Perhaps more importantly, we derive from its comprehensive results (a) the percentage of chance for each indicator to be above or below a certain value, given some subjective probability attached to the results of each model (in most of the runs we will assume equiprobability or an equal level of confidence); and (b) the likelihood intervals, used in most of the results reported, whose bounds are the average of the 12 results minus and plus the standard deviation observed: a 16–45% domestic action in a region under a given policy means a 30.5% average, with a 15.5% standard deviation.

Box 1. Model integration tool.

The Main Dividing Line: Compliance Costs and Supplementarity

Available modeling results fuel the main concern behind the supplementarity condition: six of the SAP12 models give a price lower than $30 per metric ton of carbon (tC[2]) under global trade, and one model even gets the same result under Annex B restricted trade. The figures are all the more impressive because the simulations do not incorporate carbon sinks and their price-

[2] Throughout this paper, marginal costs are $1990 U.S. per metric ton of carbon in 2010.

deflating effect. Arguably, such prices may fail to create the appropriate incentives, particularly for infrastructure and research and development, and thus may make ambitious targets beyond the first commitment period very costly (Lecocq et al. 1998). Along the same line, it can be argued that likelihood intervals of the percentage of domestic abatement on total abatement required for full compliance—as low as 16–45% in the United States, 12–32% in the European Union, and 10–28% in Japan—will not trigger a significant learning-by-doing process. In May 1999, to compensate for this risk, the European Council of Environmental Ministers proposed concrete ceilings to limit carbon imports according to two alternative formulas,[3] plus a "however" clause resulting in a 50% ceiling. This 50% ceiling was expressed in Pronk's package[4] by a sentence stating that parties "shall meet their emission commitments *primarily* through domestic action since 1990."

Conversely, the same models also fuel concerns about excessive costs for carbon. In a no-trade case, 67% of the models give costs higher than $150/tC for the United States, and 83% show costs higher than $150/tC for the European Union and Japan. Costs higher than $250/tC are given by 33% of the models for the United States and the European Union, and 67% for Japan. Simulating a full-trade scenario with perfect markets significantly lowers this risk: only one scenario gives an international carbon price higher than $100/t. However, this experiment is misleading since, as Weyant and Hill (1999) point out, gains from trade will depend mostly on transaction costs that impede the functioning of the flexibility mechanisms, particularly so for project-based mechanisms—an administratively cumbersome form of emissions trading. Thus, with no ceiling on the use of flexibility mechanisms, what we deem realistic (some will say optimistic) assumptions regarding transaction costs[5] result in a 50% risk that the international price of carbon will exceed $100/t, a level at which it can no longer be disregarded. Two alternative approaches to address this problem have been advocated:

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[3] Net carbon importers must respect the least constraining of two ceilings: option A, 5% of the average between five times their base-year emissions and their assigned amount; and option B, 50% of the difference between five times their emissions in any given year between 1994 and 2002 and their assigned amount. But they can benefit from the "however" clause. Net exporters are subject to the 5% limit without alternative.

[4] We define "Pronk's package" as the document distributed at the Hague by Jan Pronk, president of COP6, titled *Note by the President of COP6—23 November 2000*.

[5] In the following simulations, transaction costs are calibrated so as to restrict accessibility to potentials in the global market cases for each of the models: two-thirds for emissions trading and joint implementation; one-fourth for the Clean Development Mechanism (CDM) (a figure higher than the 15% retained in the EMF study by Weyant and Hill 1999); and a $10 minimum price is set for hot air trading, corresponding to a minimum transaction cost on the CDM.

- A predetermined dollar-per-ton payment by which parties can cover their excess emissions and stay in compliance (Kopp et al. 1997). Such a provision creates a safety valve against both excessive marginal and total costs while preserving a chance of proving that the Kyoto objectives can be met cheaply. The original proposal was refined into a restoration payment, with collected funds recycled in supplementary abatement during a "true-up" period through a reverse auction mechanism[6] (CIRED-RFF 2000).
- Under Article 3.4 of the protocol, the extension of eligible sequestration activities, which increases the availability of "cheap" tons in Annex B countries but is viewed in many quarters as a redefinition of Kyoto targets.

Typical of the difficulty in crossing the dividing line between optimists and pessimists regarding costs, those options can be perceived as ways to reduce domestic action. Conversely, the supplementarity condition was viewed by JUSCANZ as exacerbating risks of excessively high compliance costs. This led the advocates of supplementarity to propose, as an amendment to the concrete ceilings proposal, a waiver that operates when domestic abatement costs exceed a given level; as a substitute, a per-ton import charge could be levied by parties on their acquired emissions credits.

Private and Social Costs: The Overlooked Distinction

Discussions about how to hedge against excessively low or high compliance costs do not always clearly distinguish between the net total costs and the marginal abatement costs. A high marginal cost of carbon mitigation may indeed prove problematic, increasing the prospect for compliance default if it exceeds the willingness of energy consumers to pay for carbon mitigation.[7] Extensive experience demonstrates that energy consumers are much more sensitive to the gross signal of energy prices than to a net impact with possible but less tangible compensating effects, such as the recycling of the proceeds of a carbon tax or auctioned tradable

[6] In a reverse auction, each project is proposed at a given price per ton of carbon, but all the selected projects will receive the same price. The tonnage of retained project valued at this price clears the fund, and to be selected, the proposed price of the project has to be lower than this clearing price.

[7] We are using the notion of "willingness to pay" here not strictly in the classical sense of revealed preference for the benefits of long-term greenhouse gas abatement. Rather, we refer to a politically salient limit on the willingness to bear a certain level of short-term cost. Note that the latter notion may well be less restrictive than the former, which currently available empirical studies set at a level much lower than those we consider in this text.

emissions permits. This is why motorists and carbon-intensive industries can block measures like environmental fiscal reforms, even though these measures are supposedly Pareto-improving in specific circumstances.

Although, as noted earlier, the marginal cost of carbon control may be high, the overall social cost of control may be more tolerable—especially if revenue-recycling measures are put to use. A survey of major models by the Intergovernmental Panel on Climate Change (IPCC) Working Group III (2001) indicates that gross domestic product losses in 2010 would range between 0.2% and 2% in a no-trade case and in the absence of carbon sequestration; even when these impacts are not small, they can be halved through the Kyoto flexibility mechanisms, and could even be lower (possibly turning into a gain) with a judicious use of revenue-raising instruments.

It thus appears that a possibly too-high marginal carbon cost constitutes the main obstacle to compliance. Governments seeking to circumvent it can socialize compliance costs by funding carbon imports through public expenses, rather than let energy prices bear the full brunt. However, this *communicating vessels* mechanism between the two metrics is not unlimited: first, annual carbon imports possibly reaching billions of dollars[8] would affect trade balances[9], and second, the concentration of the corresponding transfers on one or two main exporters might entail unacceptable geopolitical risks. The only alternative that would avoid such perverse impacts is a subsidy to domestic abatement. Ultimately, though, both options imply higher welfare costs than a straightforward price-triggered compliance because of the shadow price of public funds.

Paradoxes Regarding Compliance Systems

The reference document for compliance is Pronk's package. It proposes that excess emissions from the first compliance period be subtracted from the second budget period quota negotiated in 2005, with a 1.5 penalty rate that should "be increased by 0.25 after the subsequent commitment period if [still needed]." In economic terms, this provision constitutes a *borrowing*

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[8] [8 ; 22], [4 ; 26], and [2 ; 11] billions of 1990 U.S. dollars annually for the European Union, the United States, and Japan, respectively, under a full-trade, full-compliance hypothesis, including transaction costs as defined in footnote 5.

[9] Models representing trade and capital flows point out the impact of transfers on the exchange rates of currencies (McKibbin et al. 1998).

facility. However surprising to an economist, the absence of any compliance payment can be explained as follows.

Assume a country whose consumers show a willingness to pay \$100/tC, but full compliance requires a \$150/t carbon price. Under the threat of a \$200/tC compliance penalty, a government acting in good faith will obviously use public funds to support domestic action and pay for imports at \$150/tC rather than risk the \$200/tC penalty. Conversely, a bad-faith government—having taken the risk of deliberate noncompliance facing a \$150/tC price instead of confronting its taxpayers—will logically not change its position for a \$200/tC payment. In neither case will the compliance payment be effective.

In fact, any economically credible compliance system would require a threat beyond the internal rules of UNFCCC. An obvious solution would be for the World Trade Organization (WTO) to impose trade barriers against countries not in compliance with global environmental treaties. But because a linkage between UNFCCC and WTO has not been considered so far, an option of Pronk's sort appears the only possible compliance provision.

This has a critical implication for the benchmark with which negotiation packages should be compared. A scenario in which governments socialize the costs of meeting the targets regardless of their extent would be a form of "Candide" conduct[10] and is too optimistic; a more realistic assumption is that even good-faith governments will take full advantage of the flexibility in legal provisions.

The Real Terms of the Supplementarity Problem

The preceding sections force us to rethink the terms of the supplementarity quarrel.

Transaction costs associated with Clean Development Mechanism (CDM) credits raise the international carbon price and thus considerably reduce the risk of not complying with a 50% condition. This risk disappears altogether for the United States, seems low for the European Union, and is significant only for Japan (columns 1 and 2 in Table 1)—an unsurprising result, since all models reveal a flatter marginal cost curve in the United States than in the other countries.

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[10] Candide is a character from Voltaire, a naïve young man who, though a repeated victim of the common flaws of human nature, sticks to the very end to his overly optimistic mentor's teaching that "everything is the best in the best of the world"—that is, everybody's conduct is good-faith conduct.

	Global trade w/o transaction costs	Global trade with transaction costs...	...and a 1.3 shadow price of carbon imports	...and a 1.5 shadow price of carbon imports
European Union	[12 ; 32]%	[43 ; 65]%	[45 ; 68]%	[47 ; 70]%
United States	[16 ; 45]%	[58 ; 85]%	[61 ; 89]%	[63 ; 92]%
Japan	[10 ; 28]%	[33 ; 55]%	[35 ; 58]%	[36 ; 59]%
Market price	$[6 ; 74]	$[39 ; 204]	$[32 ; 169]	$[29 ; 151]

Table 1. Domestic abatement on total abatement under full compliance.

In addition, governments may consider the hidden cost of foreign carbon payments, depending on the shadow price of imports and their concerns about the geopolitical implications of large foreign transfers concentrated on one or two main exporters. Table 1 provides results for a 1.3 estimate[11] and a 1.5 value embodying a strong geopolitical concern.[12]

Thus, the odds that domestic action will exceed a symbolic 50% seem very substantial. A closer scrutiny of detailed results gives a 100%, 92%, and 42% probability for such an outcome for the United States, Europe, and Japan, respectively. Interestingly, the supplementarity issue appears less worrisome, at least as long as the CDM does not encompass a large amount of sequestration that compensates for its transaction costs.

However, the supplementarity question reappears through a totally different channel: Table 2 displays how domestic action drops from Candide conduct—governments are ready to socialize the cost of any reduction necessary for compliance if it surpasses the private willingness to pay (in a political sense, as defined above)—to a more realistic assumption: governments take advantage of borrowing facilities when facing a limited willingness to pay. Three levels of willingness to pay (WP) are here considered, Annex B-wide \$50/tC, \$75/tC, and \$100/tC.

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[11] This value is commonly found in macroeconomic literature (CGP 1984) but should obviously be differentiated according to importing zones.

[12] The fact that the shadow price of carbon has a low impact on domestic action is explained as follows: consider one importer with target T and linear abatement cost $p=aA$, and an exporter with linear abatement cost $p=b(I-H)$, where H is hot air. Compliance yields $\frac{\partial A/T}{\partial b} = \frac{T-H}{T}\frac{a}{(a+b)^2}$ and a variation in b (e.g., including the shadow cost of imports) has little impact on domestic abatement because of the hot air.

	Candide	WP $50	WP $75	WP $100
European Union	[43 ; 65]%	[22 ; 43]%	[30 ; 53]%	[34 ; 59]%
United States	[58 ; 85]%	[27 ; 65]%	[39 ; 74]%	[47 ; 78]%
Japan	[33 ; 55]%	[15 ; 41]%	[21 ; 48]%	[26 ; 51]%
Market price	$[39 ; 204]	$[47 ; 52]	$[59 ; 80]	$[64 ; 105]

Table 2. Domestic abatement under limited willingness to pay (WP) (without shadow cost of imports).[13]

The contraction of domestic abatement is striking: under a $75/tC and a $100/tC WP, the expected value falls below 50% for the European Union. At $50/tC WP, it does so for the United States, too, and the entire likelihood interval drops below this symbolic level for the European Union and Japan. The existence of an implicit borrowing facility is thus unsurprisingly confirmed as a major threat to significant domestic effort.

Annex B Compromise Space *Without* Extended Activities Under Article 3.4

Let us now turn to the numerical analysis of various compromise packages. For the sake of clarity, we distinguish between results under Candide conduct and those with more realistic behavioral assumptions.

Supplementarity and Compliance Costs under Candide Conduct

We first analyze the consequences on supplementarity of a 50% concrete ceiling[14] on buyers.[15] As noted, such a condition has a significant impact only on Japan, according to seven of the SAP12 models. Table 3 displays a lower-bound increase of 12 percentage points for Japanese domestic action. The increase is only 4% for Europe, but the United States shows a decrease; the explanation for this paradox is that reduced Japanese demand results in a slight

[13] The shadow costs of imports are drastically lower than in the Candide case because beyond a certain price per ton, postponements have been substituted for imports.

[14] We drop here the concrete ceiling on sellers because of its implications in terms of market power for carbon exporters.

[15] This is a laxer constraint than option A (defined in footnote 3) in all cases, and laxer than option B in 46 of 48 cases, the only exceptions being the United States, Canada, Australia, and New Zealand in one scenario. Estimates for option B are derived from Baron et al. (1999).

decrease in international carbon prices, causing those nations or zones with marginal costs below the ceiling to increase their imports.

	Candide	Ceilings	Ceilings + waiver $75	Ceilings + waiver $100
European Union	[45 ; 68]%	[49 ; 66]%	[47 ; 68]%	[49 ; 67]%
United States	[61 ; 89]%	[60 ; 88]%	[61 ; 89]%	[61 ; 88]%
Japan	[35 ; 58]%	[47 ; 57]%	[37 ; 58]%	[39 ; 58]%
Market price	$[32 ; 169]	$[30 ; 168]	$[32; 169]	$[31 ; 168]

Table 3. Percentage of domestic abatement with European ceilings on buyers.

All in all, a 50% condition increases Annex B abatement by an average of 1 MtC only: the expected value of imports shifts from 117.5 to 113.5 MtC for the European Union, from 53.5 to 48.5 MtC for Japan, and increases by 8 MtC in the United States. The deflating effect on carbon prices also explains why the likelihood space of total compliance costs (domestic abatement expenditures plus carbon imports) does not change for the European Union, increases only by 3.8–3.1% in Japan, but decreases by 4.2–0.4% for the United States (Table 4).

	Candide	Ceilings	Ceilings + waiver $75/tC	Ceilings + waiver $100/tC
European Union	$[6.1 ; 32.4]B	$[6.1 ; 32.4]B	$[6.1 ; 32.4]B	$[6.2 ; 32.5]B
United States	$[12.4 ; 48.4]B	$[11.9 ; 48.2]B	$[12.3 ; 48.3]B	$[12.1 ; 48.3]B
Japan	$[2.6 ; 12.7]B	$[2.7 ; 13.1]B	$[2.6 ; 12.7]B	$[2.6 ; 12.7]B
Market price	$[32 ; 169]	$[30 ; 168]	$[32; 169]	$[31 ; 168]

Table 4. Annual costs of compliance with European ceilings on buyers.

These findings suggest that the dispute about a concrete ceiling is mostly rhetoric under a Candide-conduct assumption, since this option dramatically increases neither domestic action, as hoped by its proponents, nor the total burden, as feared by its detractors. Rather, it has the paradoxical but fairly explicable outcome of placing more burden on Japan and making the United States better off.

The discrepancy between the constrained and unconstrained scenarios explains why adding a waiver to the concrete ceiling has little numerical impact: it decreases both the extra burden for Japan and the U.S. gain. However, the total of domestic abatement in the importing parties increases only by an average 0.4% for a $100/tC waiver.

The economic logic of an import charge is different, since it necessarily increases domestic effort in all countries for all scenarios, but its supplementarity effect is significant with high charges only (Table 5): for a $5/tC charge it is negligible for Japan and yields a 1 percentage point gain for the United States and the European Union; it shifts to 2 to 3 percentage points in the case of a $15/tC charge, which means an increase of 6% to 8% of domestic abatement.

	Candide	With $5 import charge	With $10 import charge	With $15 import charge
European Union	[45 ; 68]%	[46 ; 69]%	[47 ; 70]%	[48 ; 71]%
United States	[61 ; 89]%	[62 ; 90]%	[63 ; 91]%	[63 ; 92]%
Japan	[35 ; 58]%	[35 ; 58]%	[36 ; 58]%	[37 ; 59]%
Market price	$[32 ; 169]	$[33 ; 170]	$[35 ; 171]	$[36 ; 172]

Table 5. Domestic abatement with import charges.

The paradox that occurred with ceilings disappears, since U.S. costs increase along with those in other countries or zones. Abatement by importing zones increases by 0.8–1.1% with a $5/tC charge, and by 2.0–2.3% and 3.4–3.4% for $10/tC and $15/tC, respectively, compared with 0.2–0.4% under a concrete ceiling plus a $100/tC waiver[16].

Supplementarity and Compliance Costs under Realistic Behavior

Let us now turn to the assumption that even good-faith parties, facing a limit on consumers' willingness to pay, will take advantage of the compliance provision of Pronk's package by postponing abatements that would imply higher domestic energy prices.

[16] This modest result is due to transaction costs' impairing the flexibility mechanisms. The impact would be more substantial with high amounts of cheap sequestration in the CDM.

Ineffective Supplementarity Tools

Under this assumption, neither a 50% concrete ceiling nor an import charge significantly increases domestic abatement:

- A 50% concrete ceiling affects only zones or countries that simultaneously have a domestic effort below this level *and* face a carbon price lower than consumers' willingness to pay. With a $100/tC WP, these conditions occur in 9 cases of 48, and under a $50/tC WP, in 2 cases. The largest upward shift of the likelihood interval for the Japanese domestic effort occurs at $100/tC WP, but it is offset by the opposite impact on the United States, because of the price deflation as explained above. On average, the general tonnage of domestic abatement in the importing zones shifts only by 0.2%, 0.5%, and 0.8% for import charges of $50/tC, $75/tC, and $100/tC, respectively.
- An import charge increases domestic abatement only when the carbon price is lower than the WP: a $10 charge over a $100/tC WP causes a 3 percentage point increase of the likelihood space for all zones, with a 2.6% increase in the expected value for domestic abatement. However, when the WP is binding, imports cease at a marginal price equal to the WP minus the import charge. Thus total abatement decreases, since domestic abatement is unchanged.

The Supplementarity Effect of Restoration Payments

In the first analysis, a restoration payment (RP) set at the same level as the WP of private agents does not change the level of domestic abatement. In contrast, an RP dramatically increases the risk of excessive foreign transfers for importing countries: even if the funds are collected nationally, the cheaper projects selected through a reverse auction (see footnote 6) will likely be in developing countries, Russia, and Ukraine. As stated earlier, it is impossible to predict how the shadow price of carbon imports considered in public policies might evolve, given the specific risks attached to a narrowly polarized destination. But to illustrate the magnitude of the problem, let us say that the shadow price of carbon imports that equates the total foreign transfers under an RP regime to those obtained without such payments and a null shadow cost of carbon imports is 2.4 to 3.7 for a $50/tC RP and still 1.4 to 1.7 for a $100/tC RP. This suggests that the additional foreign payment will not be neutral vis-à-vis the level of domestic action.

Table 6 indicates the order of magnitude of how a 1.3 coefficient[17] applied by all zones affects domestic action. Compared with Table 2, likelihood intervals for domestic abatement shift upward by 3% to 10%. The same supplementarity effect appears in the tonnages of domestic abatement by importing zones, with 24–16%, 19–11%, and 11–7% increases for $50/tC, $75/tC, and $100/tC WP, respectively.

	RP $50	RP $75	RP $100
European Union	[28 ; 50]%	[35 ; 61]%	[38 ; 65]%
United States	[34 ; 75]%	[47 ; 81]%	[53 ; 82]%
Japan	[18 ; 47]%	[26 ; 52]%	[29 ; 54]%
Market price	$[44 ; 53]	$[52 ; 80]	$[53 ; 98]

Table 6. Domestic effort under restoration payments with 1.3 shadow cost of imports.

Of course, this higher domestic abatement, while maintaining the level of marginal effort, comes at some expense in terms of total costs—all the more so as the WP is low, since it implies a greater number of tons to be covered by the RP. On average, total costs of importing zones increase by 70%, 36%, and 17% for a $50/tC, $75/tC, and $100/tC RP, respectively. This is significant compared with a scenario with no compliance payment. However, it does not undermine the purpose of the restoration payment, since it implies gains of 44%, 28%, and 19% compared with a Candide full-compliance scenario (first column of Table 4).

A restoration payment thus significantly makes up for the absence of compliance payments or of border taxes on noncomplying countries: good-faith governments can guarantee consumers a maximum energy price increase and have a rational incentive to adopt supplementary public policies to attenuate both geopolitical risks and the pressure on their current account, without incurring a dramatic additional macroeconomic burden. Formulated to respond to the concerns of the pessimists on costs, the tool is useful in promoting domestic action, as opposed to the borrowing implicit in Pronk's package.

[17] Contrary to the Candide case, under a restoration payment a shadow price will necessarily induce increased public spending—subsidies to carbon-efficient technologies, investment in infrastructures—since any diminution of the imports through a tax would be exactly compensated for by increased restoration payments.

Perhaps more importantly, the distinction between a good-faith and a bad-faith government will immediately be apparent, since the latter will not pay the restoration payment. In the initial Pronk proposal, in contrast, both types are indistinguishable at the start and reveal themselves only in the long run. A bad-faith government will act only if the political cost of the cumulative environmental debt becomes significant, with the possibility that as the total postponed tonnage reaches excessively high levels, the debt will be downgraded and the corresponding abatement definitively abandoned. This mechanism has worked repeatedly in the case of conventional economic debt, and there is no reason why it should not operate in the case of an environmental debt.

Environmental Assessment of Compromise Packages

Despite the significant supplementarity effect of a restoration payment, it is still uncertain whether any particular price cap would be acceptable to those who seek environmental integrity as well as to those who prioritize cost control. The search for a compromise implies that both camps take a step in each other's direction.

Judgment on environmental integrity under a non-Candide scenario and Pronk's compliance depends only on the level of confidence attached to the recovery of postponed abatement. One easy indicator of the risk of ultimate default is the total tonnage postponed: 291 MtC under a $50/tC WP, and still 104 MtC for a $100/tC WP (with upper bounds of 741 and 572 MtC, respectively), when the likelihood space of the overall abatement required to meet the Kyoto targets is 810–1,077 MtC.

As noted earlier, none of the envisaged supplementarity tools improve significantly upon this result, whereas a restoration payment lowers the risks of endlessly postponed abatement by prepaying part of the restoration. However, placing an upper bound on carbon prices comes at the expense of uncertainty about environmental performance. A measure of this uncertainty is shown in Figure 1, which displays the likelihood interval (shaded boxes), extreme bounds, and median values (dashes and crosses) of emissions for various levels of willingness to pay with and without the RP.

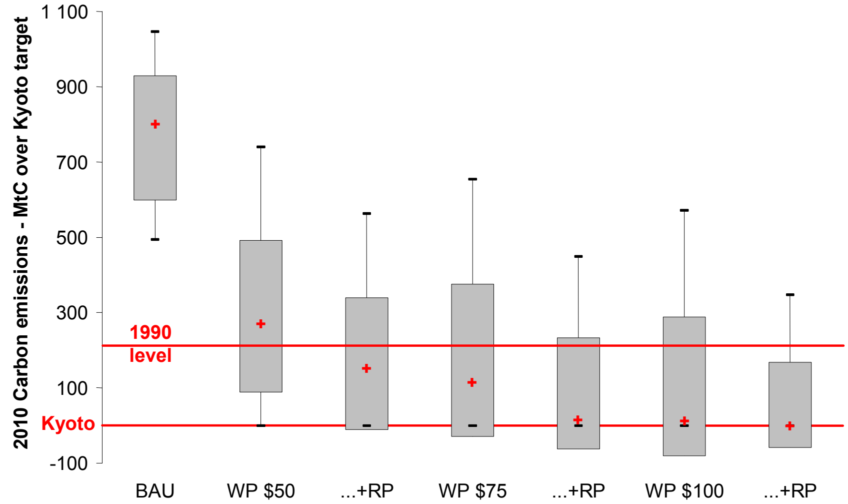


Figure 1. Effect of restoration payments on environmental integrity.

The gain from an RP provision can be seen from the downward shift of the likelihood intervals of environmental performance for various levels of willingness to pay. Although a $100/tC RP secures a high probability of meeting the Kyoto targets, the chance is still 50% with a $75/tC RP (the median is close to the Kyoto level).[18] With a $50/tC RP there is still a good chance of abating to 1990 levels, but meeting the targets is much more uncertain, at a low 25%. It follows that a negotiable range of RP levels could be between $75 and $100 per ton. Although this is not a very wide range, it can be enlarged from two perspectives.

First, to facilitate full ratification, objectives laxer than the Kyoto targets might be accepted instead of an implicit revision under Article 3.4. A stabilization of emissions from the energy sectors at 1990 levels could amount to a 1% emissions reduction from 1990 levels with some carbon sinks, thus falling into the span defined by Dominique Voynet, France's environment minister: "...what really matters: to begin reducing [greenhouse gas] emissions.... Starting from there, the reduction level, be it 1% or 5%, is not essential" (*Le Monde* 21 April

[18] Note that the extension of some likelihood intervals beyond the Kyoto targets is due solely to their statistical nature. Models do not consider any sort of overshooting, and the fact that a likelihood interval (standard deviation around the expected value) reaches below Kyoto simply indicates that the underlying probability distribution is biased in that direction.

2001, our translation).[19] In Figure 1, this would be consistent with a \$50/tC RP and even a \$35 level—the lower limit for a 50% chance of reaching the redefined target.

A second perspective, without *ex ante* revision of targets, assumes that the European Union, consistent with its concerns about low prices, gives more credibility to optimistic models.

	Neutral stance		Optimistic stance	
	Emissions at Kyoto commitments	Emissions under 1990 levels	Emissions at Kyoto commitments	Emissions under 1990 levels
RP \$35	8%	50%	17%	67%
RP \$50	25%	75%	50%	83%
RP \$75	50%	83%	67%	92%
RP \$100	75%	83%	83%	92%

Table 7. Distribution of modeling results on environmental integrity under a restoration payment.

Table 7 displays how probabilities of reaching both Kyoto and 1990 levels evolve from a neutral stance to an optimistic stance, obtained by weighting model results with the following factors: 1 for the four most pessimistic, 2 for the four medium, and 3 for the four others. Chances of meeting the Kyoto targets with a \$50/tC RP switch from 25% to 50%, with the laxer target guaranteed at 83%, which again makes the \$50 level acceptable. Besides, the \$35/tC level yields a 67% chance of meeting the relaxed target, and the odds of meeting the Kyoto targets improve slightly, from 8% to 17%.

Annex B Compromise Space With Sequestration Under Article 3.4

Let us now turn to the option of increasing carbon sequestration in Annex B, which was considered during the last days of COP6 as a way to control compliance costs and alleviate the burden on the energy system.

To discuss the pros and cons of an extended 3.4 sequestration option as opposed to a restoration payment, we compared levels of both options yielding the same reduction of the

[19] This passing point is still compatible with keeping greenhouse gas concentrations under a 450 ppm level (Ha-Duong et al. 1997, 1999).

expected value of compliance costs. The cost of carbon sequestration, while quite uncertain, is generally expected to be far lower than that of carbon abatement in the energy sector. To avoid arbitrary assumptions that would blur the core of the argument, we assume a null cost for sequestration in the following simulations: the estimated tonnages for different proposals were simply subtracted from the Kyoto targets to obtain the new level of abatement to be achieved in the energy sector. This was done for all the existing proposals, but for the sake of simplicity we report only on the extended-sequestration option: the Umbrella proposal as circulated during COP6, with the following tonnages estimated by French forestry experts:

	European Union	United States	Japan	CANZ group	EIT
Kyoto abatement requirements	[190 ; 336]MtC	[430 ; 546]MtC	[74 ; 120]MtC	[64 ; 125]MtC	[-301 ; -56]MtC
Abatement from sequestration	13 MtC	115 MtC	4 MtC	29 MtC	21 MtC

Table 8. Abatement from sequestration under the Umbrella proposal.

Under these assumptions, overall costs for the importing zones countries drop to $37.7 billion on average, a 40% decrease from their $67.7 billion full-compliance level. To achieve an equivalent (expected value) cost reduction, a restoration payment should be set at $54/tC.

Effect on Environmental Integrity, Compliance, and Supplementarity

The environmental assessment of each option depends on judgments regarding the integrity of postponed and sequestered tons. As stated earlier, the integrity of postponed abatement depends on the credibility of its recovery during further commitment periods. As for sequestered tons, some argue that they correspond to reductions that would have occurred anyway and/or that the underlying activities were not taken into account at Kyoto;[20] others oppose this critique and support the view that the IPCC Land Use, Land Use Change and Forestry special report gives far greater credence to the legitimacy of activities beyond those recognized in Article 3.3 if properly monitored. We will not venture to settle this controversy but rather report on basic outcomes.

[20] Note that the "hot air" does not introduce the same problem: the larger its amount, the higher the emissions from importing countries, but without any effect on total Annex B emissions.

Under Candide conduct, Figure 2 distinguishes among (a) domestic (energy sector) abatement, (b) genuine tons imported, (c) hot air imported, (d) tons abated during a true-up period through the restoration payments, (e) tons sequestered, and (f) tons postponed to a subsequent compliance period. For those who consider action in the energy sector indispensable to the long-term objective of climate control, a computation of the relevant abatement (categories a, b, and d) gives a slight advantage to the restoration payment, which guarantees 64.6% of the target, compared with 61.2% for the sequestration option.

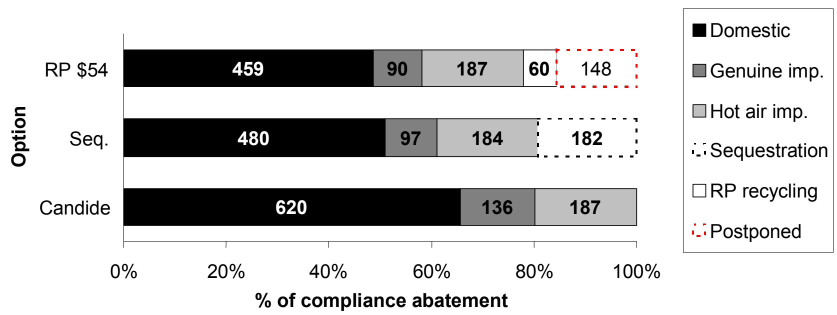


Figure 2. Split of annual abatement for the importing zones, Candide perspective.

Furthermore, an equal average of expenses masks the fact that although marginal carbon prices hit a $54/tC ceiling under the RP, they can go far beyond this level under the sequestration option (see below). This takes us back to the question of limited willingness to pay and to the comparison between Candide and non-Candide conducts: under a $75/tC limit the Umbrella proposal decreases the domestic and genuine imported tons, inducing 74 MtC of postponed abatement because the sequestration remains at the same level as without WP. Going down to a $54/tC limit causes a postponement of 123 MtC, and action in energy sectors consecutively drops to 48.1% of Kyoto targets (Figure 3).

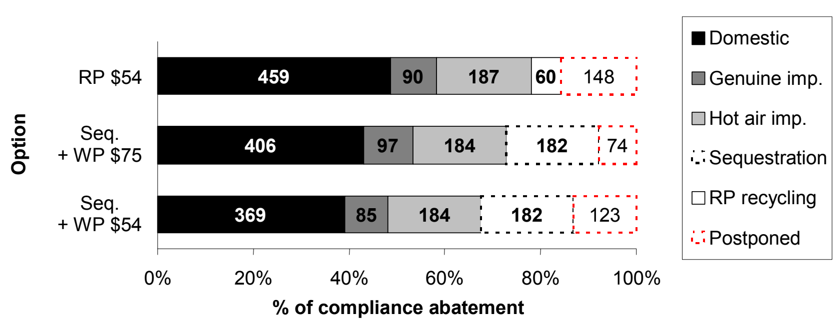
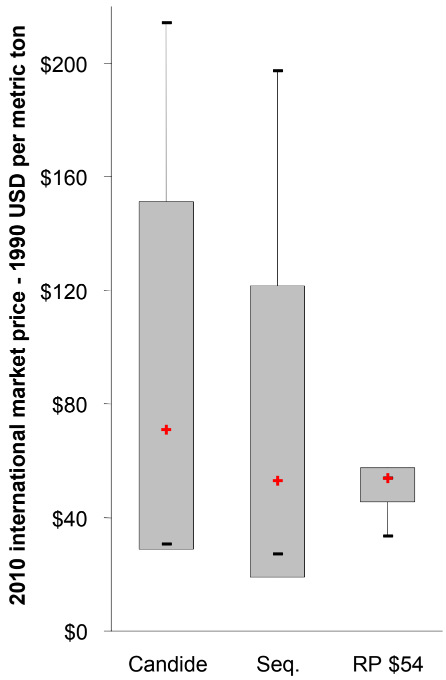


Figure 3. Split of annual abatement for the importing zones, realistic perspective.

Besides, the slight advantage sequestration had in terms of supplementarity (Figure 2) is gone: the 50.9% expected domestic action in the energy sector drops to 43.1% and 39.1%, substantially below the 48.7% expected value for the $54/tC RP.

Effects on Costs Uncertainty

The very principle of a restoration payment is to give an upper bound to the marginal cost to energy consumers. It is a different economic rationale than that of extended sequestration, which *de facto* amounts to a downward shift of all cost curves. For this reason the qualitative insights derived from Figure 4 are not surprising. But the order of magnitude of the difference between the two options in the likelihood interval of carbon prices is more striking. Figure 4 presents the modeling results in a format equivalent to the one used in Figure 1. The reduction in uncertainty is dramatically higher with an RP than with the sequestration proposal: in the Candide scenario, the likelihood interval's width is reduced by 90% under the RP, compared with an almost negligible 16% in the sequestration option.



Graph 3. ***Sequestration vs. RP Effect on marginal prices***

We do not plot here the results in terms of total compliance costs, although the differences are of the same order of magnitude: sequestration produces a $13 billion to $63 billion likelihood interval, compared with $31 billion to $44 billion for the restoration payment.

Note that the lowest bound of carbon prices (and compliance costs) is higher with an RP than with an extended sequestration. This is because the $54/tC price cap is never reached in the very optimistic models and thus does not affect the results, whereas tons from sequestration shift the cost curves of every model in the same downward way, whatever their optimism on costs.

The policy implications from these results can be derived in two ways corresponding to the symmetrical and contradictory concerns about compliance costs:

- For a reduction of the expected value of compliance costs identical to the one obtained with a $54/tC restoration payment, extended sequestration is less efficient in allaying the concerns of pessimists about abatement costs. A closer scrutiny of modeling results reveals that the risks that carbon costs may exceed $120/t and $90/t are still 17% and 25%, respectively, while a $54/t level is of course guaranteed by the RP.

- The difference in the lower bound of the likelihood intervals has a very important implication for minimizing risks of too-low price signals over the first budget period, which is the basic rationale behind the supplementarity condition. A $19/tC lower bound under sequestration aggravates the deficit in supplementarity, compared with a $45/tC lower bound with a $54/tC price cap.

A Long-Term Dividing Line: The North-South Issue

The Clean Development Mechanism is the main provision of the Kyoto Protocol likely to reconcile two contradictory demands: one by the G77 that developed countries demonstrate their willingness to combat climate change; the other from the U.S. Senate (Byrd-Hagel resolution, June 12, 1997) that developing countries face "new specific scheduled commitments to limit or reduce greenhouse gas emissions." However, the CDM is from the outset the subject of a misunderstanding. It is viewed by Annex B countries as a flexibility mechanism similar to joint implementation, even though Article 12.2 clearly assigns it three objectives: (a) to assist non-Annex I countries in achieving sustainable development; (b) to assist non-Annex I countries in contributing to the ultimate objective of the convention; and (c) to assist Annex I countries in achieving compliance with their quantified emissions limitation and reduction commitments.

Policies in accord with this implicit ranking are still unclear. In many quarters of the G77 the argument prevails that technological and financial transfers through the CDM may not provide development benefits (Estrada 1998; Thorne and La Rovère 1999). The extent of the contribution of CDM projects to development is conditional both on the very content of the projects[21] and on the split of the net economic rent generated by the difference between their incremental cost and the international value of carbon. What proportion of the rent will remain in the host country depends on its bargaining power relative to the investor's, a core issue in designing the CDM modalities.

[21] Under certain circumstances, CDM projects can have a leverage effect on development (Mathy et al. 2001). The corresponding field of research is marred by the continuing confusion between the CDM and joint implementation.

The first proposal put forward as yielding less-uncertain gains is the extension to all flexibility mechanisms of a "share of the proceeds" (SP) of CDM transactions (Article 12.8). Our calculations reveal that such an extension would multiply by 4 the expected value of a $2/tC SP fund; still, at $0.4 billion to $0.9 billion, it would be approximately only a tenth of the expected surplus on CDM markets. Reaching the symbolic $1 billion envisaged in Pronk's text would necessitate doubling the extended levy, to $4/tC. These figures assume the extensive market volume of a Candide scenario, thus overestimating the ultimate gain and casting doubt on the appropriateness of the SP mechanism as an answer to the G77 concerns[22].

The second proposal, initiated by Brazil before Kyoto, is the creation of a compliance fund, akin to the restoration payment envisaged in this paper. Table 9 displays how total transfers and surpluses are modified under a willingness to pay of $50/tC and $75/tC if, for the sake of simplicity, the auction is directed to the developing world only.[23]

	WP $50/tC	RP $50/tC	WP $75/tC	RP $75/tC
Market transfers	$[0.8 ; 4.2]B	$[1.0 ; 3.6]B	$[2.7 ; 6.7]B	$[2.4 ; 5.5]B
Transfers from RP	–	$[0.8 ; 21.8]B	–	$[-5.1 ; 23.5]B
Market surplus	$[0.3 ; 1.6]B	$[0.4 ; 1.4]B	$[1.2 ; 2.8]B	$[1.0 ; 2.3]B
Surplus from RP	–	$[-0.3 ; 8.5]B	–	$[-2.3 ; 8.7]B

Negative values do not correspond to actual result, cf. footnote 24

Table 9. Transfers to the developing world with and without restoration payments.

Developing countries appear strikingly better off, with higher bounds for their potential surplus multiplied by approximately 6 and 4, respectively. Admittedly, a restoration payment restricts the first market for CDM projects because of a higher level of domestic action in Annex B, but the reverse auction guarantees that rents accrue to the host country, thereby more than compensating for this contraction. Both levels of RP even allow a net gain over full compliance,

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[22] Note, finally, that legitimizing the extension by advocating that a levy on CDM transfers exclusively constitutes an inequitable competitive distortion is arguable: at $2/tC; simulations reveal that the consecutive decrease in market transfers is roughly compensated for by the level of the SP fund levied.

[23] This places an upper bound on the capacity of the system to attract developing countries to actively participate in climate policies. Without such a constraint, though, postponed abatements would be lower (a larger carbon supply would decrease the equilibrium price of the reverse auction), as would total external payments.

where total transfers are –$0.5 billion to $17.3 billion, with a corresponding –$0.6 billion to $8.1 billion surplus.[24]

Conclusion: The Narrow Pathway to a Recovered Deal?

The central issue of the post-Kyoto process was that hedging against uncertainty on compliance costs, either in the form of a price cap or through the extension of sequestration activities, risked creating a loophole in the Kyoto cap-and-trade system. The analysis presented here suggests that the two hedging tools are very different in nature, and that a restoration payment may provide a negotiation space large enough to accommodate all the prevailing world views:

- As regards environmental integrity, the restoration payment compensates for the absence of financial penalties or formal linkage to the WTO in the compliance system, since good-faith conduct is immediately distinguishable by a government's contribution to the restoration fund. It is, moreover, an efficient supplementarity tool because of the risks of extraterritorial payments. And finally, it limits the risks of endlessly postponed abatements in case energy consumers have a limited willingness to pay.
- As regards costs control, the restoration payment provides a more efficient hedge against the risks of too-high carbon prices than an equivalent amount of tons under Article 3.4, which symmetrically exacerbates the risks of too-low prices.
- Concerning developing countries, a restoration payment provides a significant source of transfers in the spirit of the Brazilian 1997 proposal, whereas extended sequestration activities under Article 3.4 would undermine the prospects for significant CDM and share-of-the-proceeds revenues.

Ultimately, the restoration payment option, instead of *ex ante* revising Kyoto targets, gives Kyoto a chance until an *ex post* assessment in 2012: it more than triples its 8% probability under a $50 willingness to pay, and can even raise it to 50% if one gives greater credence to the more optimistic models.

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[24] Obviously, none of the models actually give negative market transfers to the CDM hosts (who do not have any binding commitment), but the way the likelihood intervals are built (see Box 1) does not preclude negative lower bounds.

The secret hope of the engineering economist is to inject some objectivity into policy discussions. To pursue this aim in climate change affairs is a daunting task because parties with opposing expectations and visions of fairness are likely to view all models as controversial. The rational lesson from our model simulations is that it is essential to incorporate uncertainty into the framework of international coordination, rather than engage in infinite controversies that delay action and could make ambitious targets unreachable.

Beyond the Kyoto targets and timetables, it appears that a hybrid quantity-price instrument is robust to cope with uncertainties, hence facilitating the negotiation of further budget periods and the appeal of active climate policies to developing countries. The usefulness of such an economic message depends on two conditions: first, that every party acts in a manner consistent with its stated world view and is not motivated by a hidden agenda; and second, that diplomats, policymakers, and environmentalists remember an old Roman saying, *Audi alteram partem:* Listen to the other side.

Postscript

Most of this work was conducted to provide insight into the economic background of COP6. We decided not to address the Bonn accord in the core of the text because our objective was to derive general lessons regarding the role played by the cost uncertainty in global environment agreements. Concerning the environmental cost of The Hague's Lost Deal, however, SAP12 provides the following information in the absence of monopolistic behavior by the Economies in Transition:

- the Bonn agreement implies a 50% chance of a carbon price lower than $28/t; the 50% threshold is $54 for the $54/t RP option, and $53 for the Umbrella sequestration option;
- under the Bonn agreement, the total of domestic abatement in the energy sector for Annex B countries (excluding the United States) is in a [65 ; 200] MtC likelihood space, compared with [120 ; 250] MtC for the RP option, a 53 MtC decrease from the average; a loss appears even compared with the sequestration option, with an average 13 MtC lower; and
- under Bonn, net transfers to the developing countries fall drastically, to an average of $2.4G in CDM projects (with 50% of SAP12 models giving a total below $1G).

The assessment regarding U.S. abatement depends both upon whether the United States would have ultimately endorsed either of the two deals examined in this paper, and upon the extent of its future domestic abatement outside the Kyoto framework. Relevant data from SAP12 are the following: assuming ratification, U.S. domestic abatement under a restoration payment at $54/tC is between 172 and 377 MtC; under the Umbrella sequestration option it ranges from 206 to 366 MtC.

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