The role of fixed cost in international environmental negotiations

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APPENDIX

Proof of Lemma 3

The function $2B(x) - c(x)$ is concave. It attains its maximum at point x^*. It is increasing for $x < x^*$and decreasing for $x > x^*$. We know that x^* is higher than $\widehat{\widehat{a}}$, because $2B'(\widehat{\widehat{a}}) - c'(\widehat{\widehat{a}}) = B'(\widehat{\widehat{a}}) > 0$. We also know that $\widehat{\widehat{a}}$ is higher than $\widehat{a}$, because $B'(\widehat{a}) > B'(2\widehat{a}) = c'(\widehat{a})$. This implies that $B'(\widehat{a}) - c'(\widehat{a}) > 0$. Consequently, $2B(x^*) - c(x^*) > 2B(\widehat{\widehat{a}}) - c(\widehat{\widehat{a}}) > 2B(\widehat{a}) - c(\widehat{a}) > B(2\widehat{a}) - c(\widehat{a})$. The final inequality is related to the concavity of the function $B(.)$ which implies that $2B(x) > B(2x)$ (with $B(0) = 0$. If not, we would consider the function $(B(x) - B(0))$ and obtain an equivalent result).

Proof of Proposition 1

At Type 1 equilibrium, the countries maximize their (identical) utility function: $Max_{a_i}[B(a_i + a_{-i}) - c_o - c(a_i)]$. We obtain $a_i = a_{-i} = \widehat{a}$ as the solution of these maximization programs. The payoffs of the countries at the equilibrium are then equal to $B(2\widehat{a}) - c_o -\ c(\widehat{a})$.

At Type 2 equilibrium, the payoff of country i which abates is deduced from the following maximization program: $Max_{a_i}[B(a_i) - c_o - c(a_i)]$ because $a_{-i} = 0$. We obtain $a_i = \widehat{\widehat{a}}$ as the solution of this program. At equilibrium, the payoff of the country which does not abate is equal to $B(\widehat{\widehat{a}})$, and the payoff of the country which undertakes an abatement effort is equal to $B(\widehat{\widehat{a}}) - c_o - c(\widehat{\widehat{a}})$.

At Type 3 equilibrium, the payoffs of the countries which do not abate are null.

Let us first show that the payoffs of the countries at Type 1 equilibrium are deduced from Nash equilibrium given the assumptions $c_{o1} > 0$ and, $c_o < c_{o1}$. If country 1 unilaterally deviates (the same for country 2), i.e., if it does not abate it gets $B(\widehat{\widehat{a}})$ which is lower than $[B(2\widehat{a}) - c_o - c(\widehat{a})]$ given the above assumptions, $c_{o1} > 0$ and $c_o < c_{o1}$.

Let us show now that the payoffs of the countries at Type 2 equilibrium are those of Nash equilibrium given the assumption $c_{o1} < c_o < c_{o2}$. Country 1 (which abates) has no interest in deviating if $\left[B(\widehat{\widehat{a}}) - c_o - c(\widehat{\widehat{a}})\right] > 0$, i.e., if $c_o < c_{o2}$. As concerns country 2, it has no incentive to deviate unilaterally if $B(\widehat{\widehat{a}}) > [B(2\widehat{a}) - c_o - c(\widehat{a})]$, i.e., if $c_o > c_{o1}$.

Finally, if $c_o > c_{o2}$, country 1 deviates to Type 3 equilibrium.

Proof of Lemma 4

The maximization of the function $N(a_1, a_1, t)$ for agreement U ($a_1 = a_2 = \overline{a}$ and $t = 0$) leads to the following first-order condition: $[2B'(2a) - c'(a)][B(2a) - c_o - c(a) - NB_2^*] = -[2B'(2a) - c'(a)][B(2a) - c_o - c(a) - NB_1^*]$. This condition defines $\overline{a}$. This holds true for the three Nash equilibria which represent the threat points of the negotiation on agreement U.

The maximization of the function $N(a_1, a_1, t)$ for agreement DT ($a_1 \neq 0, a_2 = 0$ and $t \neq 0$) leads to the following first-order conditions: $(B'(a_1) - c'(a_1))[B(a_1) - t - NB_2^*] + B'(a_1)[B(a_1) - c_o -\ c(a_1) + t - NB_1^*] = 0$ and $[B(a_1) - c_o -\ c(a_1) + t - NB_1^*] = [B(a_1) - t - NB_2^*]$.

As concerns Type 1 Nash equilibrium, we have $NB_1^* = NB_2^* = B(2\widehat{a}) - c_o - c(\widehat{a})$. Then, the expression of transfers in agreement DT takes the following form, $t = \frac{(c_o + c(a_1))}{2}$. Consequently, we obtain $(B'(a_1) - c'(a_1))[B(a_1) - \frac{(c_o+c(a_1))}{2} - B(2\widehat{a}) + c(\widehat{a})] + B'(a_1)[B(a_1) + \frac{c_o}{2} - \frac{c(a_1)}{2} - B(2\widehat{a}) + c(\widehat{a})] = 0$. This condition leads to a_1.

As concerns Type 2 Nash equilibrium, we have $NB_1^* = B(\widehat{\widehat{a}}) - c_o - c(\widehat{\widehat{a}})$ and $NB_2^* = B(\widehat{\widehat{a}})$. Then, the expression of transfers in agreement DT takes the following form, $t = \frac{(c(a_1) - c(\widehat{\widehat{a}})}{2}$. Consequently, we obtain $(B'(a_1) - c'(a_1))[B(a_1) - B(\widehat{\widehat{a}}) - \frac{((c(a_1) - c(\widehat{\widehat{a}}))}{2}] + B'(a_1)[B(a_1) - B(\widehat{\widehat{a}}) - \frac{\left[c(a_1) - c(\widehat{\widehat{a}})\right]}{2}] = 0$. This condition defines a_1.

As concerns Type 3 Nash equilibrium, we have $NB_1^* = NB_2^* = 0$. Then, the expression of transfers in agreement DT is the following, $t = \frac{[c_o + c(a_1)]}{2}$. Consequently, we obtain $(B'(a_1) - c'(a_1))[B(a_1) - \frac{(c_o+c(a_1))}{2}] + B'(a_1)[B(a_1) - \frac{(c_o+c(a_1))}{2}] = 0$. This condition defines a_1.

As the expressions of transfers in the three cases show, there exists a unique level of transfers such that the two countries are equally well off. This is derived from the definition of the Nash bargaining solution and the assumption that all the countries have the same negotiation powers.

Proof of Proposition 2

$[B(2\overline{a}) - c_o - c(\overline{a})] < \left[B(a_1) - \frac{[c_o + c(a_1)]}{2}\right]$ if and only if $c_o > \overline{c_o}$.

The (identical) payoff of the countries in agreement U when the threat point is represented by Type 1 Nash equilibrium is the following: $[B(2\overline{a}) - c_o - c(\overline{a})]$, which exceeds their payoff at the threat point $[B(2\widehat{a}) - c_o - c(\widehat{a})]$ because $\overline{a}$ maximizes the function $B(2x) - c_o - c(x)$.

Proof of Proposition 3

$[B(2\overline{a}) - c_o - c(\overline{a})] < \left[B(a_1) - \frac{\left[c(a_1) - c(\widehat{\widehat{a}})\right]}{2}\right]$ if and only if $c_o > \overline{\overline{c_o}}$.

The payoffs of the countries in agreement DT when the threat point is represented by Type 2 Nash equilibrium are the following: $\left[B(a_1) - \frac{\left[c(a_1) + c(\widehat{\widehat{a}})\right]}{2} - c_o\right]$ for country 1 and $\left[B(a_1) - \frac{\left[c(a_1) - c(\widehat{\widehat{a}})\right]}{2}\right]$ for country 2. These payoffs exceed those at the threat point ($NB_1^* = B(\widehat{\widehat{a}}) - c_o - c(\widehat{\widehat{a}})$ and $NB_2^* = B(\widehat{\widehat{a}})$), because a_1 maximizes the function $2B(x) - c(x)$. Consequently, we have $B(a_1) - \frac{c(a_1)}{2} > B(\widehat{\widehat{a}}) - \frac{c(\widehat{\widehat{a}})}{2}$.

Proof of Proposition 4

$[B(2\overline{a})-c_o-c(\overline{a})]<\left[B(a_1)-\frac{[c_o+c(a_1)]}{2}\right]$ if and only if $c_o>\overline{c_o}$.

The payoff of the countries in agreement U when the threat point is represented by Type 3 Nash equilibrium is the following: $[B(2\overline{a})-c_o-c(\overline{a})]$, which exceeds 0 if $c_o<c_{oU}$.

The payoff of the countries in agreement DT when the threat point is represented by Type 3 Nash equilibrium is the following: $\left[B(a_1)-\frac{[c(a_1)+c_o]}{2}\right]$, which exceeds 0 if $c_o<c_{oDT}$.

Proof of Lemma 5

1) $c_{o2}<c_{oU}$ because $B(\widehat{a})-c(\widehat{a})<B(2\overline{a})-c(\overline{a})$. This holds true because $B(2x)>B(x)$ for every x, since $B(.)$ is an increasing function. Consequently, the maximum of the function $B(2x)-c(x)$ is higher than that of the function $B(x)-c(x)$.

$c_{oU}<c_{oDT}$ because $B(2\overline{a})-c(\overline{a})<2B(a_1)-c(a_1)$. This holds true because $B(2x)<2B(x)$ by the concavity of the function $B(.)$ and by the assumption that $B(0)=0$. Consequently, the maximum of the function $2B(x)-c(x)$ is higher than that of the function $B(2x)-c(x)$.

2) We know that $\overline{c_o}=2c_{oU}-c_{oDT}$, then $\overline{c_o}<c_{oU}$ because $c_{oU}<c_{oDT}$ (see above). Since the inequality $c_{oDT}>2c_{oU}$ could exist, $\overline{c_o}$ could be negative.

3) $\overline{\overline{c_o}}<\overline{c_o}$ because $B(2\overline{a})-c(\overline{a})-B(a_1)-\frac{\left[c(\widehat{\widehat{a}})-c(a_1)\right]}{2}<2(B(2\overline{a})-c(\overline{a}))-(2B(a_1)-c(a_1))=2\overline{\overline{c_o}}+c(\widehat{\widehat{a}})$.

Proof of Proposition 6

$B'(2\widehat{a})=c'(\widehat{a})<c'(2\widehat{a})$ and $B'(\widehat{\widehat{a}})=c'(\widehat{\widehat{a}})$. The property that the function $B'(.)$ is decreasing and the function $c'(.)$ is increasing implies that $2\widehat{a}>\widehat{\widehat{a}}$. A similar argument leads to $2\overline{a}>a_1$.

Proof of Proposition 7

We first study the condition of **internal stability**: $NB_n(p+m-1)\leq NB_s(p+m)$. These utility levels are defined in the following way:

$NB_n((p-1)+m)=w\left[(p-1)a_s+(N-(m+p-1)a_n\right]-c_o-\frac{ca_n^2}{2}$.

$NB_s(p+m)=w\left[pa_s+(N-(m+p))a_n\right]-\dfrac{p}{m+p}\left[c_o+\dfrac{ca_s^2}{2}\right]$.

We have $a_s(m+p)=\dfrac{(m+p)w}{c}$ and $a_n=\dfrac{w}{c}$. Substituting, we obtain:

$NB_n((p-1)+m)=w\left[(p-1)\left(\dfrac{(m+p-1)w}{c}\right)+(N-(m+p-1)\dfrac{w}{c}\right]-c_o-\frac{c}{2}\left(\dfrac{w}{c}\right)^2$.

$NB_s(p{+}m)=w\left[p\left(\dfrac{(m+p)w}{c}\right)+(N-(m+p))\dfrac{w}{c}\right]-\dfrac{p}{m+p}\left[c_o+\dfrac{c}{2}\left(\dfrac{(m+p)w}{c}\right)^2\right]$.

Then, the condition $NB_n(p+m-1) \leq NB_s(p+m)$ reduces to the following: $\frac{w^2}{2c}\left[3+p(p-4)+m(p-2)\right] \leq \frac{m}{m+p}c_o$.

We now study the condition of **external stability**: $NB_n(p+m) \geq NB_s(p+m+1)$. These utility levels are defined in the following way:

$NB_n(p+m) = w\left[(pa_s+(N-(m+p)a_n\right] - c_o - \frac{ca_n^2}{2}$.
$NB_s(p+m+1) = w\left[(p+1)a_s+(N-(m+p+1))a_n\right] - \dfrac{p+1}{m+p+1}\left[c_o+\dfrac{ca_s^2}{2}\right]$.

We have $a_s(m+p) = \dfrac{(m+p)w}{c}$ and $a_n = \dfrac{w}{c}$. Substituting, we obtain:

$NB_n(p+m) = w\left[p\left(\dfrac{(m+p)w}{c}\right)+(N-(m+p))\dfrac{w}{c}\right] - c_o - \frac{c}{2}\left(\dfrac{w}{c}\right)^2$.

$NB_s(p+m+1) = w\left[(p+1)\left(\dfrac{(m+p+1)w}{c}\right)+(N-(m+p+1))\dfrac{w}{c}\right]$
$-\dfrac{p+1}{m+p+1}\left[c_o+\dfrac{c}{2}\left(\dfrac{(m+p+1)w}{c}\right)^2\right]$.

Then, the condition $NB_n(p+m) \geq NB_s(p+m+1)$ reduces to the following: $0 < \frac{2cc_o}{w^2} \leq \frac{m+p+1}{m}(m(p-1)+p(p-2))$.

Let us turn now to the core of the proof of Proposition 7.

1) The condition of **internal stability** is written in the following way in this case (the calculus for agreement U is similar if we put $m=0$ and $t=0$ in the calculus above): $NB_s(p) - NB_n(p-1) = \frac{w^2}{c}(-\frac{1}{2}p^2+2p-\frac{3}{2}) \geq 0$.

The condition of **external stability** is (the calculus for agreement U is similar if we put $m=0$ and $t=0$ in the calculus above): $NB_n(p)-NB_s(p+1) = \frac{w^2}{c}(\frac{1}{2}p^2-p) \geq 0$.

These conditions are identical to those in Barrett (1994). We will show that only $p=2$ and $p=3$ satisfy these two conditions.

$NB_s(p) - NB_n(p-1)$ is a polynomial in p with a maximum attained for $p=2$. This maximum implies the following value $\frac{w^2}{c}(\frac{1}{2}) > 0$. This polynomial is equal to 0 for $p=1$ and $p=3$, it is negative for $p>3$.

$NB_n(p) - NB_s(p+1)$ is also a polynomial with a minimum attained for $p=1$. This minimum implies the following value $\frac{w^2}{c}(-\frac{1}{2}) < 0$. It is equal to 0 for $p=2$ and is strictly positive for $p>2$.

2) The condition of **internal stability** is written in the following way in this case (see above): $(3+p(p-4)+m(p-2)) \leq \frac{m}{m+p}\frac{2cc_0}{w^2}$.

The condition of **external stability** is (see above): $(m(p-1)+p(p-2)) \geq \frac{m}{m+p+1}\frac{2cc_0}{w^2}$.

For $p=1$, we check that the second condition does not hold because $\frac{m}{m+2}\frac{2cc_0}{w^2} > 0$. For $p=2$, these two conditions are written in the following way: the first condition $-1 \leq \frac{m}{m+2}\frac{2cc_0}{w^2}$ and the second condition $m \geq \frac{m}{m+3}\frac{2cc_0}{w^2}$, or $\frac{w^2}{2cC_0} \geq \frac{1}{m+3}$, which is true for each m strictly positive. We should now prove that a stable coalition could not exist for $p \geq 3$ and $m \geq 1$. Recall the condition of internal stability $(3 + p(p-4) + m(p-2)) \leq \frac{m}{m+p}\frac{2cC_0}{w^2}$. We know that $(3 + p(p-4) + m(p-2))\frac{m+p}{p}$ exceeds $(3 + p(p-4) + m)\frac{m+p}{p}$ when $p \geq 3$ and $m \geq 1$. This latter expression is strictly superior to 1 for $p \geq 3$ and $m \geq 1$. However, we have $\frac{2cC_0}{w^2} \leq 1$ by assumption. Consequently, the condition of internal stability does not hold for $p \geq 3$ and $m \geq 1$.

Proof of Proposition 8

1) The individual payoff under agreement U (with a coalition size of $p = 3$) is as follows: $NB_s^U(3) = \frac{w^2(2N+3)}{2c} - c_o$.

The individual payoff under agreement DT (with a coalition size of $2 + m$, with $m \geq 1$) is as follows: $NB_s^{DT}(2+m) = \frac{w^2 N}{c} - \frac{2c_o}{m+2}$.

$NB_s^{DT}(2+m) > NB_s^U(3)$ if $c_o > \frac{3w^2(m+2)}{2cm}$, which is incompatible with our initial assumption $c_o < \frac{w^2}{2c}$. Therefore, $NB_s^U(3) > NB_s^{DT}(2+m)$.

2) The individual abatement under agreement DT is: $a_S^{DT}(2+m) = \frac{(2+m)w}{c}$.

The individual abatement under agreement U is: $a_S^U(3) = \frac{3w}{c}$. We then have $a_S^U \leq a_S^{DT}$ because $m \geq 1$.

3) The global abatement under agreement U is as follows:

$A^U = pa_S^U + (N-m-p)a_n = 3\frac{3w}{c} + (N-3)\frac{w}{c} = \frac{w}{c}(6+N)$.

The global abatement under agreement DT is as follows:

$A^{DT} = pa_S^{DT} + (N-m-p)a_n = 2\frac{(2+m)w}{c} + (N-m-2)\frac{w}{c} = \frac{w}{c}(2+N+m)$.

$A^{DT} > A^U$ if $m \geq 5$.

Proof of Proposition 9

We first study the condition of **internal stability**: $NB_n(p+m-1) \leq NB_s(p+m)$.

We have $a_s(m+p) = \dfrac{(m+p)w}{c}$ and $a_n = 0$. We obtain:

$$NB_n(p+m-1) = w\left[(p-1)\left(\frac{(m+p-1)w}{c}\right)\right].$$

$$NB_s(p+m) = w\left[p\left(\frac{(m+p)w}{c}\right)\right] - \frac{p}{m+p}\left[c_o + \frac{c}{2}\left(\frac{(m+p)w}{c}\right)^2\right].$$

Then, the condition $NB_n(p+m-1) \leq NB_s(p+m)$ reduces to the following: $\frac{w^2}{2c}\left[-2 + p(4-p) + m(2-p)\right] \geq \frac{p}{m+p}c_o$.

We now study the condition of **external stability**: $NB_n(p+m) \geq NB_s(p+m+1)$. We have $a_s(m+p) = \dfrac{(m+p)w}{c}$ and $a_n = 0$. We obtain:

$$NB_n(p+m) = w\left[p\left(\frac{(m+p)w}{c}\right)\right].$$

$$NB_s(p+m+1) = w\left[(p+1)\left(\frac{(m+p+1)w}{c}\right)\right] - \frac{p+1}{m+p+1}\left[c_o + \frac{c}{2}\left(\frac{(m+p+1)w}{c}\right)^2\right].$$

Then, the condition $NB_n(p+m) \geq NB_s(p+m+1)$ reduces to the following: $\frac{w^2}{2cc_o}(m(1-p)+p(2-p)+1) \leq \frac{p+1}{p+m+1}$.

Let us turn now to the core of the proof of Proposition 9.

1) The condition of **internal stability** is written in the following way in this case (the calculus for agreement U is similar if we put $m=0$ and $t=0$ in the calculus above): $(-p^2+4p-2) \geq \frac{2c_oc}{w^2}$. This inequality does not hold for $p=1$ because $w^2 < 2c_oc$. It holds for $p=2$ if $2 \geq \frac{2c_oc}{w^2}$. Neither it can hold for $p=3$ because $w < \sqrt{2c_oc}$, nor for $p>3$ because $\frac{2c_oc}{w^2} > 0$.

We should now prove that the condition of **external stability** (the calculus for agreement U is similar if we put $m=0$ and $t=0$ in the calculus above) holds for $p=2$. In the general case, this condition is written in the following way $(-p^2+2p+1) \leq \frac{2c_oc}{w^2}$, and the case $p=2$ satisfies this inequality.

2) The condition of **internal stability** is written in the following way (see above): $(m(2-p)+p(4-p)-2) \geq \frac{p}{m+p}\frac{2cc_o}{w^2}$.

The condition of **external stability** is (see above): $(m(1-p)+p(2-p)+1) \leq \frac{p+1}{m+p+1}\frac{2cc_o}{w^2}$.

For $p=1$, the first condition leads to $(m+1)^2 \geq \frac{2cc_o}{w^2}$, and the second condition implies $(m+2) \leq \frac{2cC_0}{w^2}$. Since the total number of countries is 2, the number of signatories which make a transfer is 1 ($m=1$). Consequently, the two conditions imply the following relationship $3 \leq \frac{2cc_o}{w^2} \leq 4$.

For $p>2$ and $m \geq 1$, we note that the condition of internal stability $(m(2-p)+p(4-p)-2)$ is lower than $(2-p)+p(4-p)-2 = -p^2+3p$. This final expression is a polynomial with an integer maximum attained for $p=1$ and $p=2$. These maxima imply the following value (2). This polynomial is inferior or equal to zero for $p \geq 3$. Consequently, the condition of internal stability does not hold for $p \geq 3$.

For $p=2$, the condition of internal stability is equal to $2 \geq \frac{2}{m+2}\frac{2cc_o}{w^2}$. This holds for a given value of m higher than a threshold level, if the total number of countries is sufficiently high. The condition of external stability is equal to $(1-m) \leq \frac{3}{m+3}\frac{2cc_o}{w^2}$, which always holds for $m \geq 1$.

Proof of Proposition 10

1) The individual payoff under agreement U (with a coalition size of $p=2$) is as follows: $NB_s^U(2) = \frac{2w^2}{c} - c_o$.

The individual payoff under agreement DT (with a coalition size of 2) is as follows: $NB_s^{DT}(2) = \frac{w^2}{c} - \frac{c_o}{2}$.

$NB_s^{DT}(2) > NB_s^U(2)$ if $w^2 < \frac{cc_o}{2}$, which is incompatible with the assumption $c_o \leq \frac{w^2}{c}$ needed to have a coalition size of 2 in agreement U. Therefore, $NB_s^U(2) > NB_s^{DT}(2)$.

2) The global payoff under agreement U (with a coalition size of $p=2$) is as follows:

$V^U(2) = (m+p)NB_s^U + (N-m-p)NB_n^U = 2\left[\frac{2w^2}{c} - c_o\right] = \frac{4w^2}{c} - 2c_o$, because there is no non-signatory for $N=2$.

The global payoff under agreement DT (with a coalition size of $m+p=2$) is as follows: $V^{DT}(2) = (m+p)NB_s^{DT} + (N-m-p)NB_n^{DT} = 2\left[\frac{w^2}{c} - \frac{c_o}{2}\right] = \frac{2w^2}{c} - c_o$.

$V^U(2) > V^{DT}(2)$ if $w > \sqrt{\frac{cc_o}{2}}$.

3) The individual abatements under agreements U and DT are as follows: $a_S^U(2) = a_S^{DT}(2) = \frac{2w}{c}$.

4) The global abatement under agreement U is as follows: $A^U = 2a_S^U(2) = \frac{4w}{c}$.

The global abatement under agreement DT is as follows: $A^{DT} = a_S^{DT}(2) = \frac{2w}{c}$.

We have $A^{DT} < A^U$.

Proof of Proposition 11

1) The individual payoff under agreement U (with a coalition size of $p=2$) is as follows: $NB_s^U(2) = \frac{2w^2}{c} - c_o$.

The individual payoff under agreement DT (with a coalition size of $2+m$) is as follows: $NB_s^{DT}(2+m) = \frac{w^2(m+2)}{c} - \frac{2c_o}{m+2}$.

It is easy to check that $NB_s^{DT}(2+m)$ is always higher than $NB_s^U(2)$.

2) The global payoff under agreement U (with a coalition size of $p=2$) is as follows: $V^U(2) = 2NB_s^U + (N-2)NB_n^U = 2\left[\frac{2w^2}{c} - c_o\right] + (N-2)\left[\frac{4w^2}{c}\right] = \frac{4w^2}{c}(N-1) - 2c_o$.

The global payoff under agreement DT (with a coalition size of $2+m$) is as follows: $V^{DT}(2+m) = (2+m)NB_s^{DT} + (N-m-2)NB_n^{DT} = (2+m)\left[\frac{w^2(m+2)}{c} - \frac{2c_o}{m+2}\right] + (N-m-2)\left[\frac{2w^2(m+2)}{c}\right]$

$= \frac{w^2}{c}\left[2N(m+2) - (m^2+4m+4)\right] - 2c_o$.

$V^{DT}(2+m) > V^U(2)$ if $N \geq 4$.

3) The individual abatement under agreement U is as follows: $a_S^U(2) = \frac{2w}{c}$.

The individual abatement under agreement DT is as follows: $a_S^{DT}(m+2) = \frac{(m+2)w}{c}$.

We have $a_S^{DT}(m+2) > a_S^U(2)$.

4) The global abatement under agreement U is as follows: $A^U = 2a_S^U(2) = \frac{4w}{c}$.

The global abatement under agreement DT is as follows: $A^{DT} = 2a_S^{DT}(m+2) = \frac{2(m+2)w}{c}$.

We have $A^{DT} > A^U$.

Table A1: Illustration of Cases 1 and 2 of Proposition 5

Case 1: $\alpha = \beta = \gamma = 1$	Case 2: $\alpha = 1$, $\beta = 0.1$, $\gamma = 1$
$c_{o1} = 0.013$; $c_{o2} = 0.25$	$c_{o1} = 0.31$; $c_{o2} = 0.45$
$c_{oU} = 0.4$; $c_{oDT} = 0.66$	$c_{oU} = 1.42$; $c_{oDT} = 1.66$
$\overline{c_o} = 0.13$; $\overline{\overline{c_o}} = 0.004$	$\overline{c_o} = 1.19$; $\overline{\overline{c_o}} = 0.38$
$NB^*_{1T1} = NB^*_{2T1} = 0.38 - c_o$	$NB^*_{1T1} = NB^*_{2T1} = 1.18 - c_o$
$NB^*_{1T2} = 0.25 - c_o$; $NB^*_{2T2} = 0.37$	$NB^*_{1T2} = 0.45 - c_o$; $NB^*_{2T2} = 0.86$
$NB^*_{1T3} = NB^*_{2T3} = 0$	$NB^*_{1T3} = NB^*_{2T3} = 0$
$NB^U_{T1} = NB^U_{T2} = NB^U_{T3} = 0.4 - c_o$	$NB^U_{T1} = NB^U_{T2} = NB^U_{T3} = 1.42 - c_o$
$NB^{DT}_{T1} = NB^{DT}_{T3} = 0.33 - (c_o/2)$	$NB^{DT}_{T1} = NB^{DT}_{T3} = 0.83 - (c_o/2)$
$NB^{DT}_{1T2} = 0.27 - c_o$; $NB^{DT}_{2T2} = 0.39$	$NB^{DT}_{1T2} = 0.62 - c_o$; $NB^{DT}_{2T2} = 1.04$
$t_{T1} = t_{T3} = 0.11 + (c_o/2)$; $t_{T2} = 0.04$	$t_{T1} = t_{T3} = 0.69 + (c_o/2)$; $t_{T2} = 0.48$

Note: The subscript Tj with $j = 1, 2, 3$ stands for Type 1, Type 2 and Type 3 Nash equilibrium.

Table A2: Illustration of Case 3 of Proposition 5

Case 3: $\alpha = 1$, $\beta = 0.1$, $\gamma = 2$
$c_{o1} = 0.19$; $c_{o2} = 0.23$;
$c_{oU} = 0.83$; $c_{oDT} = 0.90$
$\overline{c_o} = 0.75$; $\overline{\overline{c_o}} = 0.26$
$NB^*_{1T1} = NB^*_{2T1} = 0.66 - c_o$
$NB^*_{1T2} = 0.23 - c_o$; $NB^*_{2T2} = 0.46$
$NB^*_{1T3} = NB^*_{2T3} = 0$
$NB^U_{T1} = NB^U_{T2} = NB^U_{T3} = 0.83 - c_o$
$NB^{DT}_{T1} = NB^{DT}_{T3} = 0.45 - (c_o/2)$
$NB^{DT}_{1T2} = 0.34 - c_o$; $NB^{DT}_{2T2} = 0.56$
$t_{T1} = t_{T3} = 0.41 + (c_o/2)$; $t_{T2} = 0.29$

Note: The subscript Tj with $j = 1, 2, 3$ stands for Type 1, Type 2 and Type 3 Nash equilibrium.