Climate coalitions cannot avert the crisis only by moving first in choosing emission and abatement targets

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I. Introduction: a. motivation

- Global environmental problems, especially climate change, are toping the global political agenda

- Characteristics of international negotiations

- Free riding incentives: Countries have an incentive to forfeit their obligations to reduce their emissions so that they minimize their costs while enjoying the benefits of lower emissions by the other countries
  - When one country exits the coalition the rest adjust to a higher emission level

- Self-enforcing IEAs have to be designed
  - Internal stability constraints (No country that signs the agreement has incentives to free-ride ex-post)
  - External stability constraints (No country that hasn't joined the agreement has incentives to join in ex-post)

I. Introduction: b. literature review

- Modeling IEAs as a non-cooperative one-shot, two-stage game*:
  - 1st stage: participation choice (yes/no)
  - 2nd stage: choice of either emissions or abatement level

- Results:
  - Simultaneous game: De Cara & Rotillon (2001), Rubio & Casino (2001) and Finus & Rundshagen (2001): A stable coalition consists, at maximum, of 2 countries
  - Leadership game : Barrett (1994), Diamantoudi & Sartzetakis (2006). Based on simulations, Barrett suggests that a stable coalition could consists of a large number of countries, while D&S prove that the maximum number of countries is limited to four if emissions are constrained to be positive
  - Barrett (1994) pointed to the paradox of cooperation, which states that stable coalitions achieve very little especially when the potential benefits from cooperation are large. The literature has discussed this result extensively (more recent, McGinty, 2020 and Finus et al., 2021).

* Critical assumption: each country upon withdrawing from the agreement assumes that the agreement will remain intact (myopic behavior)

I. Introduction: c. contribution

- Fresh look and a synthesis of the literature on the formation of international environmental agreements,
  - using general functional forms and
  - introducing two choice variables: emissions and abatement

- Results:
  - Prove that larger coalitions are stable without violating the emissions positivity constraint
  - Verify the so-called "green paradox"
  - Provide clear intuition of the conditions under which each of the above results emerge, based on the effect that abatement costs and environmental damages have, independent from each other, on countries' welfare and thus their choices

- Notation
  - n identical countries $N=\{1, \ldots, n\}$
  - e_i : country i's emissions, $e_i>0$ and $E=\sum_{i\in N} e_i$
  - x_i: country i's abatement, $x_i \geq 0$ and $X=\sum_{i\in N} x_i$
  - $B_i(e_i)$: country i's benefits from emissions
  - $D_i(E\text{-}X)$: country i's damages from net emissions
  - $CA_i(x_i)$: country i's cost of abatement
  - $w(e_i,x_i)$: country i's welfare function

literature:

- $w_i = B(e_i) - D(E)$

or

- $w_i = B(X) - Cx_i$

- Country i's welfare is,

$$w_i = B_i(e_i) - D_i(E-X) - CA_i(x_i)$$

$B(0)=0,\ B'\geq 0$ and $B''<0$

$D(0)=0,\ D'(NE)>0,\ D''(NE)>0$

$C(0)=0,\ C'(x_i)>0,\ C''(x_i)>0$

- Second stage: signatories and nonsignatories choose *e* and *x* (the coalition is the leader)
- Nonsignatories' indirect welfare:

$$w_{ns}(e_s,x_s,s)=\max_{e_{ns},x_{ns}}[B(e_{ns})-D[sne_s+(n-s-1)ne_{ns}+ne_{ns}]-C(x_{ns})]$$

$$\frac{\partial NE}{\partial e_{ns}}=1,\ \frac{\partial NE}{\partial x_{ns}}=-1$$

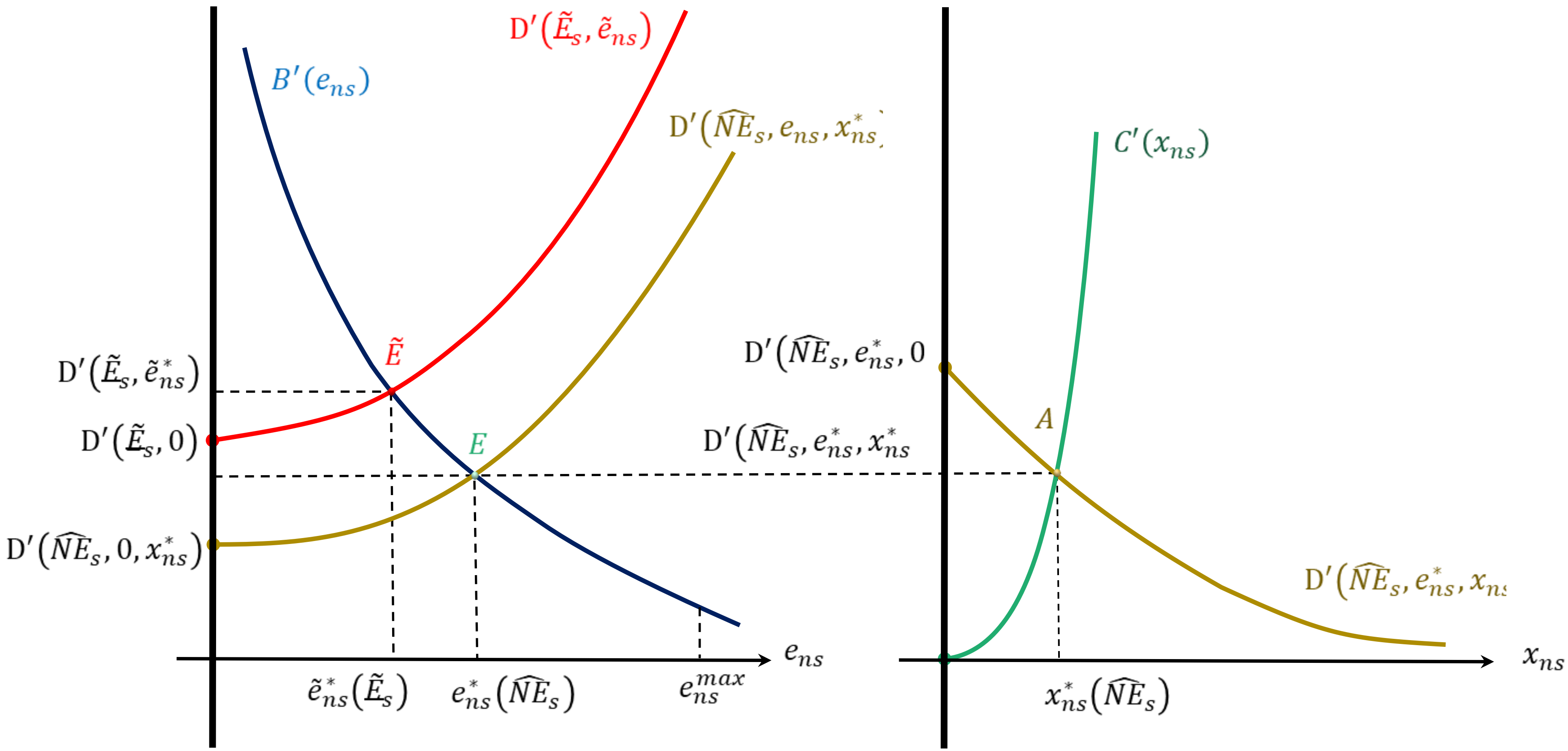
- First order conditions :

$$B'\left(e^*_{ns}(e_s,x_s,s,x_{ns})\right)=D'(NE) \qquad C'\left(x^*_{ns}(e_s,x_s,s,e_{ns})\right)=D'(NE)$$

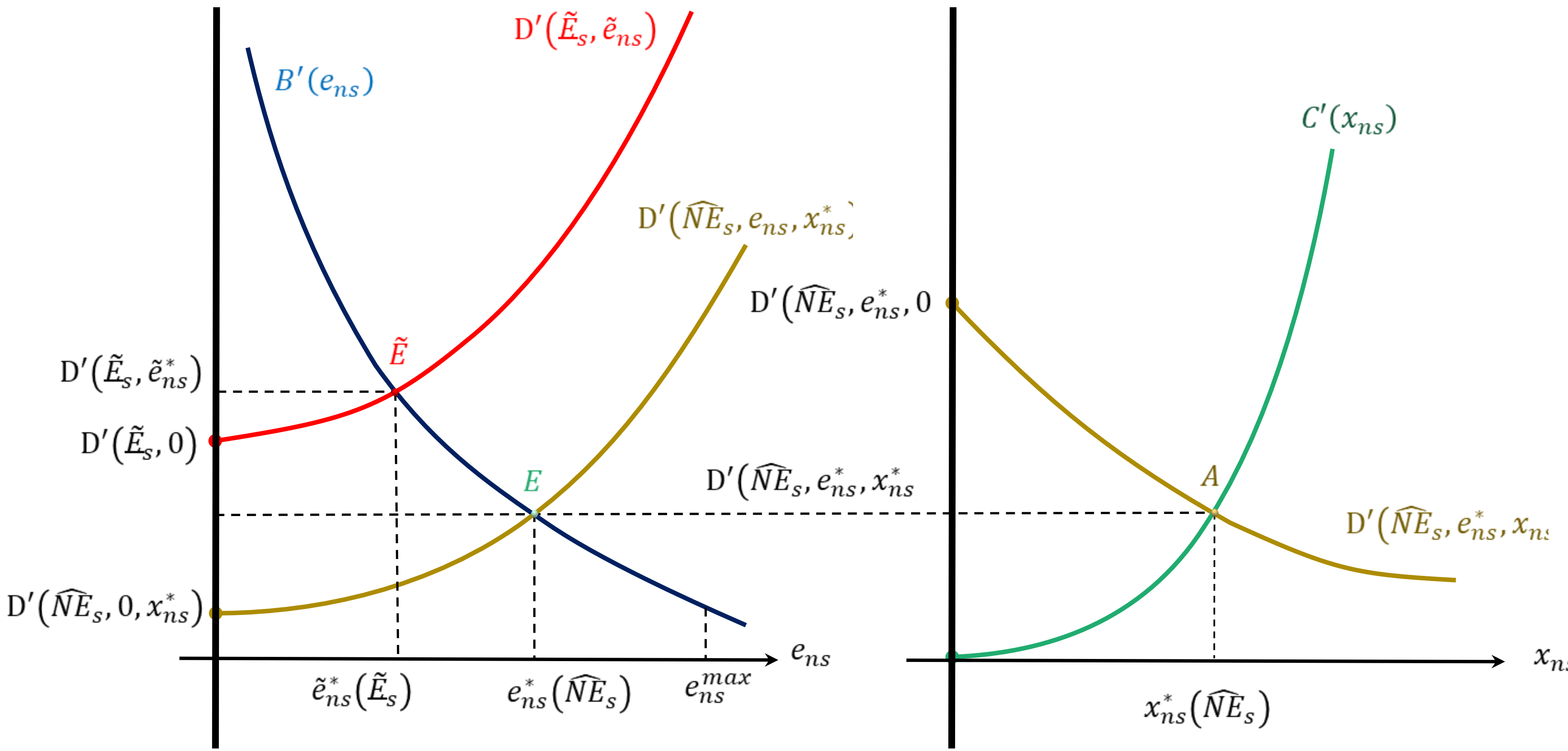
- Solving yields the best reaction functions,

$$\mathrm{Re}=e^*_{ns}(e_s,x_s,s),\ Rx=x^*_{ns}(e_s,x_s,s)$$

- Illustration of nonsignatories' first order conditions:



- Effect of adecrease in abatement cost:



The upper bound of nonsignatories' net emissions is the level of their emissions if abatement is not a choice, that is, $\varepsilon^*_{ns}(\widehat{NE}_s) \le \tilde{e}^*_{ns}(\tilde{E}_s) \le e^*_{ns}(\widehat{NE}_s)$, with equality when x^*_{ns}=0.

III. General functional forms: 2^{nd} stage

- Nonsignatories best reaction functions,

$$\mathrm{Re}=e^*_{ns}(e_s,x_s,s),\ Rx=x^*_{ns}(e_s,x_s,s)$$

- With slopes,

$$\mathrm{Re}'=\frac{\partial e^*_{ns}(e_s,x_s,s)}{\partial NE_s}=\frac{-1}{(n-s)(1-\psi)-\phi},$$

$$Rx'=\frac{\partial x^*_{ns}(e_s,x_s,s)}{\partial NE_s}=\frac{-\psi}{(n-s)(1-\psi)-\phi}$$

$$RNe'=\frac{-(1-\psi)}{(n-s)(1-\psi)-\phi}$$

$$\phi=\frac{B''\left(e^*_{ns}(E_s,X_s)\right)}{D''(NE)}<0,$$

$$\psi=\frac{B''\left(e^*_{ns}(E_s,X_s)\right)}{C''\left(x^*_{ns}(E_s,X_s)\right)}<0$$

Increasing damages or decreasing abatement costs make the reaction more responsive:

$$\frac{\partial RNe'}{\partial \phi}>0,\ \frac{\partial RNe'}{\partial \psi}<0$$

III. General functional forms: 2^{nd} stage

- Signatories' indirect welfare:

$$w_s(s)=\max_{e_s,x_s}[sB(e_s)-sD[sne_s+(n-s)ne^*_{ns}]-C(x_s)]$$

- First order conditions:

$$B'\left(e_s^*(x_s,s)\right)=D'(NE)\frac{\partial NE}{\partial e_s} \qquad C'\left(x_s^*(e_s,s)\right)=D'(NE)\frac{\partial NE}{\partial x_s}$$

where:

$$\frac{\partial NE^*}{\partial e_s}=s+(n-s)\left(\frac{\partial e^*_{ns}(e_s,x_s)}{\partial e_s}-\frac{\partial x^*_{ns}(e_s,x_s)}{\partial e_s}\right),$$

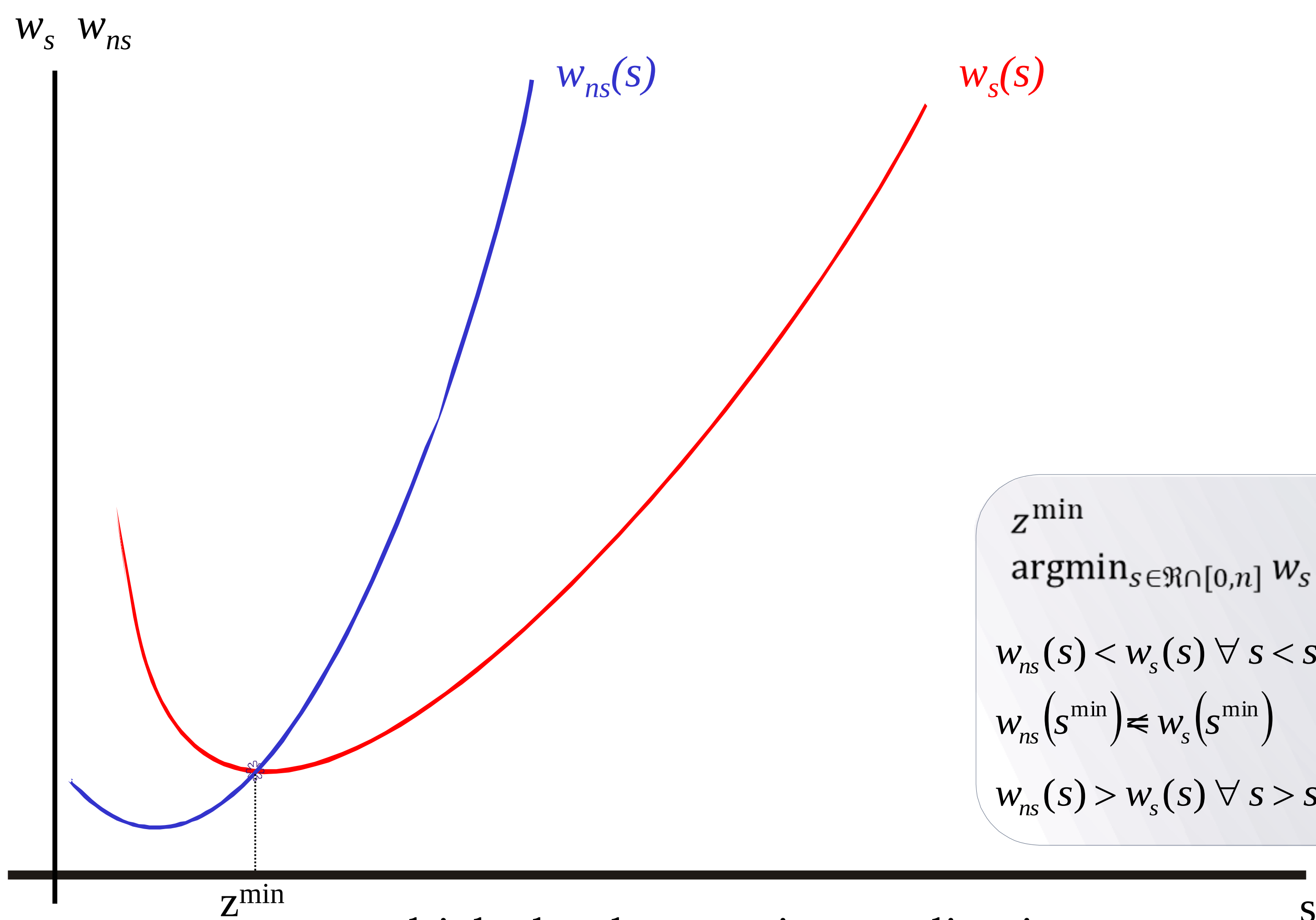
$$\frac{\partial NE^*}{\partial x_s}=-s+(n-s)\left(\frac{\partial e^*_{ns}(e_s,x_s)}{\partial x_s}-\frac{\partial x^*_{ns}(e_s,x_s)}{\partial x_s}\right)$$

Non-signatories:

$$\frac{\partial NE}{\partial e_{ns}}=1,\ \frac{\partial NE}{\partial x_{ns}}=-1$$

Only the derivatives of NE to the choice variables differentiate the choices of signatories and non signatories.
Two counterbalancing forces drive signatories' choices:
(i) damage internalization (of all members, i.e. increasing in s), and
(ii) first mover advantage (decreasing in s, as number of followers decreases).

Coalition Formation: Illustration of indirect welfare functions



$z^{\min}$
argmin$_{s \in \Re \cap [0,n]} w_s$

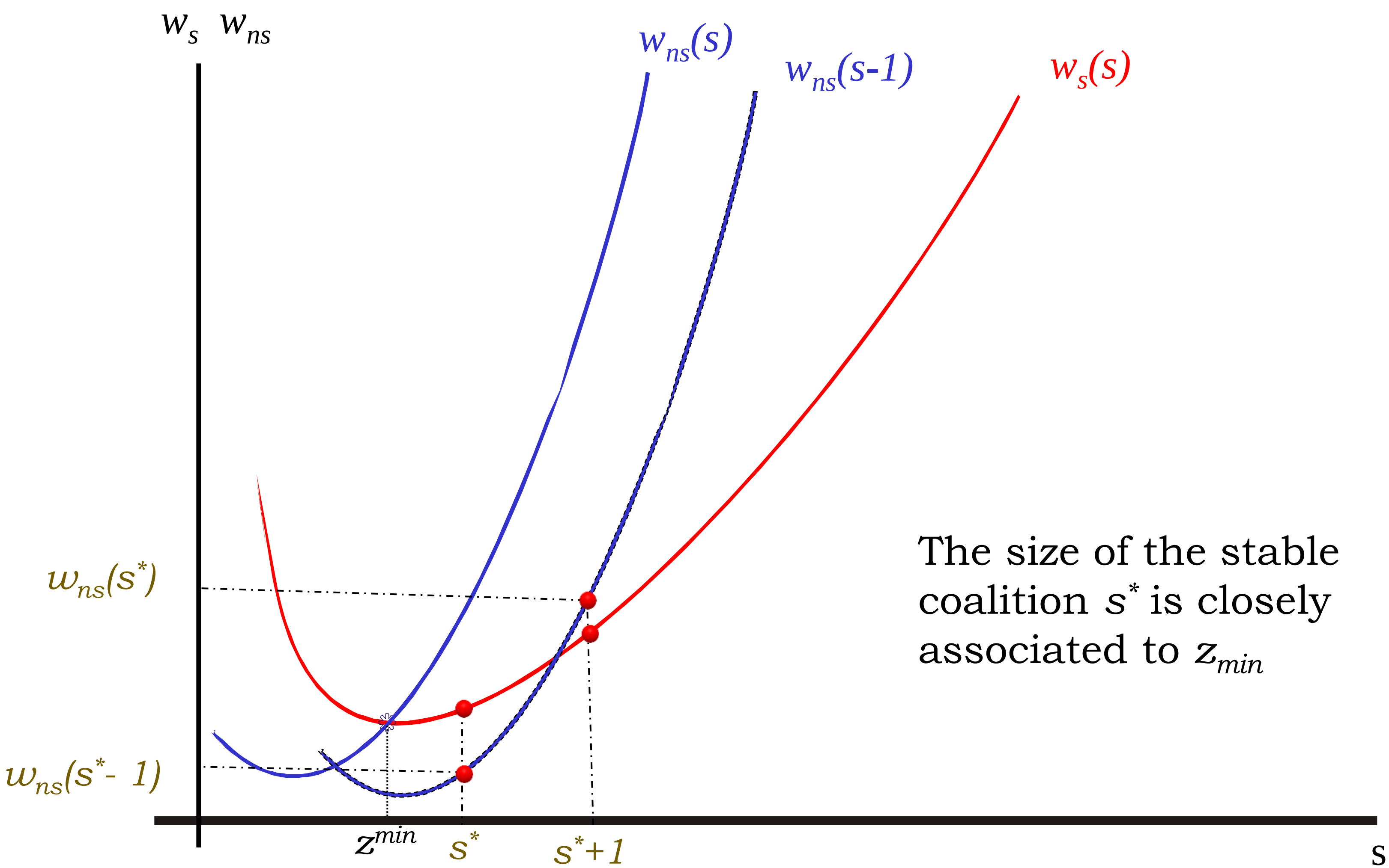
$w_{ns}(s) < w_s(s) \; \forall \; s < s^{\min}$

$w_{ns}\left(s^{\min}\right) \leqq w_s\left(s^{\min}\right)$

$w_{ns}(s) > w_s(s) \; \forall \; s > s^{\min}$

↖ at which the damage internalization equals the leadership effect

Coalition Formation: Illustration of stable size coalition



The size of the stable coalition s^* is closely associated to z_{min}

- Comparing the equilibrium choices and the indirect welfare of signatories and nonsignatories we get:

Proposition 1. Consider the indirect welfare functions of signatory and nonsignatory countries, $w_s(s)$ and $w_{ns}(e^*_s(s),x^*_s(s),s)$ respectively. Let

$$z^{min} = \frac{n\left(1-\psi\left(z^{min}\right)\right)-\phi\left(z^{min}\right)}{1-\left(z^{min}\right)-\left(z^{min}\right)}$$

then,

1. $e_s^*(s) \gtreqless e_{ns}^*(s) \Leftrightarrow s \lesseqgtr z^{\min}$ and $x_s^*(s) \lesseqgtr x_{ns}^*(s) \Leftrightarrow s \lesseqgtr z^{\min}$,
2. if $s=z^{\min}$ then $e_s^*(s)=e_{ns}^*(s)=e_{nc}$ and $x_s^*(s)=x_{ns}^*(s)=x_{nc}$,
3. $w_s(s)$ increases (decreases) in s if $s>z^{min}$ ($s<z^{min}$),
4. $z^{\min}=\arg\min_{s\in\Re\cap[0,n]} w_s(s)$,
5. $w_s(s) \gtreqless w_{ns}\left(e_s^*(s),x_s^*(s),s\right) \Leftrightarrow s \lesseqgtr z^{\min}$.

Effect of a marginal increase (decrease) in one of the signatories' emissions (abatement):
(1) increases marginal damages to all other coalition members thus has aa effect $(s\text{-}1)$;
(2) nonsignatories respond by decreasing their net emissions on aggregate by $\dfrac{s(n-s)(1-\psi)}{(n-s)(1-\psi)-\phi}$

Setting these two effects equal yields z^{min}.
As D'' increases or C'' decreases relative to B'', the higher z^{min} gets.

III. General functional forms: main contribution

- Keeping the benefit function (i.e. preferences) unchanged, we show that
  - (i) when the abatement cost function is increasing at a slower pace large coalition, including the grand, are possible, and
  - (ii) when the environmental damage function is increasing at a higher pace, slightly larger coalitions are possible and countries' net emission choices are forced at the corner.

- Significantly large coalitions only when abatement becomes really inexpensive.
- In such cases it is also individually rational to increase abatement and attain the same welfare.
- Coalition formation adds very little welfare improvements, which is not very paradoxical when the choice variables are untwined.

- Policy recommendation:
  - To avoid deepening the environmental crisis, additional actions are required, such as technology transfers, linkages with trade and other agreements, among others, as the literature has already suggested

IV. Example with quadratic functions

Notation

$$w_i = b\left[ae_i - \frac{e_i^2}{2}\right] - \frac{c}{2}NE^2 - \frac{1}{2}dx_i^2$$

$$NE = \sum_{i\in N} e_i = (n-s)(e_{ns} - x_{ns}) + s(e_s - x_s)$$

- n-s non signatory countries ($\max\limits_{e_i, x_i} w_{ns}$)

  Nonsignatories' reaction functions, $e_{ns}(e_s,x_s)$ and $x_{ns}(e_s,x_s)$ combined into $Ne_{ns}(e_s,x_s)$,

$$RNe_{nc} = \frac{\delta a - (1+\gamma\delta)NE_s}{\delta + (1+\gamma\delta)(n-s)}$$

- Then, signatories maximize the coalition's welfare, sW_s, taking explicitly into account nonsignatories' behavior,

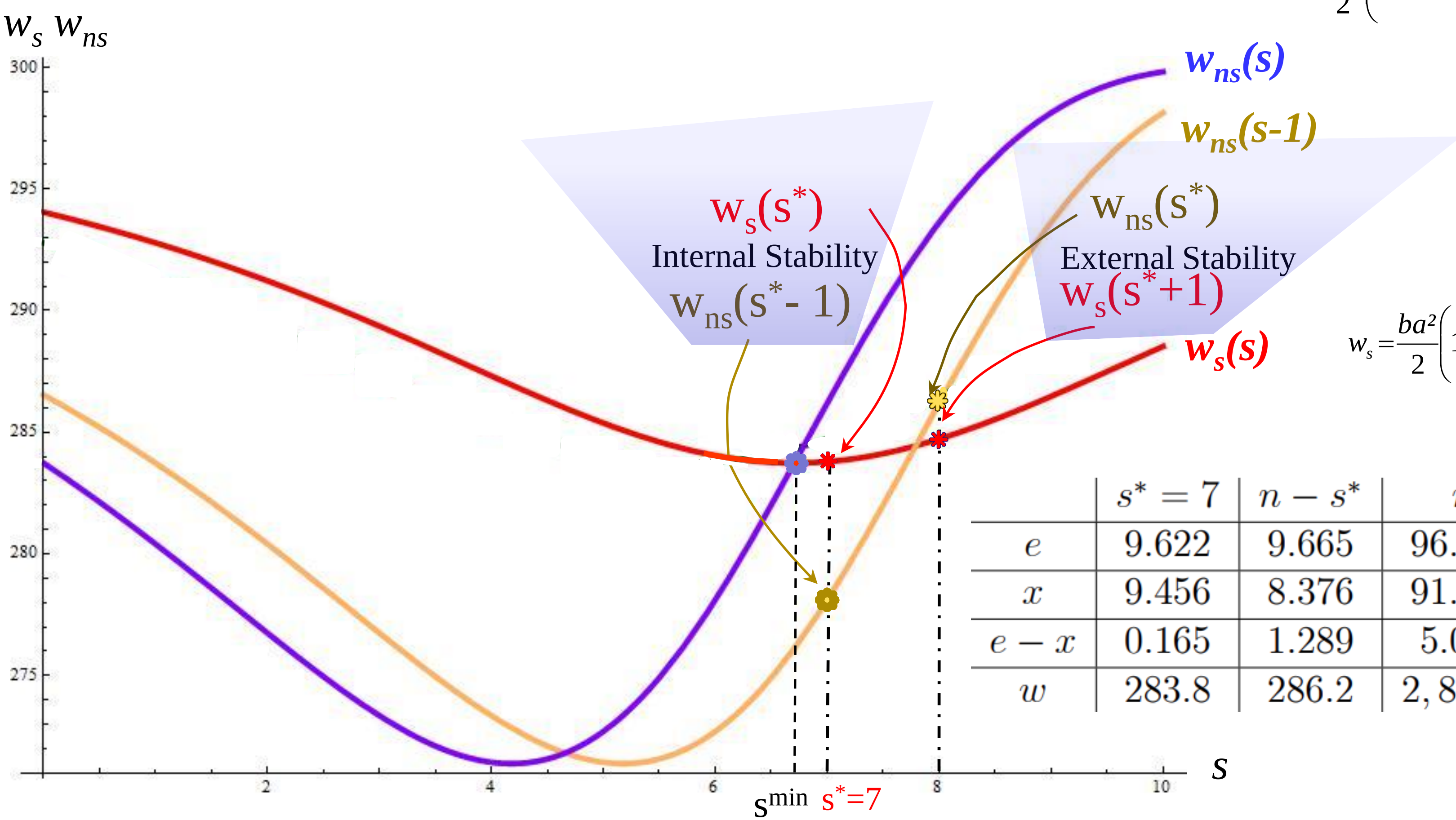
$$\max_{e_s, x_s} \sum_{i=1}^{s} w_i \Rightarrow s\left[B_s(e_s) - D_s(NE) - CS_s(x_s)\right]$$

Numerical simulations

Using the same parameter values used in D&S(2015), which find *s*=3 [n=10, a=10, b=6, c=0.399, γ=0.066 and ?=0.6 (c=0.39999 and d = 0.239994)] we find s*=7*. The option of abatement allows larger coalitions without driving emissions (production) to negative levels.

But welfare is very low despite the fact that coalition is larger

$$w_{ns} = \frac{ba^2}{2}\left(w_s - \frac{\gamma\delta n^2\left(\delta^2 s^2 - \Omega^2\right)\left(1+\delta\gamma\right)}{\Psi^2} \right)$$



$$w_s = \frac{ba^2}{2}\left(1 - \frac{\gamma\delta^2 n^2}{\Psi}\right)$$

	$s^* = 7$	$n - s^*$	n
e	9.622	9.665	96.347
x	9.456	8.376	91.322
$e - x$	0.165	1.289	5.025
w	283.8	286.2	2,845.2

Simulations with different values of ⍰

where $\gamma = \frac{c}{b}$, $\delta = \frac{d}{c}$

	$\delta = 1.637$			$\delta = 1 * 10^{-7}$		
	$s^* = 5$	$n - s^*$	n	$s^* = 10$	$n - s^*$	n
e	9.079	9.192	91.354	10	–	100
x	8.439	7.406	79.229	10	–	100
$e - x$	0.639	1.785	12.124	$1 * 10^{-8}$	–	$1 * 10^{-7}$
w	244.7	250.7	2,476.0	300.0	–	3,000.0

In order to show the effect of changes in the abatement cost which change the ratio δ, we simulate the model for two extreme values of δ: δ=*0.0000001* and δ=*1.637*. The first case indicates that abatement cost is negligible relative to environmental damages, while in the second we assume that abatement costs exceed environmental damages.

When abatement cost is high, results in s^*=5 and when it is low (almost zero) we get the grand coalition, s^*=10.

V. Epilogue

- Conclusions
  - Modelling the choice of emissions and abatement separately
    - is more realistic
    - allows us to disentangle the role of benefits, damages and abatement cost in defining the size of the stable coalition, which in turn explains the not-so-paradoxical nature of the paradox of cooperation.
  - Paradox of cooperation: small coalitions when damages are low and abatement very expensive relative to benefits. Large coalitions if abatement cost is low: very low free-riding incentives, that is, participation to the coalition is effortless since choices of members and free-riders differ very little
  - The results are the same if countries choose either emissions or abatement at a separate stage and then the coalition is formed over net emissions at a later stage, as long as there are no strategic interactions between these two stages.

    Thus, our approach unifies and compares all different types of potential formulation of the coalition formation.

Thank you for your attention

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