Multiple International Environmental Agreements

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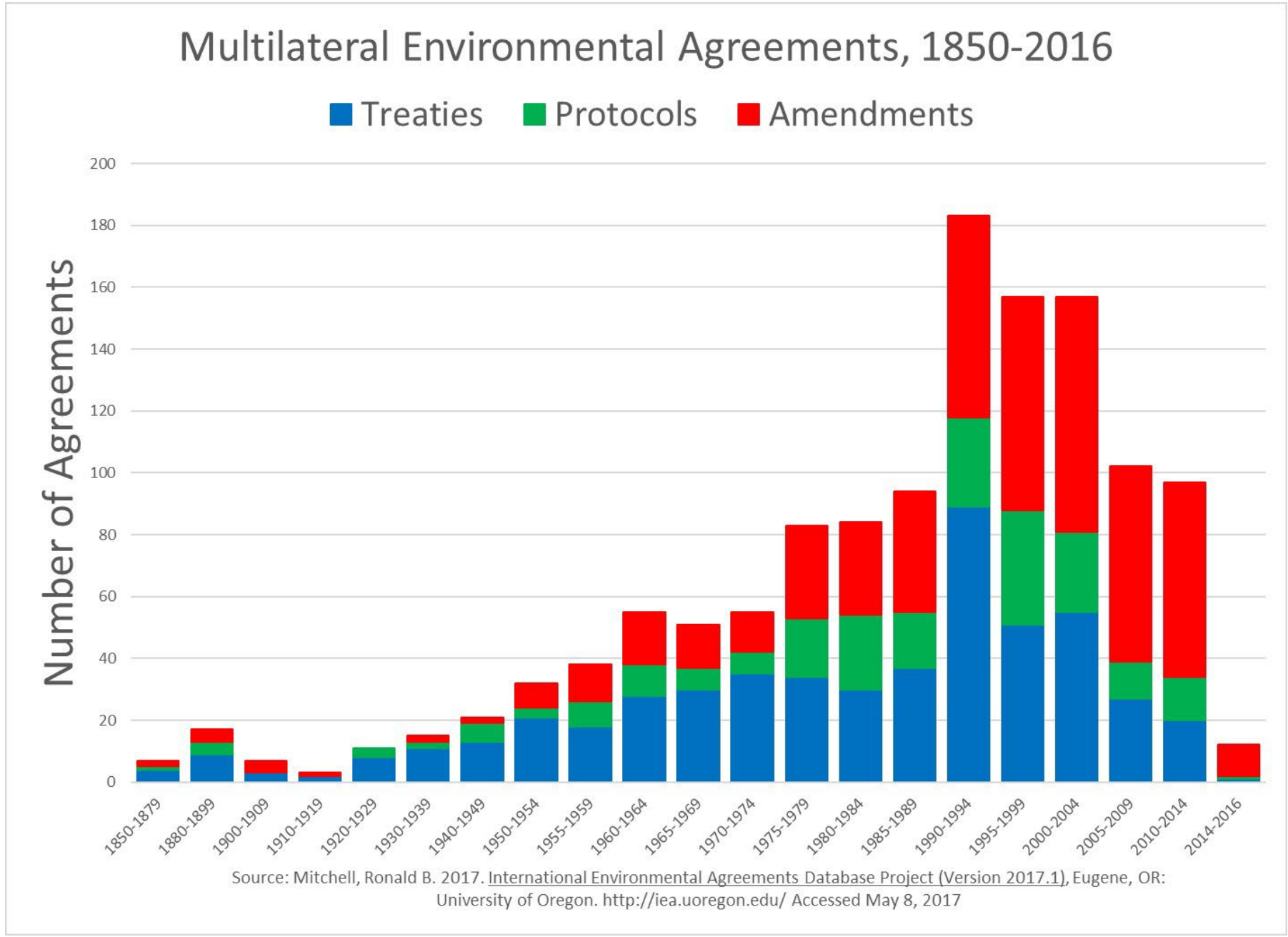
Environmental Issues

- Climate change, air pollution, deterioration of the ozone layer, ocean pollution etc.
- Transboundary or global in nature
- Mainly due to human activity and by extension GHG emissions
- Create negative externalities within each country and across countries

International Environmental Agreements

- Montreal Protocol (1987), Kyoto Protocol (1997), the Paris Agreement (2015).
- The basic problem inherent in IEAs is that each individual country has strong incentives to free ride on the cooperation of the rest.
- In general, a large coalition of signatory countries is hardly stable, and the free-rider incentive is strong.

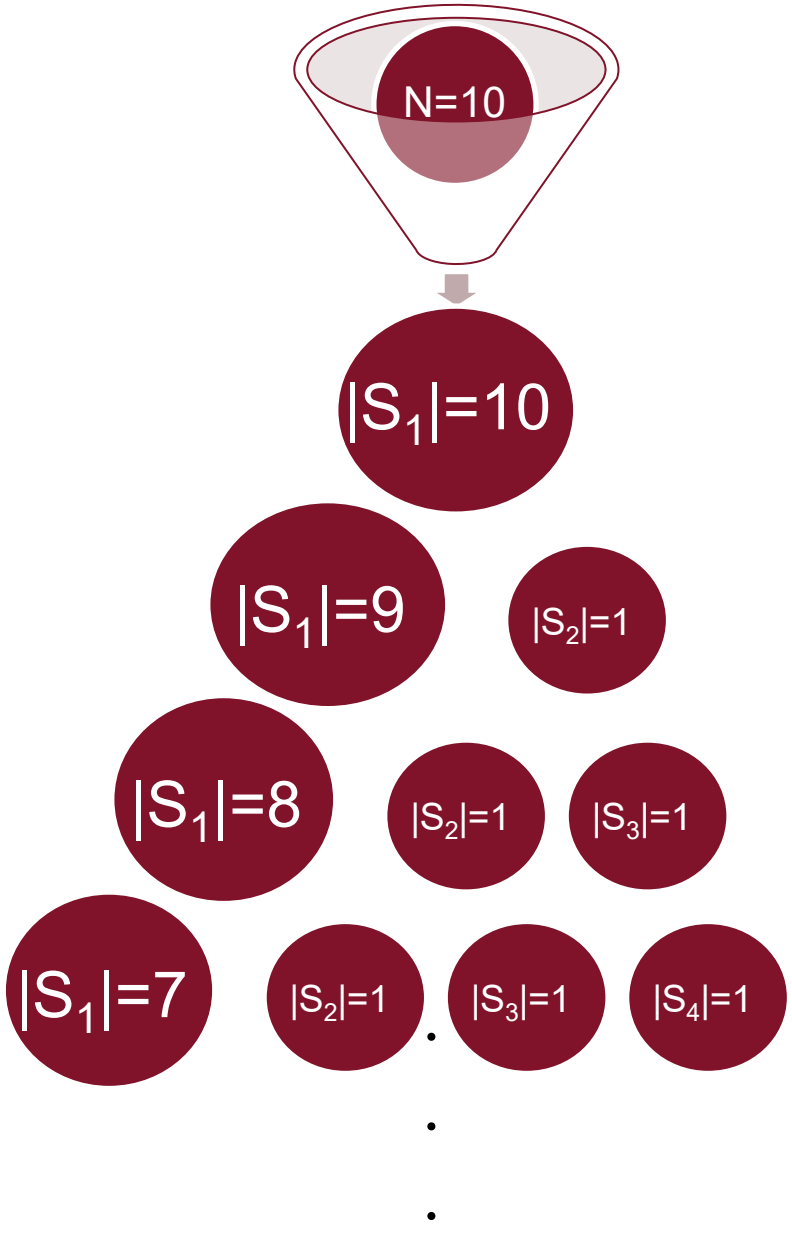

Multilateral Environmental Agreements, 1850-2016
Treaties
Protocols
Amendments
Number of Agreements
200
180
160
140
120
100
80
60
40
20
0
1850-1879
1880-1899
1900-1909
1910-1919
1920-1929
1930-1939
1940-1949
1950-1954
1955-1959
1960-1964
1965-1969
1970-1974
1975-1979
1980-1984
1985-1989
1990-1994
1995-1999
2000-2004
2005-2009
2010-2014
2014-2016
Source: Mitchell, Ronald B. 2017. International Environmental Agreements Database Project (Version 2017.1), Eugene, OR: University of Oregon. http://iea.uoregon.edu/ Accessed May 8, 2017

Literature - Barrett (1994)

- "*Self-enforcing International Environmental Agreements*" Barrett (1994) introduces the basic model with symmetric countries.
- Global Net Benefits: $\Pi = \sum_i \pi_i = B_i(Q) - C_i(q_i)$
- Country *i*'s Benefit from Abat.: $B_i(Q) = b(aQ - \frac{Q^2}{2})N$

  where $Q = \sum_i q_i$ denotes global abatement
- Country *i*'s Abatement Cost: $C_i(q_i) = \frac{1}{2}cq_i^2$
- Finding: A single coalition form and it can be of any size while emissions become negative.

Single Agreement



Literature – cont.

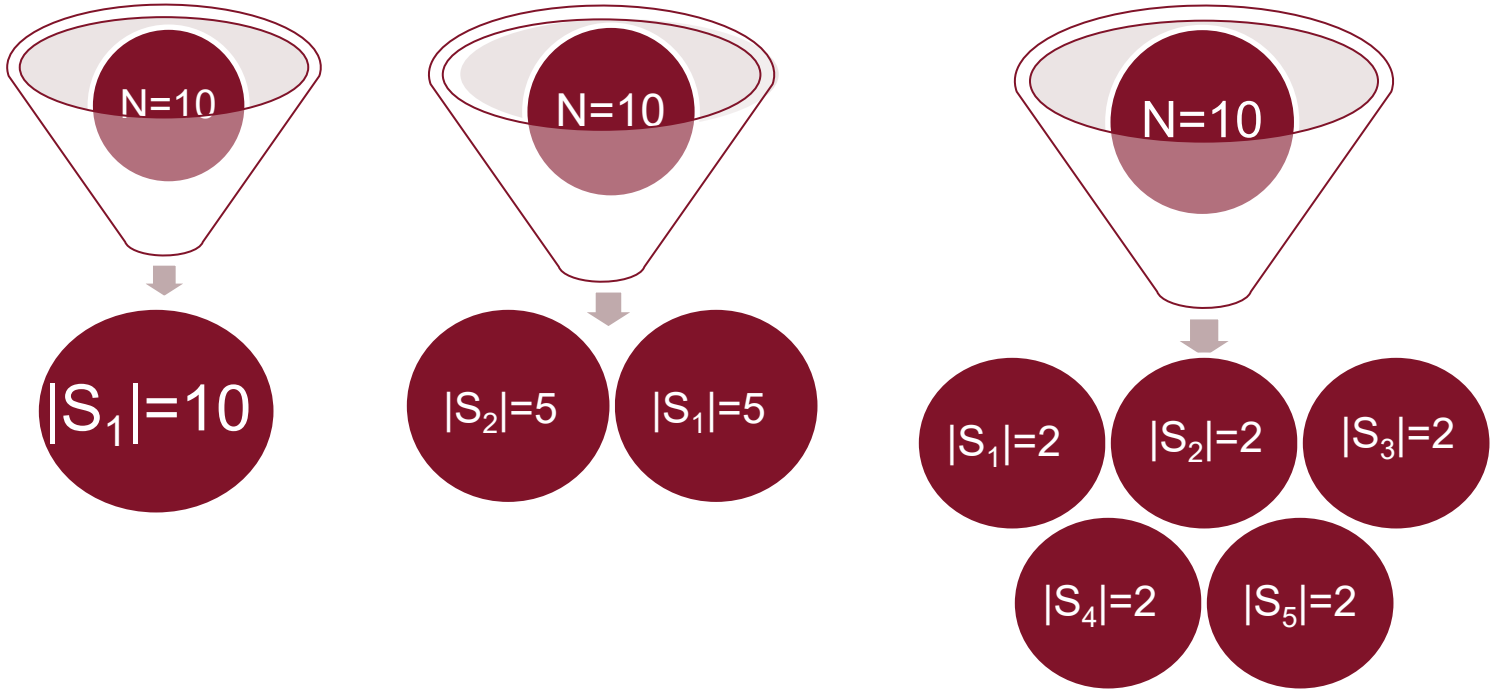
A large literature emerged on many different directions:

- Different functional forms (or general)
- Dynamic coalition formation processes (either through repetition or sequential actions)
- Different solution concepts (foresight etc)
- Heterogeneity
- Issue Linkage
- Vast majority assumed a *single* Agreement

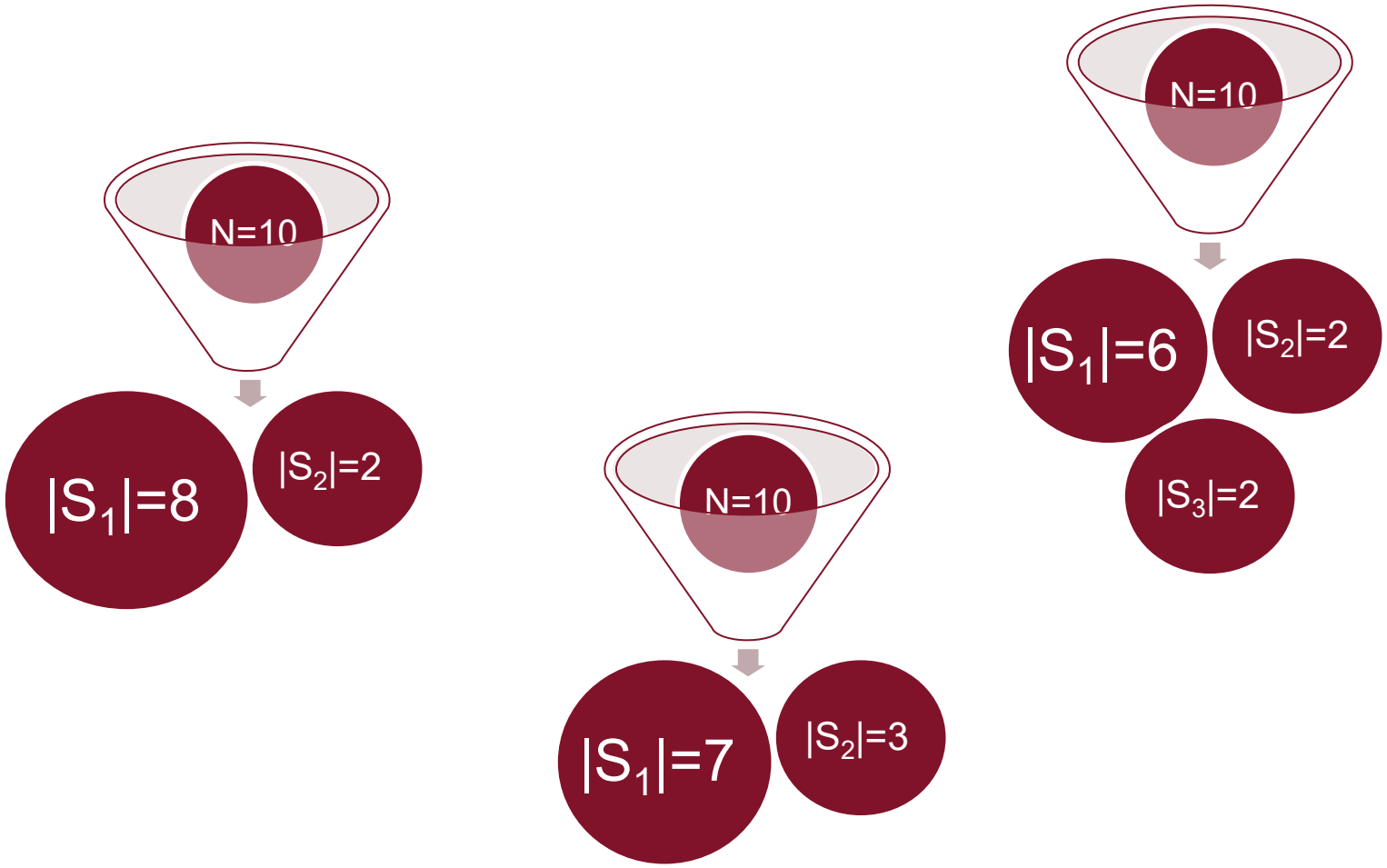
Multiple International Environmental Agreements

- North American Agreement on Environmental Cooperation (NAAEC, 1994)
- European Union Multilateral Environmental Agreements between its Member States and non-EU Member countries such the Seventh Environment Action Programme (7th EAP, 2014)
- Asia-Pacific Partnership on Clean Development and Climate (APP, 2005)

Symmetric Multiple Agreements



Asymmetric Multiple Agreements



Literature - Theoretical

- Ray and Vohra "*Equilibrium Binding Agreements*" (1997) analyze EBA in a general context where the payoff to each player depends on the actions of all other players. It concludes that every binding agreement is inefficient.
- Diamantoudi and Xue "*Coalitions, agreements and efficiency*" (2007) allows for arbitrary coalitional deviations to study conditions for efficient equilibrium binding agreements. The negative results even in the presence of transfers strengthen Ray and Vohra's outcome.

Literature – most relevant

- Finus and Rundshagen 2006
  - Multiple Agreements
  - Linear Damage Function (Dominant Strategies)
  - Strong Nash Equilibrium

Primitive Model
from Diamantoudi & Sartzetakis (2006)

- N identical countries $N = \{1, ...n\}$
- Each country generates emissions: $e_i \geq 0$
- i's Benefit Function: $B_i(e_i) = b\left(ae_i - \frac{1}{2}e_i^2\right)$
- i's Damage Function: $D_i(E) = \frac{1}{2}cE^2 = \frac{1}{2}c\left(\sum_{i=1}^{n} e_i\right)^2$
- i's Welfare Function: $W_i\left(e_i\right) = B_i(e_i) - D_i\left(E\right)$
- Where $E = \sum_{i \in N} e_i$

Coalition Formation

- A set of countries S_j signs some agreement $j \in M$ where

  $M=\{1,...,m\}$, $m \leq |N|$ and $S_j \subset N$, $S_j \cap S_k = \varnothing$ for all $j,k \in M$.

  Let $s_j = |S_j|$ and $\boldsymbol{S} = \cup S_j$.

- Set of countries of $N \backslash \boldsymbol{S}$ does not sign any agreement.

- Each member of a coalition S_j emits: e_{s_j}

- Each non-signatory country emits: e_{ns}

- Aggregate emission: $E = \sum_{i=1}^{n} e_i = \sum_{j=1}^{m} s_j e_{s_j} + \left(n - \sum_{j=1}^{m} s_j\right) e_{ns}$

Maximization

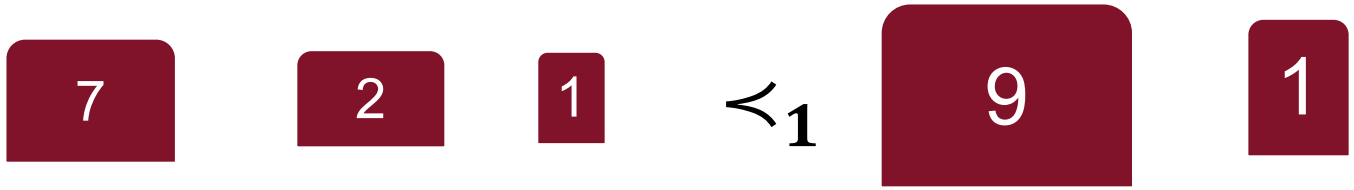
- Countries behave as follows:

- $$\max_{e_{s_j}} s_j \left[\begin{array}{c} \left(bae_{s_j} - \frac{1}{2} be_{s_j}{}^2 \right) - \\ \left(\frac{1}{2} c \left(\sum_{k=1}^{m} \left(s_k e_{s_k} \right) + (n - \sum_{k=1}^{m} s_k) e_{ns} \right)^2 \right) \end{array} \right]$$

Main Findings - Welfare

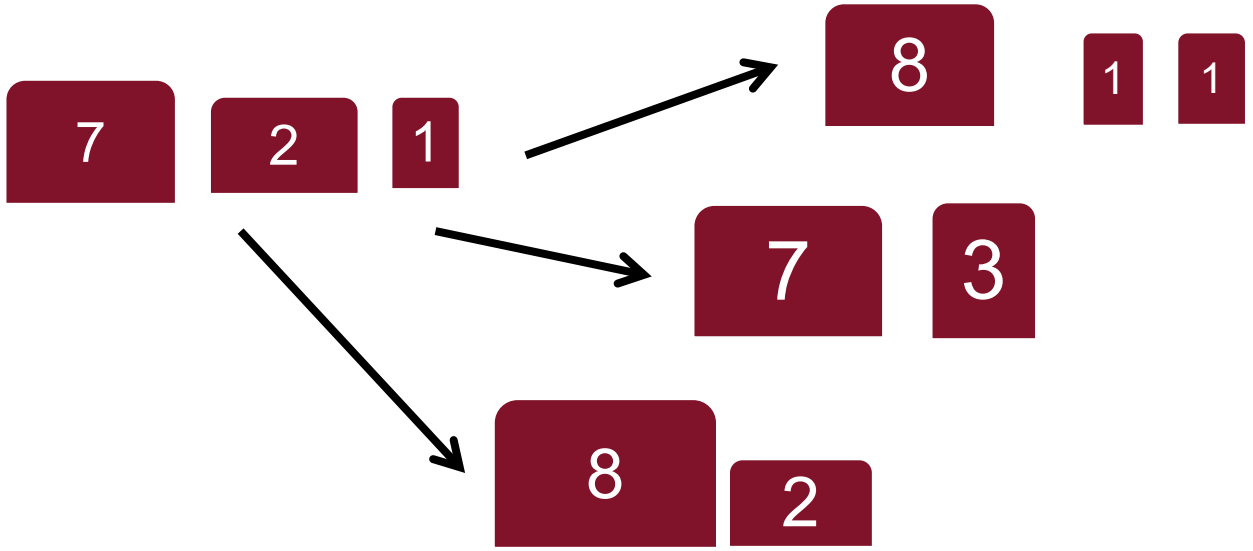
- Within a given coalition structure, the welfare of a member of a coalition is higher, the smaller the size of the coalition it belongs to.

- The welfare of a member of a coalition is higher when the number of coalitions in a given coalition structure decreases.



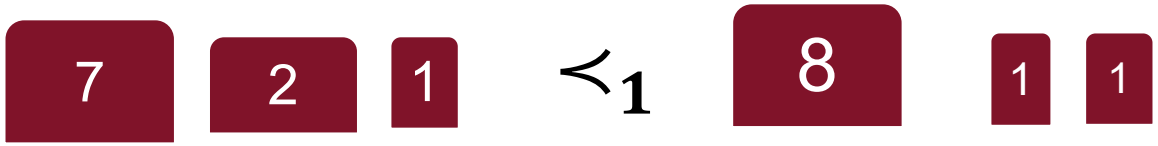
Main Findings - Welfare

- **DEF** (Yi 1997) A coalition structure P is more concentrated than a coalition structure $\hat{P}$ if P can be derived from $\hat{P}$ by a single move or a sequence of moves where one member at a time is moved from one coalition in $\hat{P}$ to another equal or larger coalition in $\hat{P}$.



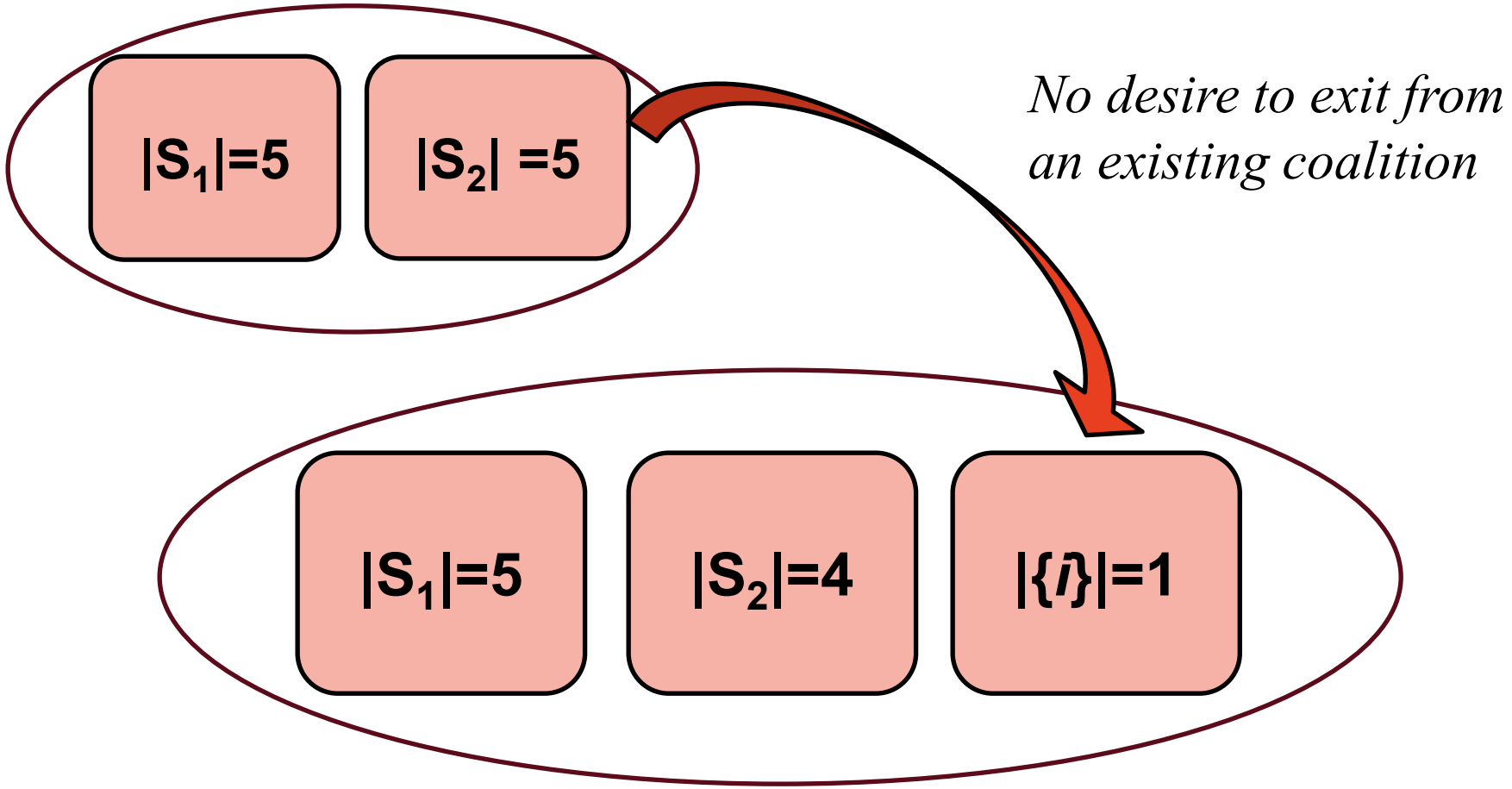
Main Findings - Welfare

- The welfare of a member of a coalition is higher when the coalition belongs in a more concentrated coalition structure.

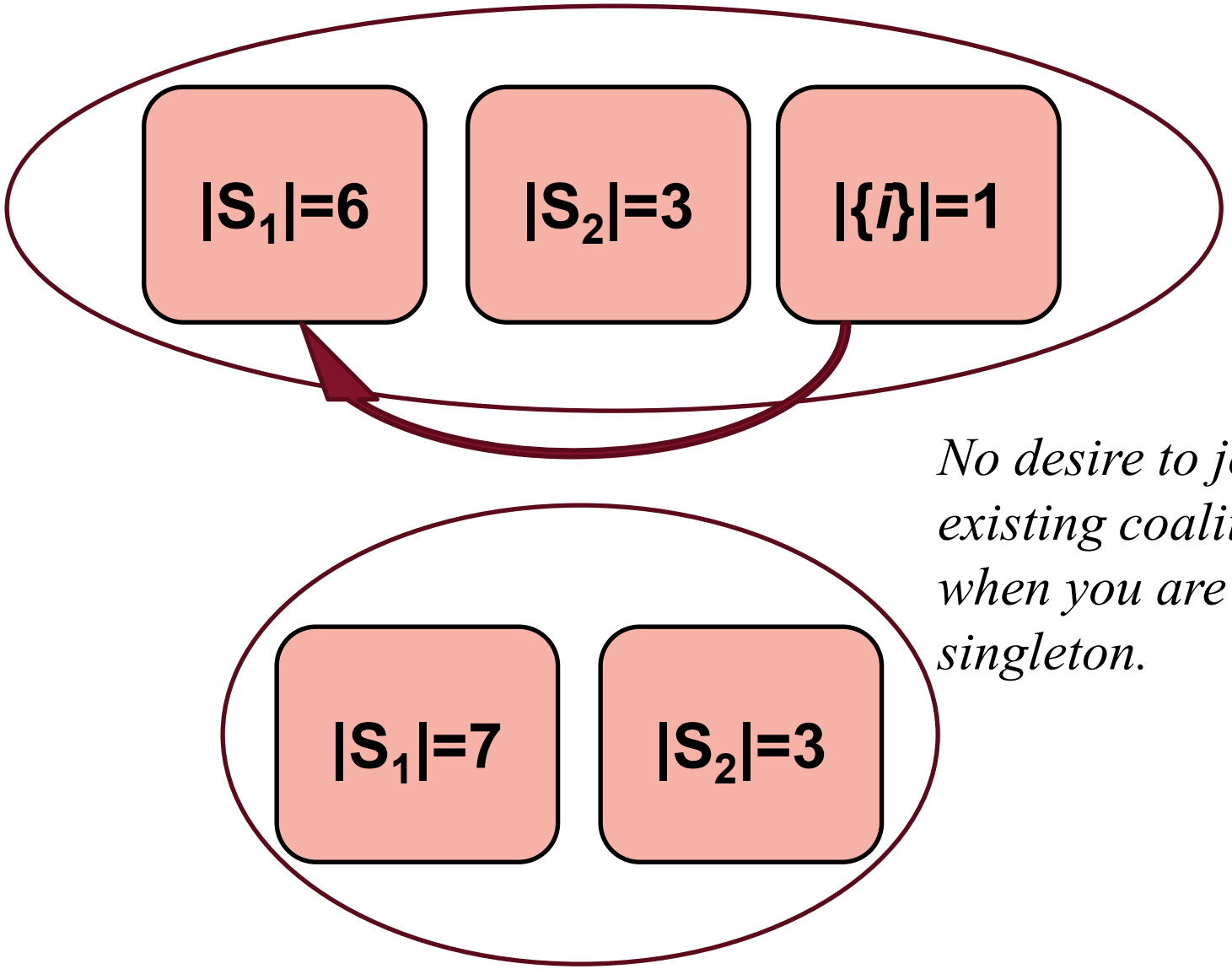


- A more concentrated coalition structure has higher total welfare than a less concentrated one.

Coalitional Stability – Internal Stability



Coalitional Stability – External Stability



No desire to join an existing coalition when you are a singleton.

Numerical Example

$P_1=\{10\}$ ω=(164)	$P_2=\{9,1\}$ ω=(152,211)	$P_3=\{8,2\}$ ω=(144,195)
$P_4=\{8,1,1\}$ ω=(140,195,195)	$P_5=\{7,3\}$ ω=(140,178)	$P_6=\{7,2,1\}$ ω=(133,177,180)
$P_7=\{7,1,1,1\}$ ω=(129,177,177,177)	$P_8=\{6,4\}$ ω=(142,162)	$P_9=\{6,3,1\}$ ω=(130,160,168)
$P_{10}=\{6,2,2\}$ ω=(126,162,162)	$P_{11}=\{6,2,1,1\}$ ω=(122,158,162,162)	$P_{12}=\{6,1,1,1,1\}$ ω=(117,158,158,158,158)
$P_{13}=\{5,5\}$ ω=(149,149)	$P_{14}=\{5,4,1\}$ ω=(134,145,162)	$P_{15}=\{5,3,2\}$ ω=(126,145,151)
$P_{16}=\{5,3,1,1\}$ ω=(121,141,151,151)	$P_{17}=\{5,2,2,1\}$ ω=(117,143,143,147)	$P_{18}=\{5,2,1,1,1\}$ ω=(112,139,143,143,143)
$P_{19}=\{5,1,1,1,1,1\}$ ω=(107,139,139,139,139,139)	$P_{20}=\{4,4,2\}$ ω=(132,132,147)	$P_{21}=\{4,4,1,1\}$ ω=(128,128,147,147)
$P_{22}=\{4,3,3\}$ ω=(128,137,137)	$P_{23}=\{4,3,1,1,1\}$ ω=(114,123,134,134,134)	$P_{24}=\{4,2,2,2\}$ ω=(114,130,130,130)
$P_{25}=\{4,2,3,1\}$ ω=(119,135,128,139)	$P_{26}=\{4,2,2,1,1\}$ ω=(109,125,125,130,130)	$P_{27}=\{4,2,1,1,1,1\}$ ω=(103,121,125,125,125,125)
$P_{28}=\{4,1,1,1,1,1,1\}$ ω=(98,120,120,120,120,120,120)	$P_{29}=\{3,3,3,1\}$ ω=(123,123,123,134)	$P_{30}=\{3,3,2,1,1\}$ ω=(113,113,121,125,125)
$P_{31}=\{3,3,2,2\}$ ω=(118,118,125,125)	$P_{32}=\{3,3,1,1,1,1\}$ ω=(108,108,120,120,120,120)	$P_{33}=\{3,2,2,2,1\}$ ω=(108,116,116,116,120)
$P_{34}=\{3,2,2,1,1,1\}$ ω=(103,110,110,115,115,115)	$P_{35}=\{3,2,1,1,1,1,1\}$ ω=(97,105,109,109,109,109,109)	$P_{36}=\{3,1,1,1,1,1,1,1\}$ ω=(91,104,104,104,104,104,104,104)
$P_{37}=\{2,2,2,2,2\}$ ω=(110,110,110,110,110)	$P_{38}=\{2,2,2,2,1,1\}$ ω=(105,105,105,105,109,109)	$P_{39}=\{2,2,2,1,1,1,1\}$ ω=(99,99,99,104,104,104,104)
$P_{40}=\{2,2,1,1,1,1,1,1\}$ ω=(93,93,98,98,98,98,98,98)	$P_{41}=\{2,1,1,1,1,1,1,1,1\}$ ω=(87,92,92,92,92,92,92,92,92)	$P_{42}=\{1,1,1,1,1,1,1,1,1,1\}$ ω=(85,85,85,85,85,85,85,85,85,85)

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