Power Measures: Theory and Applications to Environmental and Agriculture Issues

Vera Zaporozhets

Toulouse School of Economics (INRA, University of Toulouse Capitole)

ECOCEP conference, Prague
November 3-4, 2016

Introduction

Decision Making in Committees

- negotiate different policies
- involve representatives from different groups with divergent interests

Examples

- international
  EU Council of Ministers (CAP),
  United Nations Security Council (COP 21)
- national
  United States Legislative System, French Parliament
- local
  River Basin Committees

Introduction

Table: **Weights and quota in the Council of Ministers, 1958 - 2002.**

Country	1958 – 1972	1973 – 1980	1981 – 1985	1986 – 1994	1995 – 2002
Germany	4	10	10	10	10
Italy	4	10	10	10	10
France	4	10	10	10	10
UK	–	10	10	10	10
Spain	–	–	–	8	8
Belgium	2	5	5	5	5
Netherlands	2	5	5	5	5
Greece	–	–	5	5	5
Portugal	–	–	–	5	5
Sweden	–	–	–	–	4
Austria	–	–	–	–	4
Denmark	–	3	3	3	3
Ireland	–	3	3	3	3
Finland	–	–	–	–	3
Luxembourg	1	2	2	2	2
Quota	12	41	45	54	62
Total votes	17	58	63	76	87
Quota (%)	70.59	70.69	71.43	71.05	71.26

Introduction

Table: **Weights in the Adour-Garonne RBC, 1987 - 2007.**

	1987 – 1992	**1993 – 1998**	**1999 – 2004**	**2005 – 2007**
Agriculture	5	5	7	7
Industry&energy	12	12	12	13
Urban communities	1	1	2	2
Rural communities	1	1	1	1
Other communities	4	4	8	8
Region	6	6	5	6
District	18	18	18	18
Inter-district	0	0	2	3
Fishery & fish industry	3	3	4	4
Tourism	2	2	2	2
Water supply	3	3	2	2
Domestic water users	1	1	3	4
Ecologists	2	2	4	4
Professional bodies	8	8	9	8
Ministry of Environment	1	1	1	1
Ministry of land devt&rural aff	1	1	1	1
Ministry of health	1	1	1	1
Ministry of the Interior	1	0	1	1
Ministry of Industry	1	1	1	1
Ministry of agriculture	1	0	1	0
Other ministries	6	5	7	4
State prefectures	6	6	6	6
Total	84	81	98	97

Introduction

design of decision-making process

$$\updownarrow$$

effectiveness with which representatives pursue individual interests

Questions

1. To which extent is given policy-maker able to influence outcome?
2. How to assess whether or not interests of different groups are fairly represented?
3. How should committee be designed to have fair representation of different interests?

Plan

- different measures of voting power (first question)
- issue of fair representation of different interests (questions 2,3)
- other applications

Context

- EU Council of Ministers
- River Basin Committees in France (water policy)

Related Work

- Felsenthal and Machover, 1998. *The Measurement of Voting Power. Theory and Practice, Problems and Paradoxes*, Cheltenham: Edward Elgar.
- Kauppi and Widgrén, 2004. "What determines EU decision making? Needs, power or both?", *Economic Policy* 19(39), 221–266.
- Le Breton, Montero and Zaporozhets, 2012. "Voting Power in the EU Council of Ministers and Fair Decision Making in Distributive Politics", *Mathematical Social Sciences* 63, 159–173.
- Thomas and Zaporozhets, 2016. "Bargaining over Environmental Budgets: A Political Economy Model with Application to French Water Policy", *Environmental and Resource Economics,* p.1-22.
- Zaporozhets, 2015. "Voting Power and Decision Making in Environmental Committees: the Case of French Water Agencies", *Water Resources and Economics* 12, p. 40-51.
- Zaporozhets et al., 2016. "Key Drivers of EU Budget Allocation: Does Power Matter?", *European Journal of Political Economy* 43, p. 57-70.

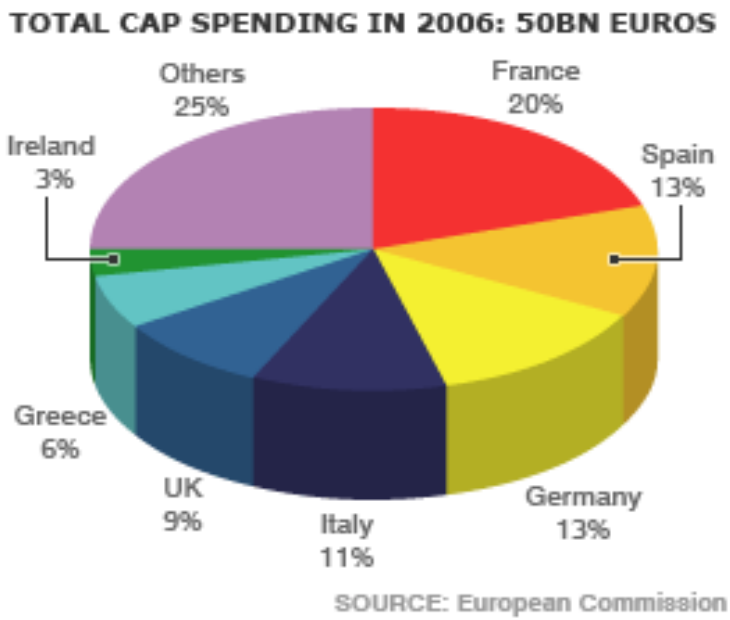
Ideology vs Distributive Politics

two types of voting situations

"ideology" (binary setting)
decision-makers can vote either "yes" or "no"

not all voting situations can be classified as binary

distributive politics
surplus distribution between stakeholders



Power Indices

"Ideology"	Distributive Politics
probability to cast decisive vote	expected share in fixed budget
Shapley-Shubik **Banzhaf**	**Shapley-Shubik** **nucleolus**

Why not voting weights?

Example

3 voters

two big (49 votes), one small (2 votes)

quota - 51

weight of small voter 24.5 times as much as weight of big voter

but

all three voters have the same voting power

change quota for 66

$\Rightarrow$ small looses power

Why not voting weights?

Table: **Weights and quota in the Council of Ministers, 1958 - 1972.**

Country	**weights**
Germany	4
France	4
Italy	4
Belgium	2
Netherlands	2
Luxembourg	1
Quota	12
Total votes	17

Luxembourg: 1 vote but powerless

Committee: formal description

- *simple game* (N, v)
  N - set of n members
  $v(S)$ - characteristic function (worth of coalition S)
  can take value 0 or 1
- coalition S is *winning* if $v(S) = 1$
  coalition S is *loosing* if $v(S) = 0$
  $\mathcal{W}$ - set of *winning coalitions*
- interpretation of $\mathcal{W}$
  S - set of members voting in favour of decision
  $\Rightarrow$ decision is accepted if $S \in \mathcal{W}$
- *weighted majority game* $[q; \omega_1, ..., \omega_n]$
  quota $q \geq 0$ and weights $\omega_1, ..., \omega_n \geq 0$
  $$v(S) = \begin{cases} 1, \ \sum_{i \in S} \omega_i \geq q \\ 0, \text{ otherwise} \end{cases}$$

Shapley-Shubik index

procedure

- players vote in specific order
- majority is reached⇒ proposal is accepted

voter turning existing coalition from losing into winning - *critical*
critical voter gets credit for having passed bill

assumption: random voting order

Shapley-Shubik index:

$$\phi_i = \frac{\text{number of orderings in which } i \text{ is critical}}{\text{total number of orderings}}$$

vector ϕ is normalized, i.e.,

$$\sum_{i=1}^{n} \phi_i = 1$$

Shapley-Shubik index: example

Veto game with three voters

$[3; 2, 1, 1]$

3 individuals with individual 1 being vetoer

decision is passed only when player 1 is in group voting for decision

being alone cannot get decision passed

6 possible orderings:

$$1\underline{2}3,\ 1\underline{3}2,\ 2\underline{1}3,\ 23\underline{1},\ 3\underline{1}2,\ \text{and}\ 32\underline{1}$$

critical player (turning set of predecessors into winning coalition)

Shapley-Shubik index

number of times that player i is underlined divided by 6:

$$\phi_1 = \frac{4}{6},\ \phi_2 = \phi_3 = \frac{1}{6}$$

Banzhaf index

swing for player i
winning coalition S containing i and such that i's departure from S would change coalition S from winning to loosing

absolute Banzhaf power:

$$\beta_i' = \frac{\text{number of swings for } i}{2^{n-1}}.$$

Banzhaf power index (normalized version):

$$\beta_i = \frac{\beta_i'}{\sum_{i=1}^{n} \beta_i'}.$$

Banzhaf index: example

Veto game with three voters (revisited)
$[3; 2, 1, 1]$

set of winning coalitions $\mathcal{W}$:
$\{\underline{1}, \underline{2}\}, \{\underline{1}, \underline{3}\}, \{\underline{1}, 2, 3\}$

Banzhaf index:

$$\begin{aligned} \beta'_1 &= \frac{3}{4},\ \beta'_2 = \beta'_3 = \frac{1}{4} \text{ and} \\ \beta_1 &= \frac{3}{5}, \beta_2 = \beta_3 = \frac{1}{5} \end{aligned}$$

EU Council of Ministers, 1958-2012

	1958 – 1972		1973 – 1980		1981 – 1985		1986 – 1994		1995 – 2002	
Country	**SSI**	**Bz**	**SSI**	**Bz**	**SSI**	**Bz**	**SSI**	**Bz**	**SSI**	**Bz**
France	0.233	0.238	0.179	0.167	0.174	0.158	0.134	0.129	0.117	0.112
Germany	0.233	0.238	0.179	0.167	0.174	0.158	0.134	0.129	0.117	0.112
Italy	0.233	0.238	0.179	0.167	0.174	0.158	0.134	0.129	0.117	0.112
Belgium	0.150	0.143	0.081	0.091	0.071	0.082	0.064	0.067	0.056	0.059
Netherlands	0.150	0.143	0.081	0.091	0.071	0.082	0.064	0.067	0.056	0.059
Luxembourg	0	0	0.010	0.016	0.030	0.041	0.012	0.018	0.021	0.023
UK	–	–	0.179	0.167	0.174	0.158	0.134	0.129	0.117	0.112
Denmark	–	–	0.057	0.066	0.030	0.041	0.043	0.046	0.035	0.036
Ireland	–	–	0.057	0.066	0.030	0.041	0.043	0.046	0.035	0.036
Greece	–	–	–	–	0.071	0.082	0.064	0.067	0.056	0.059
Spain	–	–	–	–	–	–	0.111	0.109	0.095	0.092
Portugal	–	–	–	–	–	–	0.064	0.067	0.056	0.059
Austria	–	–	–	–	–	–	–	–	0.045	0.048
Sweden	–	–	–	–	–	–	–	–	0.045	0.048
Finland	–	–	–	–	–	–	–	–	0.035	0.036

Banzhaf and Shapley-Shubik indices, Adour - Garonne RBC

	1987 – 1992		1993 – 1998		1999 – 2004		2005 – 2007	
	Bz	**SSI**	**Bz**	**SSI**	**Bz**	**SSI**	**Bz**	**SSI**
Agriculture	0.057	0.056	0.059	0.058	0.069	0.069	0.070	0.070
Industry&energy	0.135	0.146	0.139	0.151	0.121	0.126	0.133	0.140
Urban communities	0.011	0.011	0.012	0.011	0.019	0.019	0.020	0.019
Rural communities	0.011	0.011	0.012	0.011	0.010	0.009	0.010	0.009
Other communities	0.045	0.045	0.047	0.046	0.079	0.080	0.080	0.080
Region	0.068	0.068	0.071	0.070	0.049	0.049	0.060	0.059
District	0.253	0.248	0.262	0.258	0.210	0.210	0.211	0.212
Inter-district	0	0	0	0	0.019	0.019	0.030	0.029
Fishery & fish industry	0.034	0.033	0.035	0.034	0.039	0.039	0.040	0.039
Tourism	0.022	0.022	0.023	0.022	0.019	0.019	0.020	0.019
Water supply industry	0.034	0.033	0.035	0.034	0.019	0.019	0.020	0.019
domestic water users	0.011	0.011	0.012	0.012	0.029	0.029	0.040	0.039
Ecologists	0.022	0.022	0.023	0.022	0.039	0.039	0.040	0.039
Professional bodies	0.093	0.093	0.096	0.110	0.090	0.091	0.080	0.081
Ministry of Environment	0.011	0.011	0.012	0.011	0.010	0.009	0.010	0.009
Ministry of land devt&rural aff	0.011	0.011	0.012	0.011	0.010	0.009	0.010	0.009
Ministry of health	0.011	0.011	0.012	0.011	0.010	0.009	0.010	0.009
Ministry of the Interior	0.011	0.011	0	0	0.010	0.009	0.010	0.009
Ministry of Industry	0.011	0.011	0.012	0.011	0.010	0.009	0.010	0.009
Ministry of agri	0.011	0.011	0	0	0.010	0.009	0	0
Other ministries	0.068	0.068	0.059	0.058	0.069	0.069	0.040	0.039
State prefectures	0.068	0.068	0.071	0.070	0.059	0.059	0.060	0.059

Banzhaf vs Shapley-Shubik

Straffin (1977)
Bz and SSI can be derived from same basic probabilistic model

What is probability that bill supported by player *i* passes?

different assumptions regarding voting behaviour

- Bz (non-normalized): voters vote completely independently (independence assumption)
- SSI: voters have some common standards or values (homogeneity assumption)

Nucleolus

- fn $v(S)$ - worth of coalition S
- for any x and each S excess of S:
  $e(S, x) = v(S) - x(S)$
  measures how dissatisfied members of S are with x
- **natural criterion of equity**
  find allocation x that minimize $\max_S e(S, T)$
- single imputation called **nucleolus** (Schmeidler)
  recursively minimizes dissatisfaction of worst treated coalition

Nucleolus vs Shapley-Shubik

- **bargaining set** (players decide how to divide worth)
  player who is not satisfied with proposed share may object
  objection goes against another player (should share his part)
  player against whom objection is made may have counter objection
  justified objection: does not have counter objection
  bargaining set:
  no player has justified objection against any other player
- **nucleolus**:
  always exists, unique, belongs to bargaining set
  (in general Shapley value is not in bargaining set)
- **Veto game with three voters** (revisited)
  $[3; 2, 1, 1]$
  nucleolus and bargaining set: $(1, 0, 0)$
  Shapley-Shubik index: $(2/3, 1/6, 1/6)$

EU Council of Ministers, 1958-2012

	1958 – 1972		1973 – 1980		1981 – 1985		1986 – 1994		1995 – 2002	
Country	**SSI**	**Nucl**	**SSI**	**Nucl**	**SSI**	**Nucl**	**SSI**	**Nucl**	**SSI**	**Nucl**
France	0.233	**0.250**	0.179	**0.250**	0.174	**0.250**	0.134	**0.138**	0.117	**0.115**
Germany	0.233	**0.250**	0.179	**0.250**	0.174	**0.250**	0.134	**0.138**	0.117	**0.115**
Italy	0.233	**0.250**	0.179	**0.250**	0.174	**0.250**	0.134	**0.138**	0.117	**0.115**
Belgium	0.150	**0.125**	0.081	**0**	0.071	**0**	0.064	**0.069**	0.056	**0.057**
Netherlands	0.150	**0.125**	0.081	**0**	0.071	**0**	0.064	**0.069**	0.056	**0.057**
Luxembourg	0	**0**	0.010	**0**	0.030	**0**	0.012	**0**	0.021	**0.023**
UK	–	–	0.179	**0.250**	0.174	**0.250**	0.134	**0.138**	0.117	**0.115**
Denmark	–	–	0.057	**0**	0.030	**0**	0.043	**0.034**	0.035	**0.034**
Ireland	–	–	0.057	**0**	0.030	**0**	0.043	**0.034**	0.035	**0.034**
Greece	–	–	–	–	0.071	**0**	0.064	**0.069**	0.056	**0.057**
Spain	–	–	–	–	–	–	0.111	**0.103**	0.095	**0.092**
Portugal	–	–	–	–	–	–	0.064	**0.069**	0.056	**0.057**
Austria	–	–	–	–	–	–	–	–	0.045	**0.046**
Sweden	–	–	–	–	–	–	–	–	0.045	**0.046**
Finland	–	–	–	–	–	–	–	–	0.035	**0.034**

Fair representation (binary voting)

Power of European Citizens
Two-stage problem:

- 1st: citizens elect their representatives (direct power)
- 2nd: representatives make actual decision (indirect power)

Fairness principles

- Egalitarianism
  seeks to equalize utility levels for equals
- Utilitarianism
  aims to maximize total sum of voters' utilities

Fair representation (binary voting)

Felsenthal and Machover (1998)
egalitarian approach
equalize power of all citizens as measured by Bz

Penrose square root rule:
citizens' indirect BZ powers are equal $\Leftrightarrow$ representatives' BZ powers are proportional to square root of populations

Conclusion:
larger member states tend to have too little power
smaller ones - too much

Fair representation (distributive politics)

Le Breton et al. (2012)

egalitarian approach
allocate gains equally across EU citizens
as measured by nucleolus

Result:
citizens' indirect power are equal $\Leftrightarrow$ delegates' powers are proportional to population rates

EU Council of Ministers, 1958-2002 (Revisited)

Table: Population and nucleolus in CM, 1958-2002.

Country	1958 – 1972		1973 – 1980		1981 – 1985		1986 – 1994		1995 – 2002	
	$\frac{n_j}{n}$	Nucl	$\frac{n_j}{n}$	Nucl	$\frac{n_j}{n}$	Nucl	$\frac{n_j}{n}$	Nucl	$\frac{n_j}{n}$	Nucl
France	0.266	**0.250**	0.203	**0.250**	0.200	**0.250**	0.172	**0.138**	0.156	**0.115**
Germany	0.322	**0.250**	0.242	**0.250**	0.228	**0.250**	0.189	**0.138**	0.220	**0.115**
Italy	0.291	**0.250**	0.214	**0.250**	0.209	**0.250**	0.176	**0.138**	0.154	**0.115**
Belgium	0.053	**0.125**	0.038	**0**	0.036	**0**	0.031	**0.069**	0.027	**0.057**
Netherlands	0.066	**0.125**	0.052	**0**	0.053	**0**	0.045	**0.069**	0.042	**0.057**
Luxembourg	0.002	**0**	0.010	**0**	0.001	**0**	0.001	**0**	0.001	**0.023**
UK	–	–	0.218	**0.250**	0.205	**0.250**	0.176	**0.138**	0.157	**0.115**
Denmark	–	–	0.019	**0**	0.019	**0**	0.016	**0.034**	0.014	**0.034**
Ireland	–	–	0.012	**0**	0.013	**0**	0.011	**0.034**	0.010	**0.034**
Greece	–	–	–	–	0.036	**0**	0.031	**0.069**	0.02 8	**0.057**
Spain	–	–	–	–	–	–	0.120	**0.103**	0.105	**0.092**
Portugal	–	–	–	–	–	–	0.031	**0.069**	0.027	**0.057**
Austria	–	–	–	–	–	–	–	–	0.022	**0.046**
Sweden	–	–	–	–	–	–	–	–	0.024	**0.046**
Finland	–	–	–	–	–	–	–	–	0.014	**0.034**

Adour - Garonne RBC, 1987 - 2006

specificities:

- 3 groups (domestic, industrial, farmers)
- everybody (administration) participate in decision-making

simplifying assumption:

administrative representative acts on behalf of single user group

	industry		agriculture		domestic	
	$\frac{n_j}{n}$	**SSI**, **Nucl**	$\frac{n_j}{n}$	**SSI**, **Nucl**	$\frac{n_j}{n}$	**SSI**, **Nucl**
1989	0.176	**0.333**	0.106	**0.333**	0.717	**0.333**
1990	0.175	**0.333**	0.103	**0.333**	0.722	**0.333**
1991	0.171	**0.333**	0.099	**0.333**	0.729	**0.333**
1992	0.167	**0.333**	0.097	**0.333**	0.736	**0.333**
1993	0.162	**0.333**	0.094	**0.333**	0.745	**0.333**
1994	0.158	**0.333**	0.090	**0.333**	0.751	**0.333**
1995	0.158	**0.333**	0.087	**0.333**	0.756	**0.333**
1996	0.156	**0.333**	0.085	**0.333**	0.759	**0.333**
1997	0.152	**0.333**	0.084	**0.333**	0.765	**0.333**
1998	0.150	**0.333**	0.080	**0.333**	0.770	**0.333**
1999	0.148	**0.333**	0.076	**0.333**	0.776	**0.333**
2000	0.150	**0.333**	0.073	**0.333**	0.777	**0.333**
2001	0.149	**0.333**	0.070	**0.333**	0.781	**0.333**
2002	0.145	**0.333**	0.068	**0.333**	0.786	**0.333**
2003	0.142	**0.333**	0.067	**0.333**	0.791	**0.333**
2004	0.139	**0.333**	0.067	**0.333**	0.794	**0.333**
2005	0.135	**0.333**	0.063	**0.333**	0.802	**0.333**
2006	0.132	**0.333**	0.059	**0.333**	0.808	**0.333**

Fair representation (II)

How to design committee with fair representation?
voting rules which are as close as possible to first-best

EU Council of Ministers, 1958-1972
Nucleolus: $[5; 3, 2, 2, 1, 1, 0]$ is optimal
Germany: should receive more than other large countries

Adour - Garonne RBC, 1987 - 2007
SSI: $[3; 2, 1, 1]$ is optimal
Nucleolus: either $[3; 2, 1, 1]$ or $[1; 1, 0, 0]$
domestic users should receive more

Other Applications

Kauppi and Widgren (2004)

How EU budget is distributed among members?

- "needs view": agricultural production and relative income
- "power politics view": Shapley-Shubik index

Results

prevalence of selfish power motives

Follow-up study

- extended data set (1976-2012)
- more adapted techniques
- alternative power measure (nucleolus)

Results

- power matters
- importance of solidarity principles

Conclusions

- different measures of voting power
  - as influence on final outcome
  - as expected share in fixed budget
- distribution of power between members
  - EU Council of Ministers
  - River Basin Committees in France
- consequences of changes in voting rules on power distribution
- fair representation of different interests