

Annexes

ANNEX I: CALCULATION METHODOLOGY

For the analysis, we use two main data sources:

- The official electoral results on votes for each party, blank votes, and abstention rates in the three elections, obtained from the Generalitat of Catalonia¹
- Post-electoral surveys on ideological self-placement and party closeness by vote choice from the *Centro de Investigaciones Sociológicas* (CIS) numbers 2970, 3113, and 3202.

Since post-electoral survey data show an overrepresentation of Catalan nationalist parties² compared to official electoral results, survey data are rescaled, as explained below. In modelling exercises, seats are only assigned to parties that obtained parliamentary representation in the 2012, 2015, and 2017 elections.

A.1. Positioning of citizens on the nationalist and left-right dimensions

We locate citizens on two ideological dimensions – nationalism and left-right – using self-placement data from CIS surveys. This procedure and these dimensions are widely accepted in the literature (Inglehart & Klingemann, 1976; Sani & Sartori, 1980 [1976]; Alvira et al., 1978) and show high cross-national consistency (Huber & Powell, 1994).

For each election, self-placement scores (CIS 2970, P38–P40; CIS 3113, P35–P37; CIS 3202, P32–P34) are weighted according to actual electoral outcomes (party votes, blank votes, null votes, and abstention) using official data from the Generalitat of Catalonia.

A.2 Position of parties on the ideological dimensions

We follow standard practice in party-list electoral systems (see Colman & Pountney, 1978; Van Deemen, 1993; Kurrild-Klitgaard 2008), thus assuming all representatives of a party share the same ideological position. Consequently, we only estimate party-level positions.

To do so, we build on voters' perceptions rather than expert judgments³. Three alternatives are discussed in the literature (Alvira, 2019): (a) using the mean self-placement of party voters; (b) using the mean placement assigned by the entire electorate; and (c) using the mean placement assigned by a party's own voters. Each approach has limitations, but option (c) is preferred because it assumes voters are best informed about the party they support, produces intermediate positions, and is empirically supported (see Alvira, 2018; 2019; Torroglosa 2022). Besides, this option has been supported in recent studies (e.g., Mattila & Raunio, 2006; Golder & Stramski, 2010).

Accordingly, each party's ideological position on a 0–10 scale is derived from its voters' perceptions using CIS studies 2970 (P 39–P41), 3113 (P36–P38), and 3202 (P33–P35). The procedure implies only the judgment of party voters is taken into account, so no rescaling is needed at this stage.

A.3. Modeling citizens' preferences and outcomes under alternative electoral systems

In modeling electoral outcomes, rescaling is performed exclusively on valid party votes, since blank and null votes do not generate preference profiles (thus, no preferences are assigned to blank, null votes and abstention). Citizens are assumed to cast sincere votes.

A.3.1. Single non-transferable vote

Outcomes under single non-transferable vote systems are modelled using official data on party votes from the Generalitat of Catalonia.

A.3.2. Single transferable vote

Preferential votes have been estimated using the procedure described below (A.3.5). We then rescale according to party votes, and calculate the number of seats assigned to each party by a Single Transferable Vote (STV) electoral system using the Droop quota. Transfers and eliminations follow the standard STV procedure adapted to party lists, as detailed in Annex II.

³ Some studies use expert judgments to position parties, e.g.: Castles and Mair (1984), Bartolini and Mair (1990), and Ruiz and Otero (2013). However, several studies have challenged this procedure.

¹ <https://resultats.dadeselectorals.gencat.cat/#/>

² An overrepresentation of voters of Catalan nationalist parties was detected (e.g., in CIS 3202 the following overrepresentation was observed: CatComu = 131 %, ERC = 135 %, JxCAT = 130 % and CUP = 165 %).

A.3.3. Approval voting

Approval votes are calculated using respondents' self-reported closeness to political parties (CIS 2970 P32; CIS 3113 P29; CIS 3202 P26). Responses are converted into approvals as follows: 100% of "Very close" and "Close" responses count as approvals, while 50% of "Neither close nor far" responses are counted as approvals. "Far" and "Very far" responses are not counted.

Very Close	Close	Neither close/neither far	Far	Very Far
100% Approval (1 vote)		50% approval (0,5 votes)		0% (0 votes)

Approval votes are then rescaled according to actual party votes.

An attempt was made to allocate seats using the disapproval/approval vote (Heckscher, 1898 in Lagerspetz, 2014; Alcantud & Laruelle, 2014), following the below criterion:

Very Close	Close	Neither close/neither far	Far	Very Far
Approval (1 vote)		Indifference (0 votes)		Disapproval (-1 votes)

Yet, since all parties received negative scores in 2017 (all parties were disapproved by citizens)⁴, no consistent seat allocation could be proposed.

A.3.4. Score voting

To calculate **Score Voting** the same closeness data as above has been used, assigning scores from 1 ("Very close") to 0 ("Very far") in decreasing intervals.

Very close	Close	Neither close/neither far	Far	Very far
1 point	0.75 points	0.5 points	0.25 points	0 points

Party scores have been weighted according to electoral results to obtain aggregate scores.

A.3.5. Prll and borda rules

To calculate the **collective preference** respondents' relative closeness to parties has been used, considering that by positioning the options each interviewee expressed a preference relationship between couples (Van Deemen, 1993; Kurrild-Klitgaard, 2008):

⁴ Specifically, the scores were: CUP=-2,864,069; ERC=-686,969; Cat-Comú=-2.283.423; PSC-PSOE=-1,986,966; JxCAT=-1,193,146; C's=-2.351.098; PP=-4.110.506. These negative values confirm current Catalonia citizenry dissatisfaction with their political representatives, signaled as the first problem by more than 40% of respondents (CIS 3263),

	Cs	JxCAT	ERC	PSC	CatComu	CUP	PP
Cs	-	1,998,735	1,973,818	1,578,923	1,939,447	2,250,958	2,142,086
JxCAT	2,644,449	-	1,507,327	2,373,884	2,347,635	2,582,622	3,015,285
ERC	2,789,505	2,085,768	-	2,493,672	2,498,674	2,823,468	3,122,746
PSC	2,677,072	2,222,472	2,092,020	-	2,449,802	2,820,985	3,269,493
CatComu	2,673,220	1,843,342	1,651,574	2,367,978	-	2,373,692	3,131,270
CUP	2,144,950	962,196	723,784	2,086,084	1,510,786	-	2,323,510
PP	526,247	1,103,961	1,114,500	800,522	1,093,346	1,233,722	-

Figure AI.1. Example: pairwise comparison matrix for 2017 elections. Source: Own elaboration building on CIS 3202. P26. Note-worthy, the 2017 PCM provides the collective ordering: ERC > JxCAT > PSC > CatComu > Cs > XUP > PP, which points out the presence of a weak Borda paradox, since four parties were more preferred than Cs, which however was the most preferred according to the current electoral system.

- If the interviewee expressed a greater closeness for party A than for another party B, then the interviewee preferred A to B, that is, A>B
- If the interviewee expressed equal distance to two parties A and B, then the interviewee was indifferent between both parties, that is, A~B⁵.
- If the interviewee expressed a greater distance from party A than from another party B, then for interviewee A it was less preferred than B, that is, A<B.

To take into account some minimal differences in evaluations, an algorithm allowing for partial indifference has been applied (Alvira, 2018)⁶.

Then, pairwise comparison matrices (PCM) are built using the above data and procedure by rescaling them by party votes obtaining thus the overall PCM for each election. For the 2017 election, individual-level data were available, while only aggregated data were used for 2012 and 2015. Seats allocations are then calculated using the PRL rule.

Borda scores are obtained by summing each party's row in the PCM. The Borda rule provides a benchmark, as it is widely regarded that, provided sincere voting, it produces preference orderings that most closely reflect voters' preferences.

⁵ When computing the PCM we have divided the number of indifferent individuals into two, adding each half to each of the cells that implied strict preference (the only exception, if indifference was expressed between parties ranked in the last position).

⁶ The author shows that this algorithm generates more consistent PCMs. Specifically: 1) by producing Condorcet orderings of options starting closer to the median voter; 2) by generating more similar seat allocations to those obtained under Score Voting (interpretable as collective utility maximization); and 3) by producing seat allocations using the Borda rule (obtaining the score as the sum of the rows of the matrix, as proposed in Young, 1988) that increase their correlation with citizens' preferences in the ideological dimensions (Alvira, 2018).

ANNEX II. ANALYSIS OF THE SUITABILITY OF ALTERNATIVE ELECTORAL SYSTEMS

Below we analyze six alternative electoral system designs based on the following voting rules: Proportional (votes-seats pure proportionality), Single Transferable Vote (STV), Approval Vote, Borda Count, Score Voting, and Prll, all of them adapted to party's lists. We calculate each party collective preference according to each rule and subsequently assign it seats using the d'Hondt rule.

Notably, in all cases, we consider Catalonia a single constituency. According to previous studies, this reduces nationalist bias and increases proportionality between votes and collective preferences. The resulting strict proportionality benchmark with a single constituency, serves as a reference point for comparing all modelled scenarios.

4.1. Proportional

We assign to each political party a collective preference *proportional* to received votes. This electoral system would have built the following Parliaments (Table AII.1).

To assess the adequacy of this electoral system, we firstly value the Representativeness of the Chambers by comparing the location of the median citizen and representative.

Figures AII.1 and AII.2 show that the Parliaments a Proportional electoral system would have built would have preserved the bias to the right (D2), although the nationalist bias (D1) would have been reduced in the last election. Then, we assess the Polarization that can be expected from these Parliaments.

The above graphs reveal that the Parliaments a Proportional electoral system would have also generated extreme and increasing values of political polarization in the Nationalism dimension (D3=4.06; 5.54; 5.90), even greater than generated by the current electoral system. However, the maximum ideological distance between each half of representatives and the opposite half of citizens (D5) would have reduced, pointing to lower citizens' dissatisfaction and social conflict.

The analysis indicates this electoral system could slightly contribute to advance towards the resolution of the conflict.

4.2. Single Transferable Vote (STV)

We calculate the number of seats assigned to each party by a Single Transferable Vote (STV) electoral system using the Droop quota. This electoral system would have built the following parliaments (Table AII.2).

To assess the adequacy of this electoral system, we firstly value the Representativeness of the Chambers by comparing the location of the median citizen and representative.

Figures AII.3 and AII.4 reveal that the parliaments an STV electoral system would have built, would have been ideologically closer to Catalonia citizenry. There is still some bias to the right (D2), but the Nationalist bias (D1) almost disappears. Secondly, we assess the Polarization that can be expected from these Parliaments.

The above reveal that the parliaments an STV electoral system would have built would have also generated political polarization in the Nationalism dimension, both between parliamentarians (D3) and between parliamentarians and citizens (D5), the latter slightly reduced

Table AII.1. Seats assignment by 'proportional' electoral system.

Political parties			Electoral result and seats assignment					
2012	2015	2017	2012		2015		2017	
			Votes	Seats	Votes	Seats	Votes	Seats
Ciutadans	Ciutadans	Cs	275,007	9	736,364	25	1,109,732	35
CiU	JxSi	JxCAT	1,116,259	50	1,628,714	62	948,233	30
ERC		ERC	498,124	21			935,861	30
PSC	PSC	PSC	524,707	20	523,283	16	606,659	19
ICV-EUiA	CSQP	CatComu	359,705	13	367,613	11	326,360	10
CUP	CUP	CUP	126,435	3	337,794	10	195,246	6
PP	PP	PP	471,681	19	349,193	11	185,670	5
Total			3,582,272	135	4,092,349	135	4,357,368	135

Source: Own calculation building on data from the Generalitat of Catalonia and the CIS studies 2970, 3113, and 3202. *Partit dels Socialistes de Catalunya*, PSC (quoted in Magre Ferrán, 2005: 173) already proposed this electoral reform.

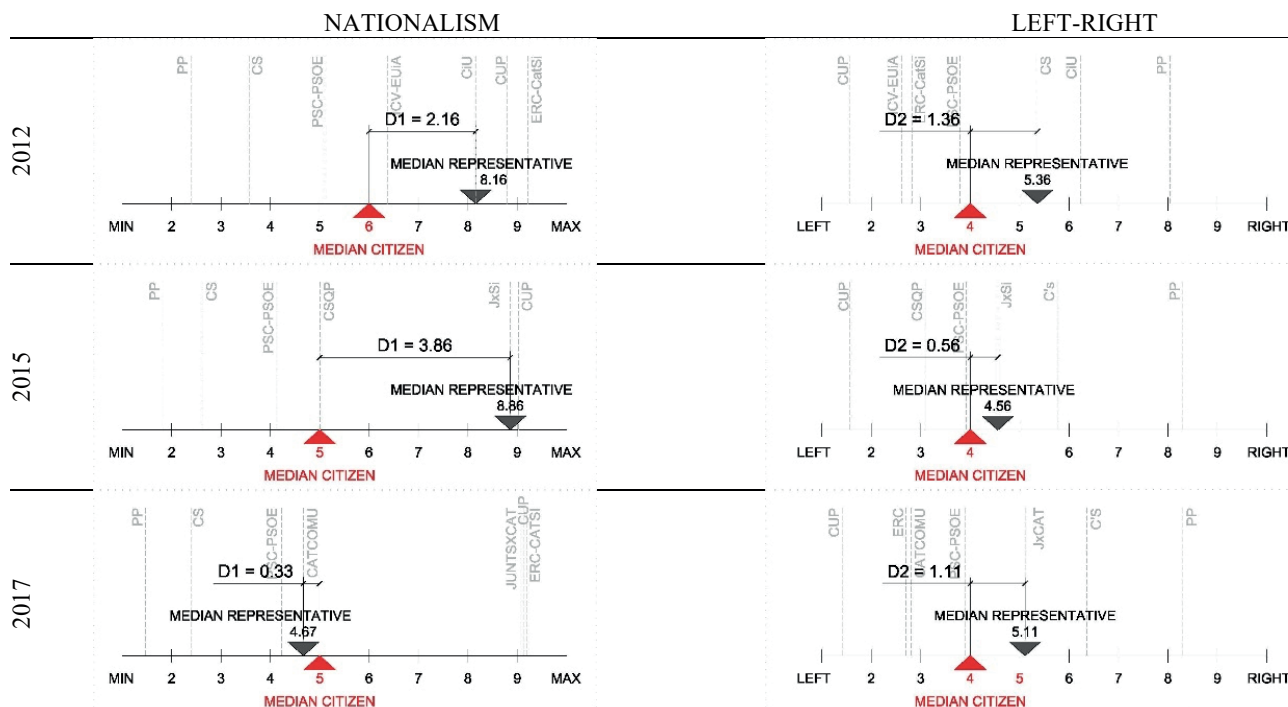


Figure AII.1. Ideological congruence representatives-citizenry. Notes: Own elaboration using the same criteria and data as in Figure 5.

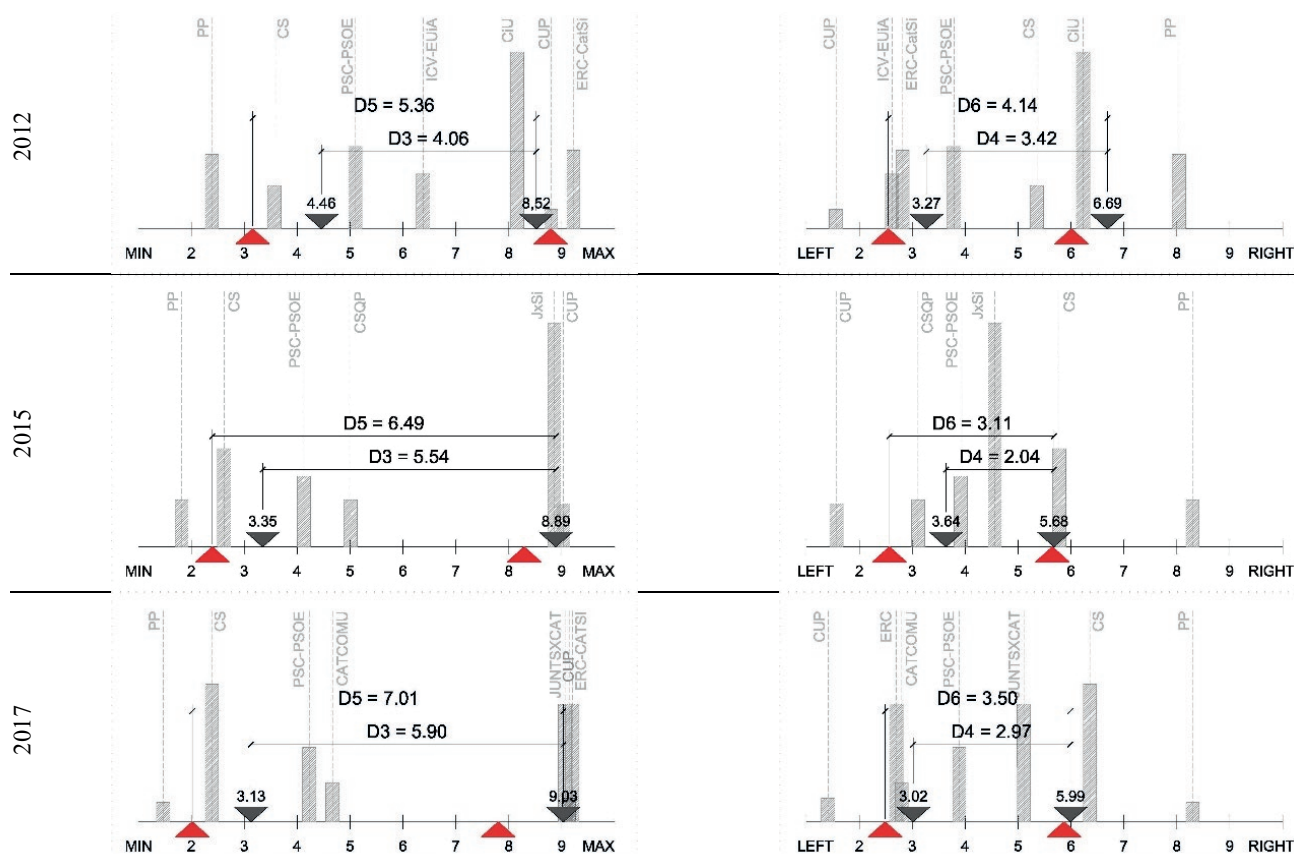


Figure AII.2. Political polarization expected from parliament composition. Notes: Own elaboration using the same criteria and data as in Figure 6.

Table AII.2. Seats assignment by ‘single transferable vote’ electoral system.

Political parties			Seats assignment					
2012	2015	2017	2012		2015		2017	
			Quota	Seats	Quota	Seats	Quota	Seats
Ciutadans	Ciutadans	Cs	-	11	-	25	-	35
CiU	JxSi	JxCAT	-	45	-	56	-	30
ERC		ERC	-	20	-		-	30
PSC	PSC	PSC	-	21	-	18	-	19
ICV-EUiA	CSQP	CatComu	-	14	-	13	-	10
CUP	CUP	CUP	-	5	-	11	-	6
PP	PP	PP	-	19	-	12	-	5
Total			24,794	135	28,993	135	31,675	135

Source: Own elaboration using the same data as Table 2.

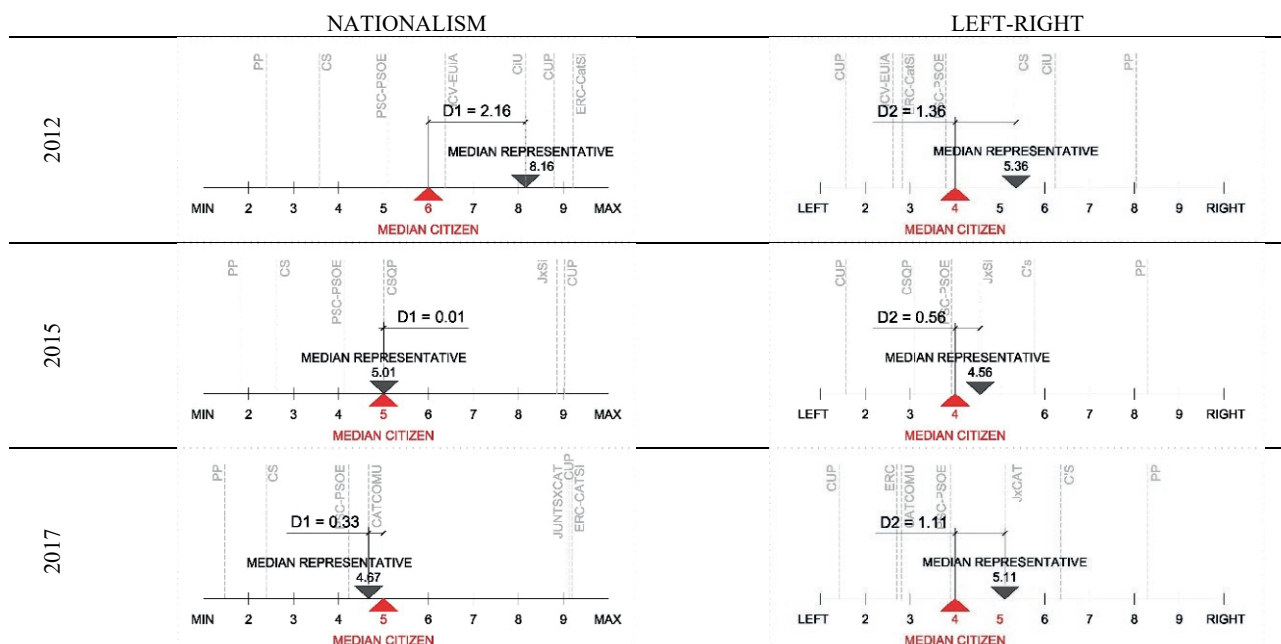


Figure AII.3. Ideological congruence representatives-citizenry. Notes: Own elaboration using the same criteria and data as in Figure 5.

since the distance between the median Representative and Citizen would decrease.

The analysis indicates this system could also contribute to advance towards the resolution of the conflict.

4.3. Approval vote

We assign to each political party a collective preference proportional to the number of Approval Votes said party would have obtained given the preferences profile

of Catalonia citizenry. This electoral system would have built the following parliaments (Table AII.3).

To assess the adequacy of this electoral system, we firstly value the Representativeness of the Chambers by comparing the location of the median citizen and representative.

Figure AII.5 and AII.6 reveal that the parliaments an Approval Vote electoral system would have built in this period would also have had a persistent Nationalist bias (D1), although the bias in the Left-Right dimension (D2) almost disappears and is even displaced towards the left.

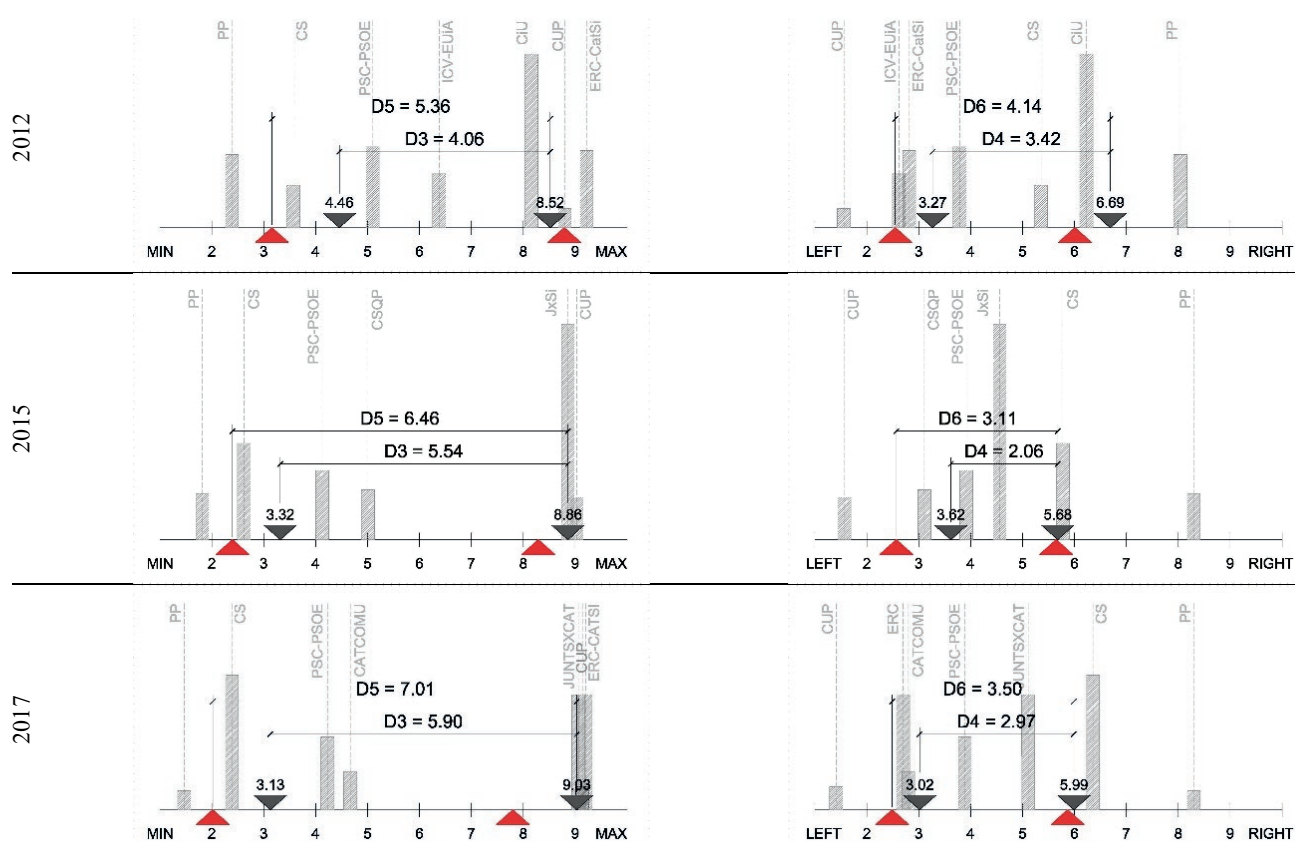


Figure AII.4. Political polarization expected from parliament composition. Notes: Own elaboration using the same criteria and data as in Figure 6.

Table AII.3. Seats assignment by ‘approval vote’ electoral system.

Political parties			Seats assignment					
2012	2015	2017	2012		2015		2017	
			Votes	Seats	Votes	Seats	Votes	Seats
Ciutadans	Ciutadans	Cs	886,790	13	1,285,985	22	1,601,679	19
CiU	JxSi	JxCAT	1,684,554	26	1,953,761	35	2,180,655	25
ERC		ERC	1,782,823	27	1,336,697	22	2,433,743	28
PSC	PSC	PSC	1,255,395	19	1,336,697	22	1,783,745	21
ICV-EUiA	CSQP	CatComu	1,588,185	24	1,293,593	22	1,635,516	19
CUP	CUP	CUP	1,085,662	17	1,395,428	24	1,345,193	15
PP	PP	PP	579,904	9	601,471	10	721,974	8
Total			8,863,312	135	7,866,934	135	11,702,504	135

Source: Own elaboration using the same data as Table 2.

Secondly, we assess the polarization that can be expected from these Parliaments.

The graphs reveal that the parliaments an Approval Vote electoral system would have built would also have generated extreme and increasing polarization values in

the Nationalism dimension, both between representatives (D3) and between representatives and citizens (D5), sometimes lower yet sometimes higher than those generated by the current electoral system.

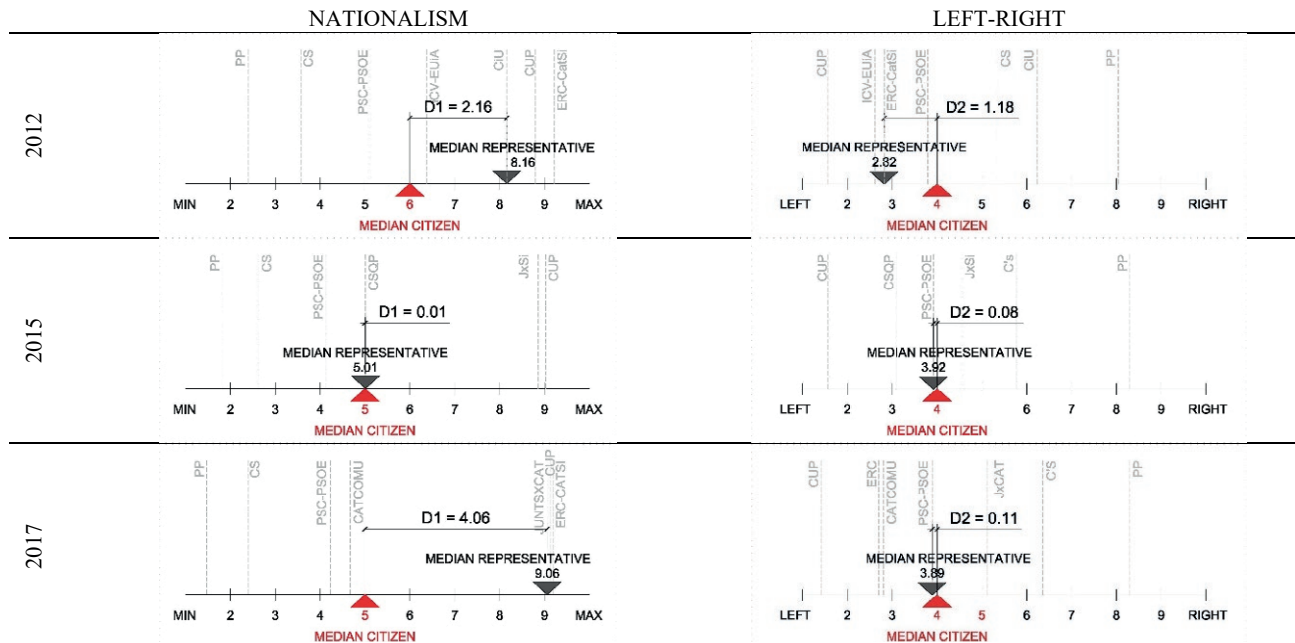


Figure AII.5. Ideological congruence representatives-citizenry. Notes: Own elaboration using the same criteria and data as in Figure 5.

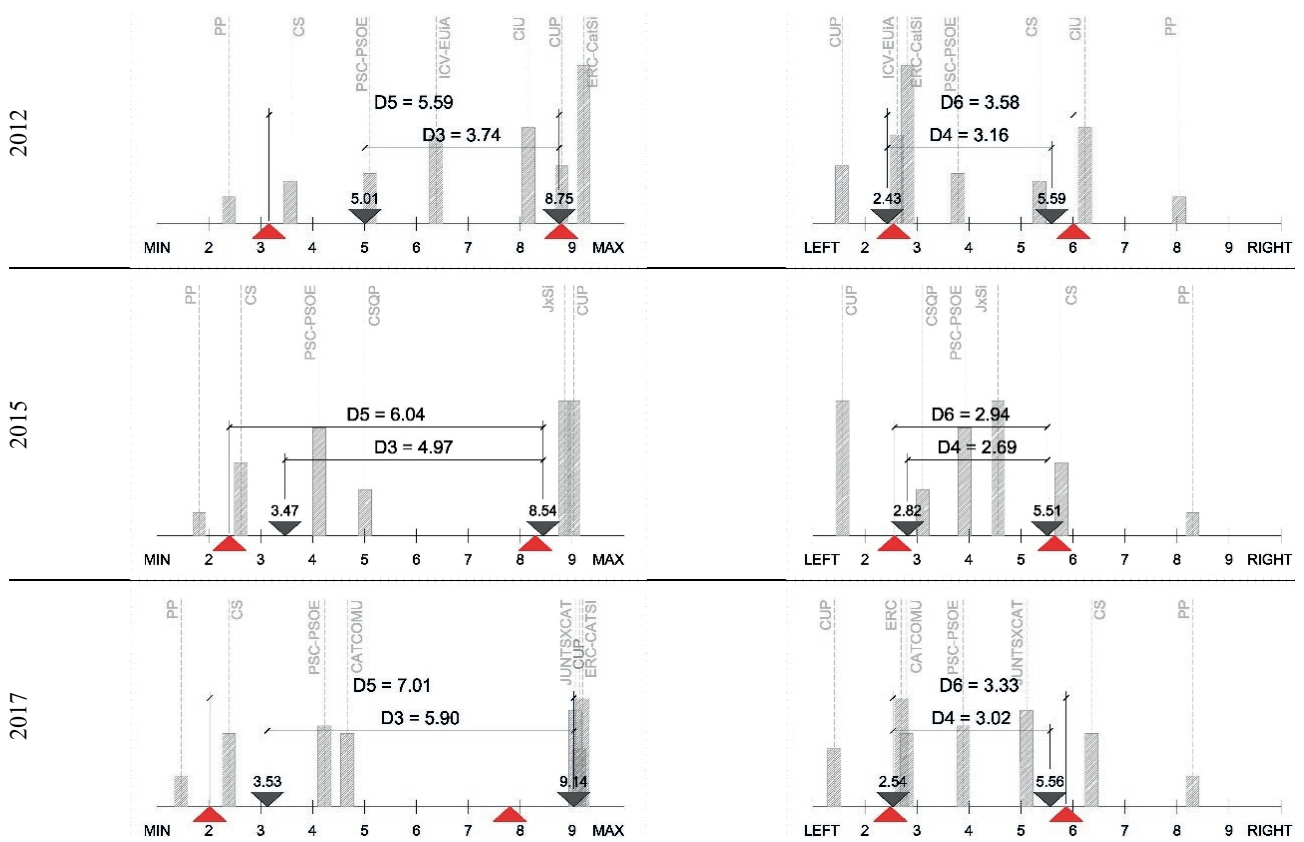


Figure AII.6. Political polarization expected from parliament composition. Notes: Own elaboration using the same criteria and data as in Figure 6.

Table AII.4. Seats assignment by 'borda count' electoral system.

Political parties			Seats assignment					
2012	2015	2017	2012		2015		2017	
			Borda count	Seats	Borda count	Seats	Borda count	Seats
Ciutadans	Ciutadans	Cs	6,760,036	13	9,054,757	21	11,883,967	18
CiU	JxSi	JxCAT	13,162,328	25	11,848,450	27	14,471,201	22
ERC		ERC	13,222,845	25			15,813,833	25
PSC	PSC	PSC	10,593,289	20	11,987,237	28	15,531,844	24
ICV-EUiA	CSQP	CatComu	13,132,132	25	12,224,641	28	14,041,077	22
CUP	CUP	CUP	9,687,456	19	10,271,677	23	9,751,310	15
PP	PP	PP	4,252,192	8	3,757,654	8	5,872,298	9
Total			70,810,278	135	59,144,415	135	87,365,530	135

Source: Own elaboration using the same data as Table 2. Notes: This electoral system is equivalent to k-Borda proposed by Chamberlin and Courant (1983), where the eligible *individuals* are the parties; k is the number of deputies, and the number of seats pi assigned to each party is the weighting/strength of its preference in the collective decision.

The analysis raises some doubts about whether this electoral system could have contributed to moderation or to advance towards the resolution of the conflict.

4.4. Borda count

We assign to each political party a collective preference proportional to the Borda Count said party would have obtained given the preference profile of Catalonia citizenry. This electoral system would have built the following parliaments (Table AII.4).

To assess the adequacy of this electoral system, we firstly value the Representativeness of the Chambers by comparing the location of the median citizen and representative.

Figures AII.7 and AII.8 reveal that the aggregate preference of the parliaments a Borda Count electoral system would have built, would have approached Catalonia citizenry, showing high (or at least sufficient) closeness between the Median Representative and Citizen (D1 and D2). Secondly, we review the Polarization that can be expected from these Parliaments.

The graphs reveal that the parliaments a Borda Count electoral system would have built also would have generated extreme and increasing polarization in the Nationalism dimension (D3=3.71; 4.40; 5.29). However, in all cases, it would have been lower than generated by the current electoral system. Likewise, the ideological distance between representatives and citizens (D5 and D6) would have been smaller.

This indicates this electoral system could contribute to ideological moderation and advancing towards the resolution of the conflict.

4.5. Score voting

We assign to each political party collective preference proportional to the Score said party would have obtained according to Score Voting given the preference profile of Catalonia citizenry. This electoral system would have built the following parliaments (Table AII.5).

To assess the adequacy of this electoral system, we firstly value the Representativeness of the Chambers by comparing the location of the median citizen and representative.

Figures AII.9 and AII.10 reveal that the aggregate preference of the parliaments a Score Voting electoral system would have built would have approached Catalonia citizenry, with even closer proximity between the Representative and the Median citizen (D1 and D2). Secondly, we review the polarization that can be expected from these Parliaments.

The graphs reveal that the parliaments a Score Voting electoral system would have built also would have generated extreme and increasing polarization in the Nationalism dimension (D3=3.92; 4.78; 5.51), yet, somewhat lower in recent years than those generated by the current electoral system. Likewise, in general, there is a reduction in the ideological distance between representatives and citizens (D5) regarding Parliaments built by the current electoral system.

The analysis indicates this electoral system could have contributed to the moderation and advancing towards the resolution of the conflict.

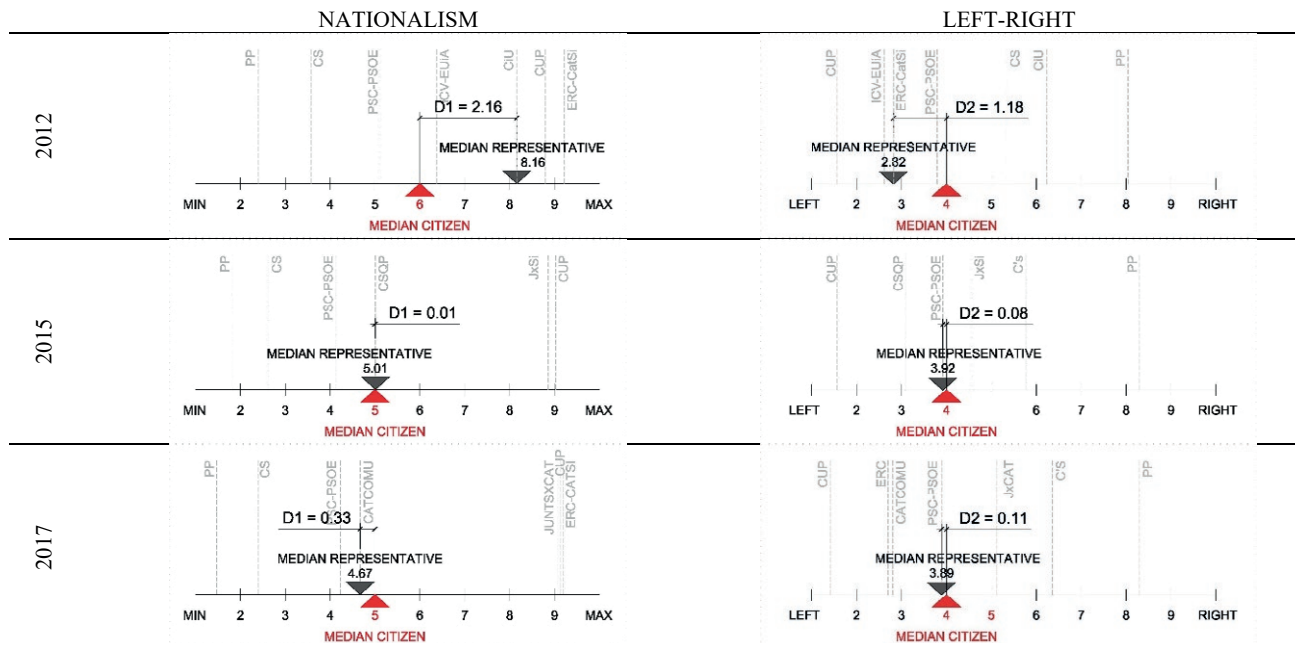


Figure AII.7. Ideological congruence representatives-citizenry. Notes: Own elaboration using the same criteria and data as in Figure 5.

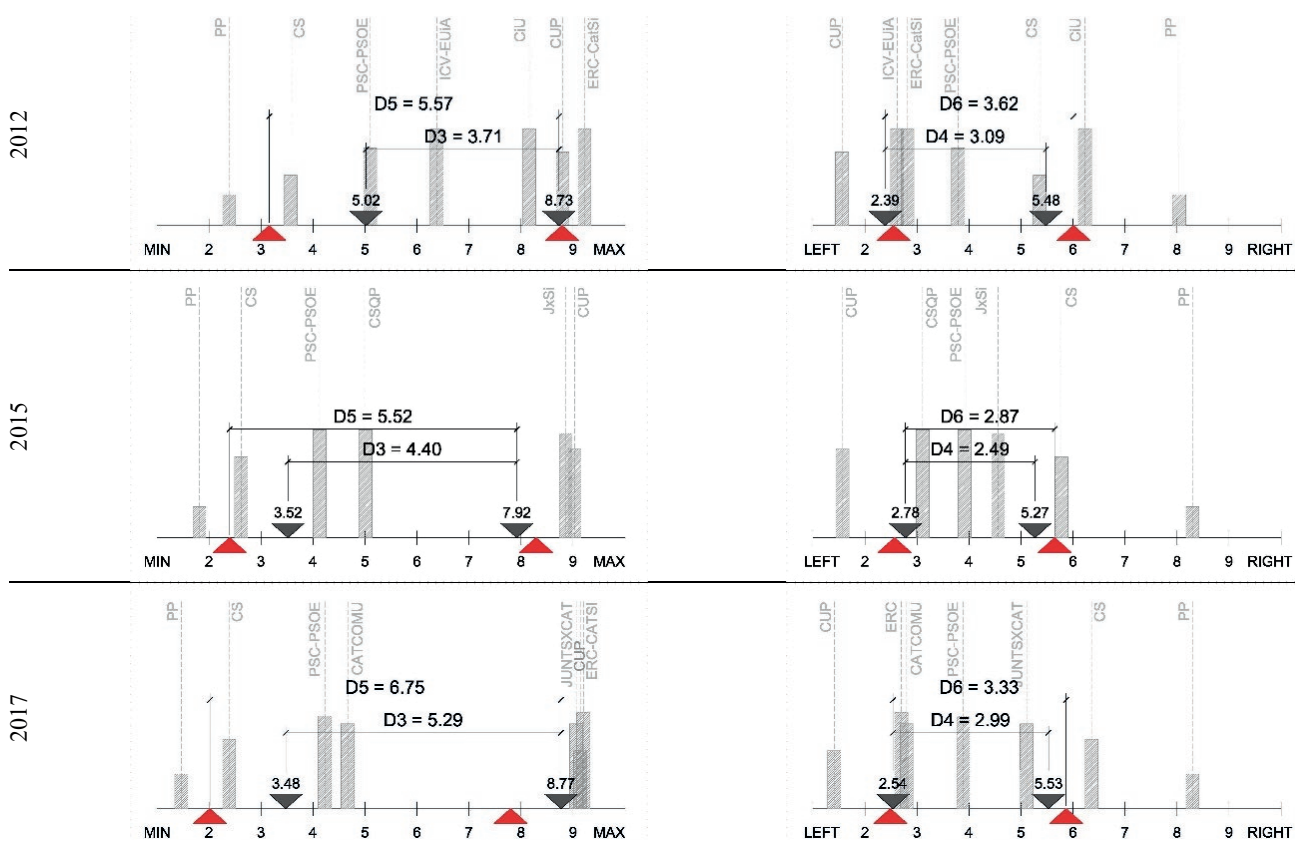


Figure AII.8. Political polarization expected from parliament composition. Notes: Own elaboration using the same criteria and data as in Figure 6.

Table AII.5. Seats assignment by ‘score voting’ electoral system.

Political parties			Seats assignment					
2012	2015	2017	2012		2015		2017	
			Score	Seats	Score	Seats	Score	Seats
Ciutadans	Ciutadans	Cs	1,202,391	15	1,547,363	21	1,643,301	17
CiU	JxSi	JxCAT	1,957,881	24	2,299,537	31	2,247,550	24
ERC		ERC	2,070,348	25			2,447,976	26
PSC	PSC	PSC	1,525,805	19	1,812,555	24	2,015,458	22
ICV-EUiA	CSQP	CatComu	1,848,175	23	1,785,635	24	1,932,901	21
CUP	CUP	CUP	1,593,823	19	1,779,746	24	1,522,872	16
PP	PP	PP	861,040	10	816,574	11	845,641	9
Total			11,059,464	135	10,041,411	135	12,655,699	135

Source: Own elaboration using the same data as Table 2.

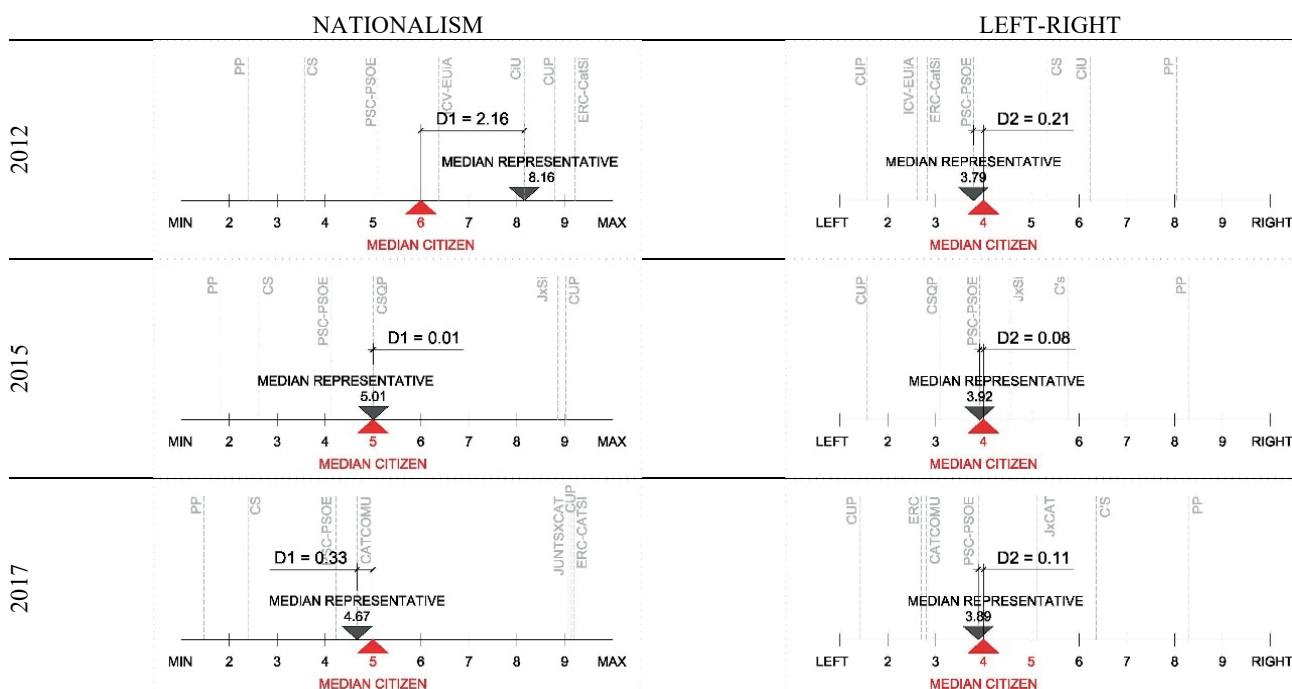


Figure AII.9. Ideological congruence representatives-citizenship. Notes: Own elaboration using the same criteria and data as in Figure 5.

4.6. Prll rule

We assign to each political party a collective preference proportional to its score/position according to Prll rule said party would have obtained given the preference profile of Catalonia citizenry. This electoral system would have built the following parliaments (Table AII.6).

To assess the adequacy of this electoral system, we firstly value the Representativeness of the Chambers by comparing the location of the median citizen and representative.

Figures AII.11 and AII.12 reveal that the aggregate preference of the parliaments a Prll electoral system would have built would also have been much closer to that of Catalonia citizenry, with high (or sufficient) closeness between the Median Representative and Citizen (D1 and D2). Secondly, we review the Polarization that can be expected from these Parliaments.

The graphs reveal that the parliaments a Prll electoral system would have built also would have generated extreme and increasing polarization in the Nationalism dimension (D3=2.91; 4.78; 5.47), yet somewhat lower in

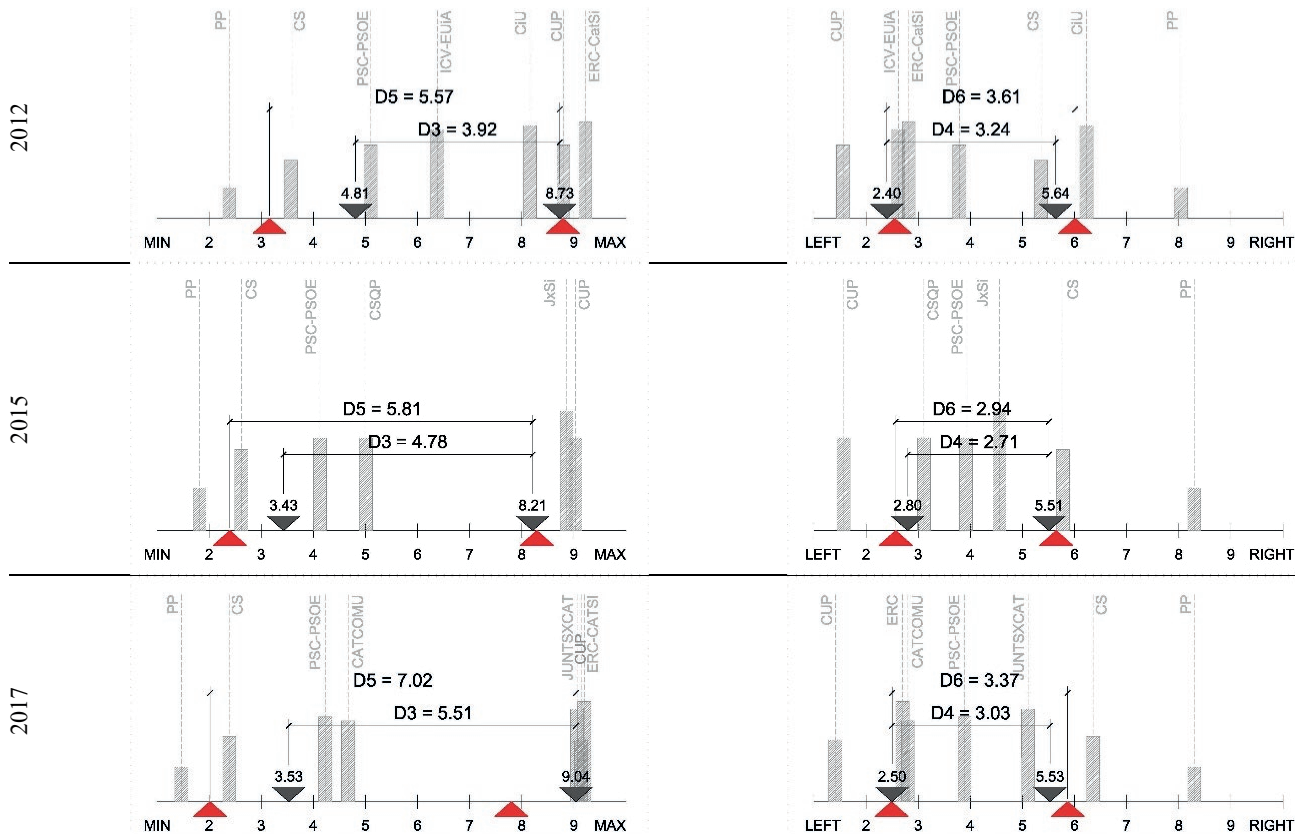


Figure AII.10. Political polarization expected from parliament composition. Notes: Own elaboration using the same criteria and data as in Figure 6.

Table AII.6. Seats assignment by 'prll' electoral system.

Political parties			Seats assignment					
2012	2015	2017	2012		2015		2017	
			Position	Seats	Position	Seats	Position	Seats
Ciudadans	Ciudadans	Cs	0.093	9	0.323	20	0.395	17
CiU	JxSi	JxCAT	0.915	29	0.432	27	0.539	24
ERC	PSC	ERC	0.876	28	0.408	26	0.605	26
PSC	PSC	PSC	0.863	16	0.408	26	0.515	22
ICV-EUiA	CSQP	CatComu	0.731	27	0.423	27	0.515	22
CUP	CUP	CUP	0.302	23	0.427	27	0.378	16
PP	PP	PP	0.523	3	0.139	8	0.201	8
Total			4.303	135	2.152	135	3.147	135

Source: Own elaboration using the same data as Table 2.

recent years than those generated by the current electoral system. Likewise, in general, there is a reduction in the ideological distance between representatives and citizens (D5) regarding the current situation.

The analysis indicates this electoral system could have – and still could – contribute to the moderation and advancing towards the resolution of the current conflict.

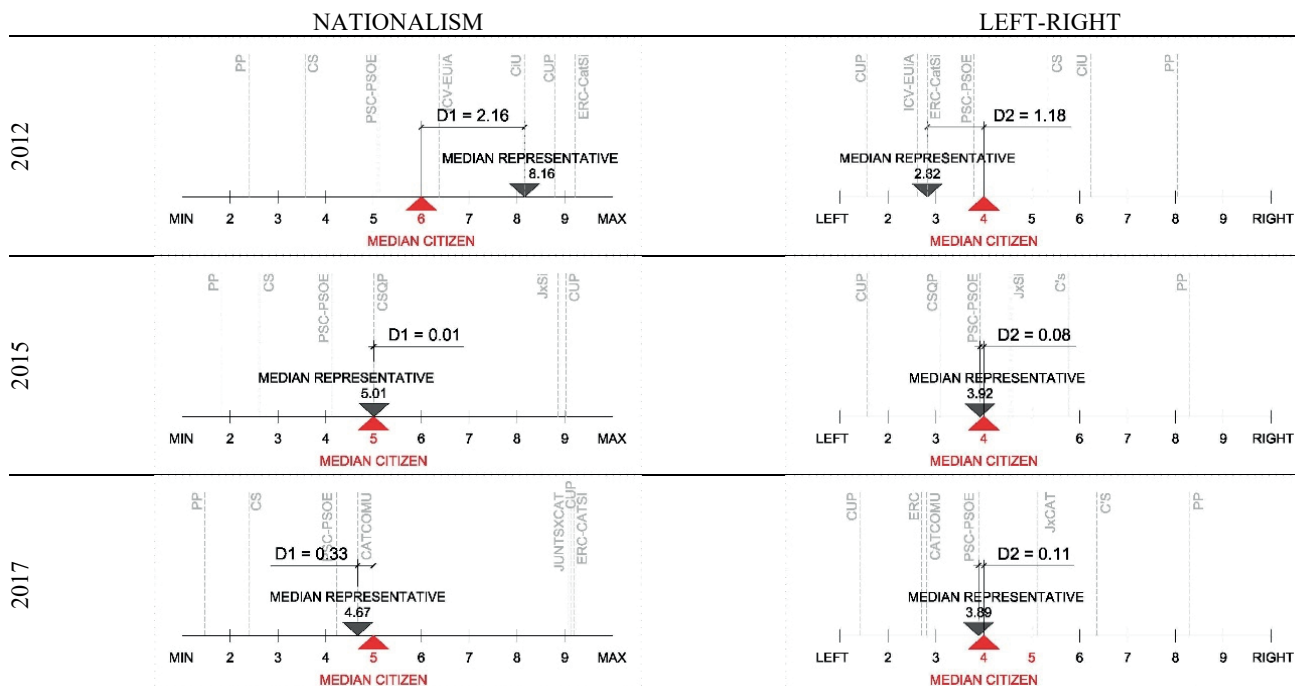


Figure AII.11. Ideological congruence representatives-citizens. Notes: Own elaboration using the same criteria and data as in Figure 5.

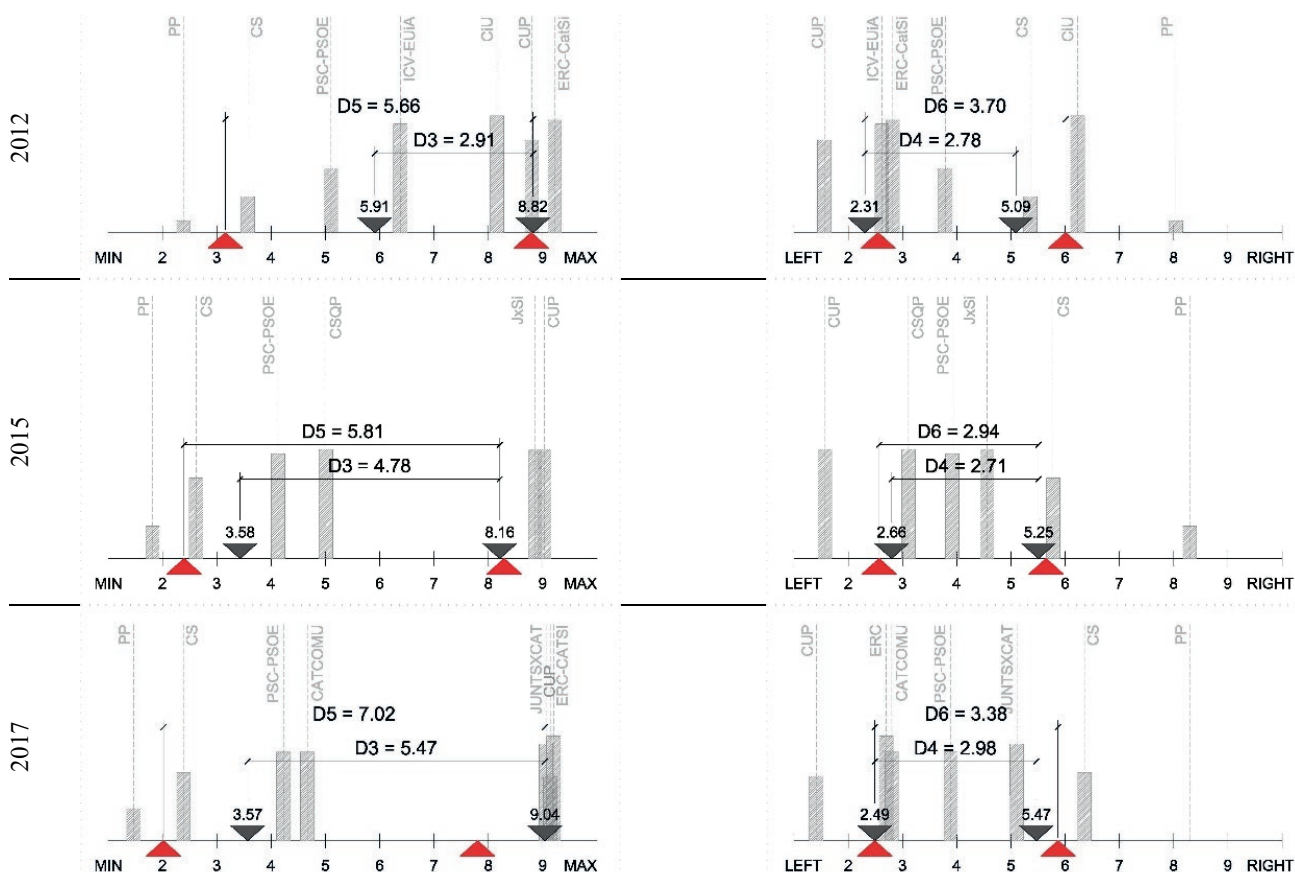


Figure AII.12. Political polarization emerging from parliament composition. Notes: Own elaboration using the same criteria and data as in Figure 6.