Diplomatic Relations in a Virtual World Supplementary Materials

Aaron Bramson[1,2,3], Kevin Hoefman[2,4], Koen Schoors[2], and Jan Ryckebusch[5]

[1]Laboratory for Symbolic Cognitive Development, RIKEN Center for Biosystems Dynamics Research, 6-7-3 Minatojima-Minamimachi, Chuo-ku, Kobe, 650-0047, Japan
[2]Department of General Economics, Ghent University, Tweekerkenstraat 2, 9000 Ghent, Belgium
[3]Department of Software and Information Systems, UNC Charlotte, Woodward 341, 9201 University City Blvd., Charlotte, NC 28223, USA
[4]Howest University College West Flanders, Marksesteenweg 58, 8500 Kortrijk, Belgium
[5]Department of Physics and Astronomy, Ghent University, Proeftuinstraat 86 9000 Gent, Belgium

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Corresponding author
Aaron Bramson

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John Doe

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A Additional Details

A.1 Further Details of *Eve Online*

Players. There are between 400,000 and 500,000 accounts created for playing *Eve Online*. On average 33,000 accounts are signed on simultaneously during our analysis period (Eve-Offline 2018). The number of participating players fluctuates, and many advanced players have multiple characters and/or accounts: the total number of registered characters exceeds 10 million. EVE's core player base is extremely dedicated: there are multiple annual game-related conferences, some drawing thousands of attendees from all over the world.

Corporations. All characters belong to a corporation, some of which are default non-player character (NPC) corporations run by the game itself, and others which are owned and run by players. Players can create and close corporations, so the number of corporations and their memberships change over time; however, there are consistently around 380,000 distinct corporations. Existing corporations have between 1 and roughly 12,000 members – many of the successful, long-lived corporations have memberships in the thousands (EveWho 2017). The leader of a corporation has complete power to determine corporate policies and represent the corporation, although the duties can also be shared among a body of directors and the leader can be replaced through a shareholder vote (UniWiki 2017).

Alliances. Corporations can unite to form alliances.[1] The largest alliance has more than 28,000 player members combined from more than 500 corporations. Most successful and long-lived alliances have thousands of player members and dozens of corporations (EveWho 2017). The player who is elected to run the alliance has the authority to decide which other alliances, corporations and/or individual players are enemies, and which are allies. Standings towards other alliances, corporations and individuals are set on a scale from -10.0 (sworn enemy) to +10.0 (close ally); or they can remain unset. A standings value of 0.0, indicating a neutral disposition, is distinct from having standings unset. Alliance standings are directed, and need not be reciprocal (see section A.3). Within the game, ships belonging to an enemy alliance show up as red, indicating to players that they are potential targets, and that they are free to engage in aggression themselves. Friendly alliance ships appear blue, and ships in alliances with unset standings appear white (which matches the various other neutral objects like stations and asteroids). Alliance members who attack friendly players (colloquially called "blues") are typically punished by their own alliance, by paying a fine or being kicked out. In some cases, these actions can trigger a large-scale conflict.

Geography. The game universe consists of 7930 solar systems, located in three-dimensional space and connected by a network of (mostly) short-range transportation channels, connected to fixed-location gates within each system. Although some expensive ships are capable of ignoring the connections network by directly jumping to systems within a certain range, most travel is done by jumping to neighboring systems through the gate network. Travel within a solar system may be just from gate to gate, but potential destinations include various stations, planets, moons, asteroid belts, landmarks, and mission areas. The setup is similar to a network of islands, well-connected to nearby islands via bridges. As a consequence, travel distance is best captured by network distance, but Euclidean distance is still appropriate for the physical separation of regions on the map.

Security. Of the 7930 solar systems, 5201 are normally navigable. These are further divided into three categories by their security level: high security systems (1090) are generally safe to travel and provide protection from attacks by other players, low security systems (817) offer much less protection and a more dangerous environment, and hostile and unregulated null security systems (3294). In addition, there are another 230 unreachable systems, used as a company testbed. The remaining 2499 systems are reachable using special equipment/skills (so-called "Wormhole space").

1. Corporations can remain independent, and some do, but the sizes of non-alliance corporations are roughly one-fifth the size across a ranked comparison.

Sovereignty. Of the 3294 null security systems, 2712 are conquerable by players. In these conquerable systems, alliances can hold sovereignty (ownership) over a system's stations and resources. Sovereignty allows an alliance to extract resources from the system, for example through mining operations or taxation, as well as to exert control over access to its stations. Many alliances do not hold sovereignty over any systems; for example, because they operate solely within high-security space or in abnormal wormhole space. Although these alliances also set standings to one another, we may assume these standings convey less information about the mutual political relations, since the parties involved can neither engage in territorial conflict with one another, nor block others from accessing their stations. An exception to this is some "renter alliances" that operate in sovereign space and defend their own assets there but live in the space of other alliances instead of managing their own. We therefore perform separate analyses for (1) all alliances with more than 200 members and (2) alliances holding sovereignty over at least one system at some time during the sample period (all these alliances turn out to have more than 200 members).

Coalitions. Alliances sometimes further coalesce into so-called coalitions: sets of alliances that cooperate for purposes of mutual protection and coordinated attack. Coalitions are emergent social superstructures. Their existence was neither planned, nor foreseen by the game designers, and there is no official designation or in-game support for these structures. Coalition members typically maintain strong positive relations to one another, and tend to share the same set of enemies. Despite there being no official record of coalition membership in the game, nor any direct effect of coalition membership to the game mechanics, the existence of these social superstructures can be confirmed through player chat logs and online forums. In the section on Polarization we show that the structure of the coalitions mirror the polarized groups predicted by structural balance theory – with some noteworthy differences. The mere existence of emergent self-organized coalitions of political alliances in the game lends credence to the applicability of balance theory to this virtual world and on the usefulness of virtual worlds to further study balance theory.

Standings. As described above, alliance executors can set the standing of their alliance with respect to other the alliances. By default there is no connection, and while ships of unconnected alliances will tend to attack each other (for fun and profit) these battles tend to be small, isolated skirmishes that do not effect the standings relationships. An exception to this is the not-red-don't-shoot ("NRDS") policy of a coalition of alliances called the Providence Holders Coalition ("Provi-Bloc"). These alliances have a policy of not shooting anybody who is a member of a friendly ıor unset alliance, but they also go out of their way to set as enemies any alliance whose members ever attack them. Unfortunately this makes their standings data incommensurable with the other alliances, but fortunately through most of our dataset there are only six sovereign alliances that are part of the Provi-Bloc coalition and we present our analysis with them excluded. The lack of a standing relationship is also highly correlated with those alliances' members infrequently interacting – because of the distance between their territories and/or because their goals do not intersect.

A.2 Structural Balance Theory

As stated earlier, the core of our analytical approach is based on structural balance theory (Heider 1946; Cartwright and Harary 1956; Harary 1959). The technical aspects of balance theory have evolved over time, and we further develop the method in this paper. Originally, researchers focused on all cycles in the social network, and classified networks as balanced if all cycles had an even number of negative links – otherwise they were unbalanced. (Hart 1974) includes two measures from (Harary, Cartwright, and Norman 1965): β, the proportion of semicycles that are positive; and λ, the minimal number of edge removals or flips necessary to balance the network. Starting with (Abell 1968) it has become standard practice to examine only triads (aka: triangles, connected triplets, 3-cycles) in the network (although also see (Facchetti, Iacono, and Altafini 2011)). Typically, the triads are considered balanced (or stable) when there are zero or two negative edges, and unbalanced (or unstable) if there are either one or three negative edges. However, it can be more insightful to look at all four types of triads separately. Rather than classifying a network as balanced or unbalanced, we are interested in the proportions of each type of triad.

From a static perspective, we can determine whether the proportion of frustrated triads is smaller or larger than expected compared to random signed networks. However, since balance theory is really about network dynamics, it has become common to measure aggregate frustration over time. This approach has been applied to both simulations (Hummon and Doreian 2003; Antal, Krapivsky, and Redner 2006) and empirical networks (Leskovec, Huttenlocher, and Kleinberg 2010; Szell, Lambiotte, and Thurner 2010; DuBois, Golbeck, and Srinivasan 2011). Balance theory implies that not only should the frustrated triads constitute a small proportion of the total network, but also their prevalence in the system should exhibit a decreasing trend (unless some event injects new information into the system). Although the theory operates at the level of individuals triads, because triads share edges, the change of a single edge can set in motion a series of subsequent edge changes, as the frustration cascades throughout the network. (Bramson *et al.* 2017).

The game offers a great deal of anecdotal evidence suggesting that players face situations and choices matching the premises of social balance. When an alliance sets a positive or negative standing to another alliance, this has a direct effect on the behaviors of everybody in both alliances (often many thousands of players), as well as indirect effects on other alliances. One such example is described in an anecdote from the history of the BRUCE alliance:

> When BRUCE first arrived in Y4Y7, a constellation in southern Syndicate at the invitation of COE, they were forced to also become friends with Anarchy Empire – a rather unpleasant group of pirates that COE had befriended. BRUCE held a closer philosophy to that of the OSS at the time and became blueboxed [i.e. had positive standing] to both OSS and the COE/AE pair. This was a strange step as the OSS faction and COE/AE faction were hostile to each other, and led almost immediately to problems in the area.
>
> This very early diplomatic challenge for BRUCE was, in their own words, handled poorly. BRUCE ended up dumping the OSS bluebox less than a week after gaining it because they, understandably, did not want to fire on COE whom invited them to Syndicate. Despite BRUCE's loathing of Anarchy Empire's philosophies they valued their word to COE more. [Soon after]…war erupted between BRUCE/COE and the OSS. (EVE-history.net 2011).

Such a story strongly indicates that theories for the dynamics of international relations in general, and structural balance theory specifically, have gainful application to alliance relations in EVE.

A.3 Making the Edges Symmetric

Although early versions of balance theory were based on directed networks, and (Hart 1974) proposed a measure of frustration as the proportion of balanced 2- and 3-semicycles, nearly all work on structural balance theory uses undirected networks. In EVE, alliance leaders set alliance standings toward other alliances, so standings are directed edges. Although not completely symmetric, they are nearly so with an average matched sign reciprocity of 84% (see Figure A.1). One coalition called Provi-Bloc has a nonstandard policy of setting standings known as "Not Red, Don't Shoot" (NRDS). Rather than leaving most standings unset, Provi-Bloc sets enemy standing to anybody who isn't explicitly an ally. This difference in interpretation leads to a situation where a number of mutual relations appear asymmetric in the dataset but are actually symmetric in practice. These can be seen as red bands of negative standings in the Standings Matrix plot (main paper).

Near symmetry has been observed in other signed networks as well; for example, (Facchetti, Iacono, and Altafini 2011) reports that the directed edges in Epinions, Slashdot, and WikiElections signed networks are nearly symmetric. The reason for symmetry is clear in the game's context: if X is an ally of Y, while Y is an enemy of X, then players in Y may get penalized if they return fire when players in X attack them. Such reasoning/motivation would be present in any aggression-modulating political standings. Considering the ubiquity of symmetry in these networks, the deviations from reciprocity may reveal interesting nuances about the relations in these datasets.

During the timeframe of our analysis, alliances set standings using values between -10 and 10 in increments of 5. In the game, the standing value between a player's alliance and that of others' ships/assets are displayed as colors: +10/very friendly = dark blue, +5/friendly = light blue, 0/neutral = white, -5/hostile = orange, and -10/very hostile = red. Previously, any value between -10 and 10 was allowed, but what matters to most players is whether the standing is positive, negative, zero,

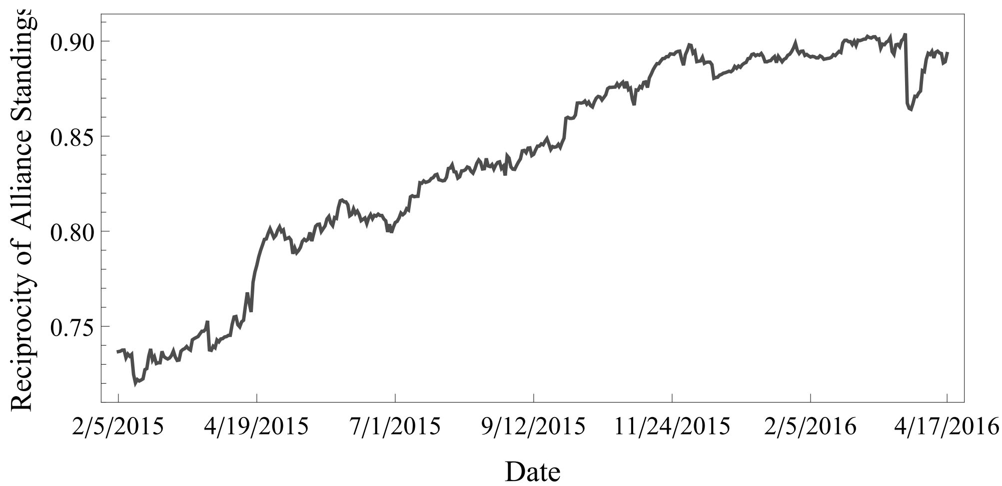

Figure A.1. The daily proportions of reciprocal standings between pairs of sovereign alliances. Alliance standings are reciprocal when they have the same valence (positive, negative, or unset) in both directions. A standing of zero counts as a negative in this plot. The trend of increasing reciprocity is another indicator of frustration reduction, however it can be partly explained by the increased number of non-Provibloc coalition alliances. Due to their non-standard rule of setting all non-friendly alliances as enemies (rather than leaving them unset), the lower the proportion of alliances that is constituted by Provibloc the larger the reciprocity is going to be.

or unset. While other, specific values could be used as a signaling device among alliance leadership, they were rarely used in practice and so the system was simplified.

Although we incorporate several weighting schemes for triads in our analysis, including a triad weight based on the total directed standing values, in the current analysis we do not use the directed standing weights in the counts and types of triads. To determine the valence for our undirected network, we set the links to be negative if either direction is negative/neutral, and positive if both directions are positive, or one is positive and the other is unset. Neutral standings (value 0) are considered negative because in EVE, any player who isn't flagged as friendly is likely to be attacked. This policy, employed by most players in the game, is called NBSI, for "Not Blue, Shoot It". Under NBSI, players with unset standings are equally likely to be met with hostility, and setting the standing to 0 makes it clear that such hostilities are permitted, without explicitly declaring the target an enemy.

A.4 Triadic Network Transformation

Our analysis below first looks at the levels of frustration through daily time-slices of the network structure of positive and negative links; however, we delve deeper to better understand triad *dynamics* and contingent behaviors. Although solutions for studying network dynamics such as RSIENA (Snijders 2017) already exist, they rely on the dyadic structure of networks. Because we are interested in the dynamics of the triadic superstructure that emerges from the structural balance interpretation of the underlying network data, we transform the network of alliance relationships into a triadic network. This transformation is illustrated in Figure A.2, and explained in more detail in Bramson *et al.* 2017 where a temporal network version of this novel triadic network representation is used to identify frustration cascades.

To build a triadic network, we generate a *triadic node* for each triplet of alliances in the network. These triadic nodes store the relevant properties for the state of the triad that we are interested in (e.g., how many positive and negative edges or whether it is frustrated), allowing us to track triad changes over time, as well as apply weights to the triads based on their properties (see below). Connections between triadic nodes are the edges of the original alliance network that are shared by pairs of triadic edges, so each edge of the original network can appear many times in the triadic network (see edge labels in Figure A.2).

Given a dyadic network of N nodes, the derived triadic node network contains a number of

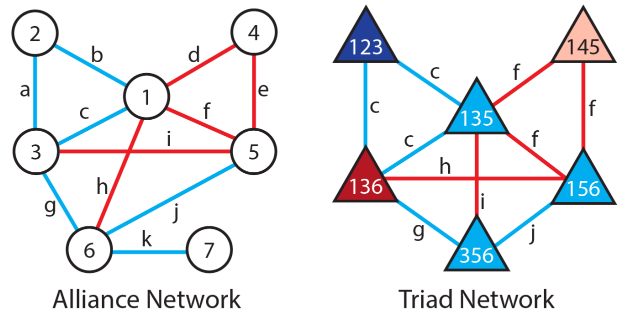

Figure A.2. Left: an alliance network consisting of 7 nodes connected by positive and negative standing edges. Right: (part of) the derived triadic network reflecting which edges are shared between pairs of triadic nodes. Dark blue indicates strongly balanced, light blue is weakly balanced, pink is weakly frustrated, and the red node is strongly frustrated.

triadic nodes equal to:

$$\frac{N!}{3! * (N-3)!} = \frac{N * (N-1) * (N-2)}{6} .$$

For our dataset of 607 alliances, the resulting triadic network contains approximately 37 million triadic nodes and approximately 1,375 trillion possible edges. This is far greater than most systems and software can handle. To make the above achievable, we wrote our own analysis toolkit in C++ that exploits the structure embedded inside the triadic network. Because we know how the triads are constructed, we also know how they are connected. In a fully created triadic network, each edge in the alliance network is replicated (N-2) times to connect (N-2) triads. Each triadic node is connected to (N-3) other triads per edge, for a total of 3 * (N-3) other triads. We construct the triadic network in computer memory using object-oriented software techniques: the triadic nodes and the edges of the original network are the objects in the software model, and the triadic nodes are interconnected through the edge objects via memory addresses.

A.5 Calculating the Weights.

Although the calculations of our weights are probably straightforward and unambiguous from the description in the main text, here we provide the details to ensure total transparency. Consider a triad made up of three alliances A, B, and C. First we standardize each property ρ for each node or edge i to be between 0 and 1 using the standard method:

$$\frac{\rho_{i,t} - \min \rho}{\max \rho - \min \rho} .$$

That is, each value at each period is regularized by the minimum and maximum values over the entire time series so that changes in the values across time are not influenced by changes in the maximum or minimum values at a particular time. This is important because alliances gain and lose members, gain and lose systems, and move locations over time. The triad weighting for the number of members (W1) is calculated by

$$\mathcal{M} = \sqrt[3]{M_A \cdot M_B \cdot M_C}$$

and weighting by the number of systems an alliance holds sovereignty over (W2) similarly becomes

$$\mathcal{S} = \sqrt[3]{S_A \cdot S_B \cdot S_C} .$$

For distance weightings we use the Euclidean distance between the coordinates of the centroids of the systems each alliance holds sovereignty over:

$$D_{ij} = \sqrt{(\bar{x}_i - \bar{x}_j)^2 + (\bar{y}_i - \bar{y}_j)^2 + (\bar{z}_i - \bar{z}_j)^2},$$

where $\bar{x}$, $\bar{y}$, and $\bar{z}$ are the mean of the x, y, and z coordinates of the alliances' systems at that time. The distances are then standardized by the maximum and minimum distances described above. The closer the alliances are to one another, the stronger the weight should be, so the distance weighting (W3) is calculated using

$$\mathcal{D} = 1 - \sqrt[3]{D_{AB} \cdot D_{BC} \cdot D_{CA}}.$$

(Below we also analyze a distance weight using the two closest systems.) The standings weights (W4) are calculated from the directed edges weights (W_{ij}) composing it as

$$\mathcal{W} = \frac{1}{60} \sum_{i=1,j=1,i \neq j}^{3,3} |W_{ij}|.$$

Neutral edges add a standings weight of 0, while both strong friends and strong enemies add 10 for each of up to 6 edges, hence the 1/60 normalization factor. For the combined weighting (W5) we use the arithmetic mean of these four weights:

$$\mathcal{C} = \frac{\mathcal{M} + \mathcal{S} + \mathcal{D} + \mathcal{W}}{4}.$$

Because each weight is already rescaled to the [0, 1] range, the combined measure is always within that range, without being again rescaled to fill that range.

A.6 Additional Triad Details

An alliance is included in every time period if it satisfies the inclusion condition (being large and/or sovereign) at any point during the analysis period. However, if the alliance was formed/dissolved during the analysis period it will (obviously) not be part of any triads before/after that time.

The number of large alliances climbed from 311 at the beginning, peaked at 348 in the middle of the dataset, and dropped back to 312 at the end (see time series plot in Supplementary Materials). However, there are actually 607 unique alliances that meet the criterion of having 200+ members within our analysis period, and all 607 of these alliances are included throughout our analysis. The number of triads among the large alliances grew steadily (though non-monotonically) from 50,265 to 170,296 during our analysis period. Although some increase can be attributed to alliances that come into existence and quickly become large during our analysis, such a dramatic growth in triads can only be explained by an increase in the edge density of the standings network.

Compared to large alliances, the numbers of sovereign alliances instead saw consistent growth from 83 at the beginning to 154 at the end with 282 unique alliances holding sovereignty over at least 1 system within our analysis period. Again, we include all 282 of these alliances throughout the analysis; i.e., the triads they form with other sovereign alliances are included at time t even if that alliance doesn't hold sovereignty at time t as long as it exists at time t and holds sovereignty at some point during our analysis period. The number of triads among these alliances grew from 10,490 to 45,373 during our analysis period. Comparing the ratio of active alliances to total unique alliances we can see that there is more churn among the sovereign alliances, thus reflecting that sovereignty is a more competitive status.

A.7 Detecting Coalitions

The alliances in EVE form unofficial coalitions: political super-entities that are not part of the game's mechanics, yet are widely recognized by players. Coalition dynamics include tacit internal no-conflict pacts, and joint strategizing among member alliances. We use player-reported, daily coalition data from (Chuggi and Sky 2017) in the form of unofficial, yet widely used, coalition maps to assess how well the network structure of actual alliance standings corresponds to these player-reported coalitions.

Note, however, that this data is collected and reported by players, which has several limitations. For one, there are instances where alliances we know to hold sovereignty on a given day are unrepresented on the maps for that day. Our analysis here is limited to the alliances for which we actually have coalition membership data. These exclusions could be because the alliances are too small to bother; are widely known to the players to be closely associated with other alliances; or are simply not members of one of the existing coalitions. In any case, no reasons for their exclusion are provided. Also, the provided maps only cover sovereign space (the part of the map where ownership is possible), whereas coalitions between non-sovereign alliances also do exist. Non-sovereign alliances occasionally also participate in the coalitions reported in the data. This isn't a major problem because sovereign space is our main focus (for reasons explained above), but it does limit the option of expanding the analysis to include other parts of the EVE universe.

Because coalitions do not officially exist inside the game, only player-reported, hand-drawn coalition maps are available, we are unable to directly perform a systematic analysis of coalition dynamics across time. Despite these limitations, these player-reported maps are the best record of alliances' membership in coalitions, and we can use them to perform a preliminary test of the hypothesis that structural balance guides the formation of polarized coalitions.

Measure of Accuracy.

After using a vector distance or network community method to partition the alliances into proposed coalitions, we need to determine how accurately they matched our best reference for the "real" coalitions. Naturally, a perfect match (getting "full points") occurs when each member of a discovered coalition is a member of that coalition in the player-reported data as well. In our approach, matches start with a full score and are then penalized for mismatches.

For each discovered coalition, we find the distribution of real coalitions for those members. We then identify the real coalition with plurality within the discovered coalition, and use it as the matching real coalition.[2] For each member of a discovered coalition that is not in the same real coalition as the plurality, we reduce the accuracy by one point. The points are then normalized by the number of alliances to create a percent accuracy score.

Note that even though this method does not directly penalize the splitting of a real coalition into two discovered coalitions, because we restrict the number of discovered coalitions to the number of real coalitions (in the case of vector distance methods), this error is still penalized insofar as it forces the displaced alliances to be associated with some other (incorrect) coalition. Thus, this measure penalizes each mismatched alliance exactly once.

2. In the case of ties we choose the first coalition by index, because the decrease in matching score is the same regardless of which tied coalition is chosen.

A Appendix: Large Alliance Triad Time Series

A.1 Large Alliances - Unweighted

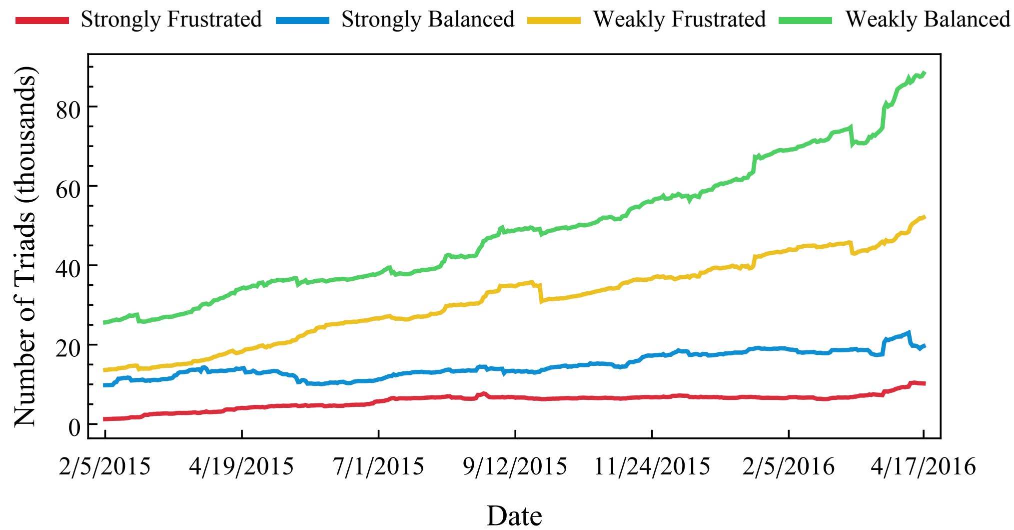

Figure A.1. The number of each triad type per day among alliances with more than 200 members.

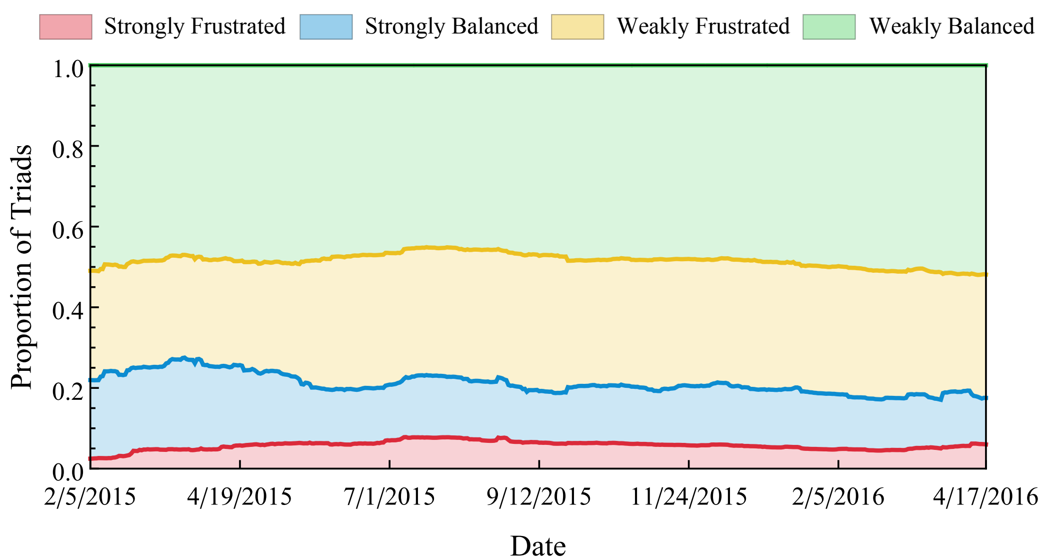

Figure A.2. The daily proportions of each triad type among alliances with more than 200 members.

A.2 Large Alliances - Member-Weighted

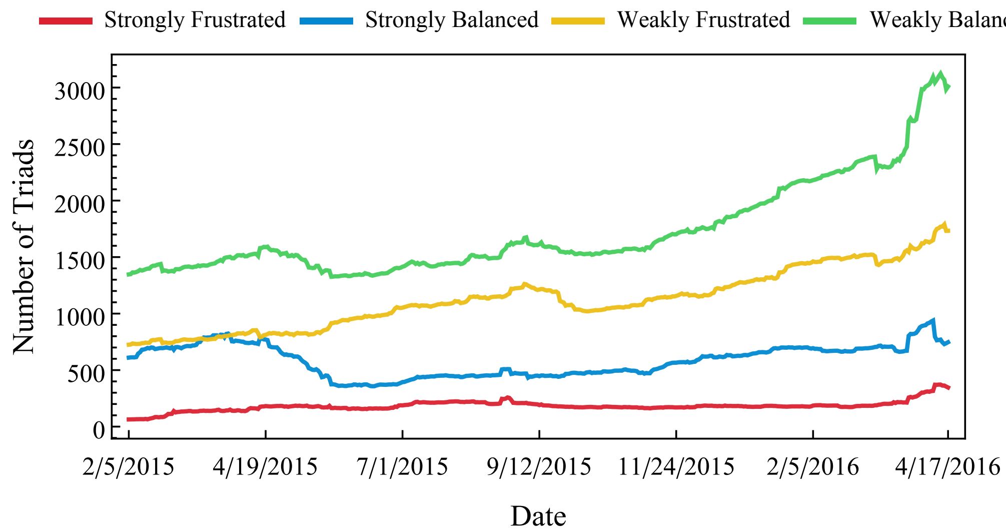

Figure A.3. The number of each triad type per day weighted by membership among alliances with more than 200 members.

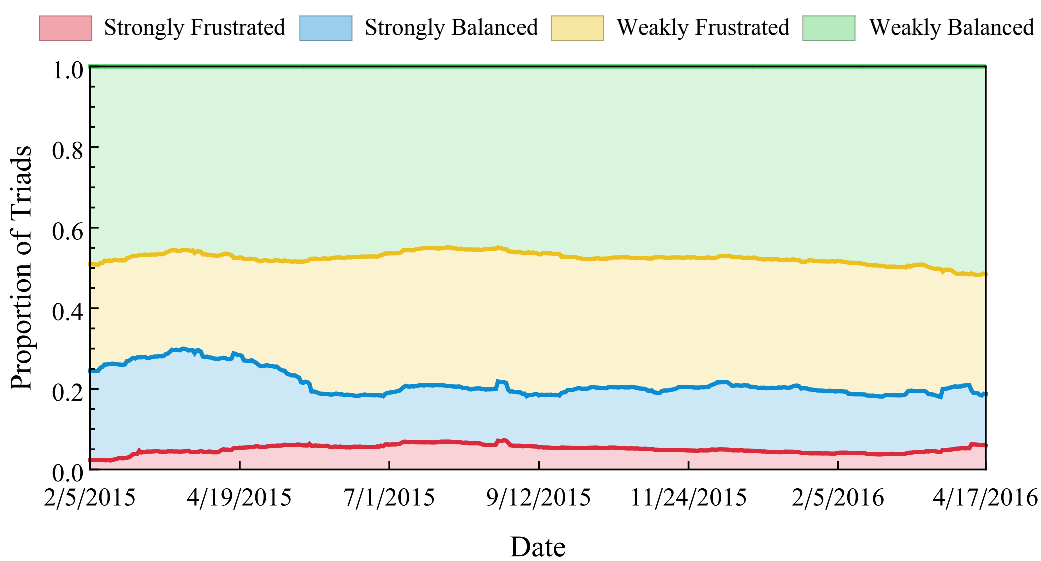

Figure A.4. The accumulated proportions of each triad type per day weighted by membership among alliances with more than 200 members.

A.3 Large Alliances - Sovereignty-Weighted

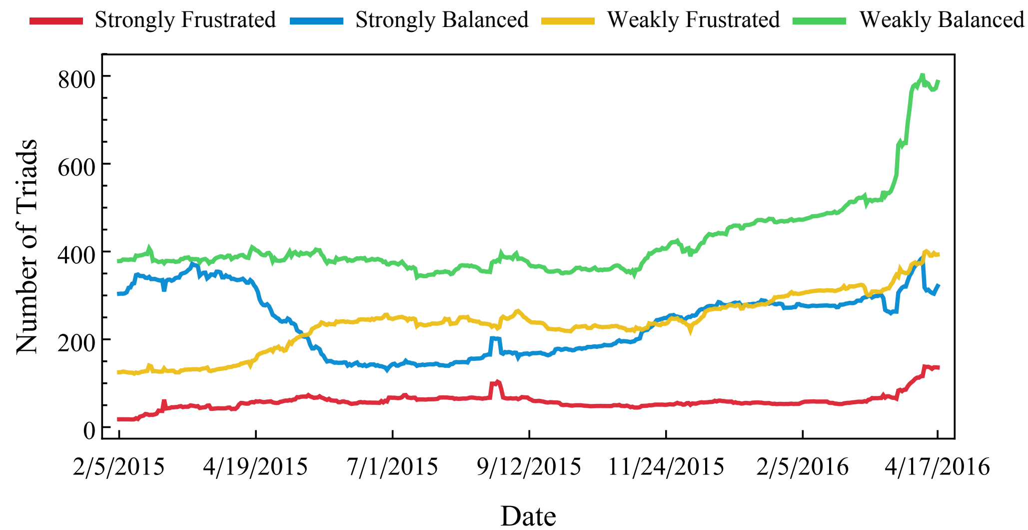

Figure A.5. The number of each triad type per day weighted by sovereignty among alliances with more than 200 members.

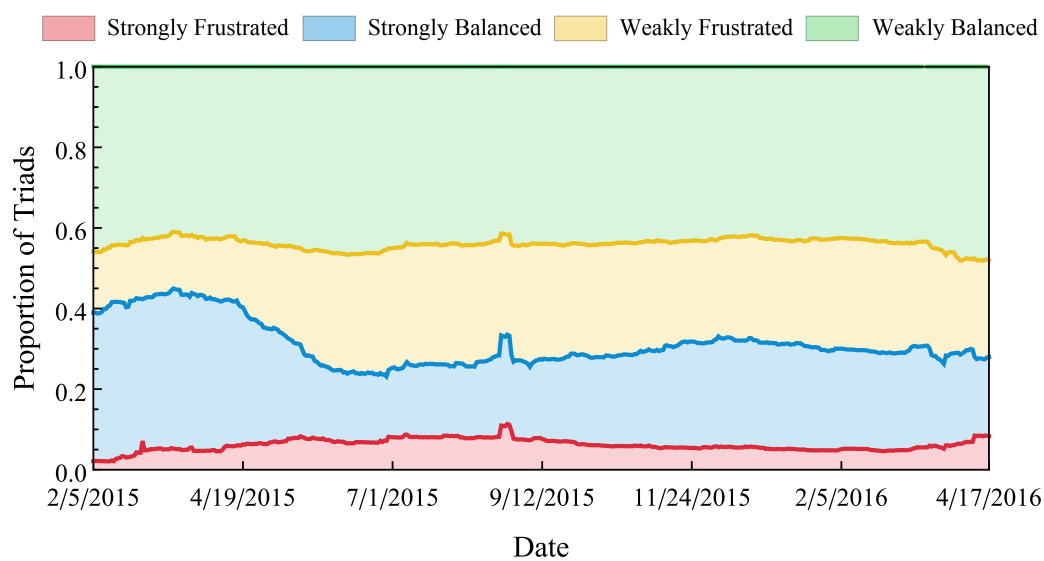

Figure A.6. The accumulated proportions of each triad type per day weighted by sovereignty among alliances with more than 200 members.

A.4 Large Alliances - Distance-Weighted

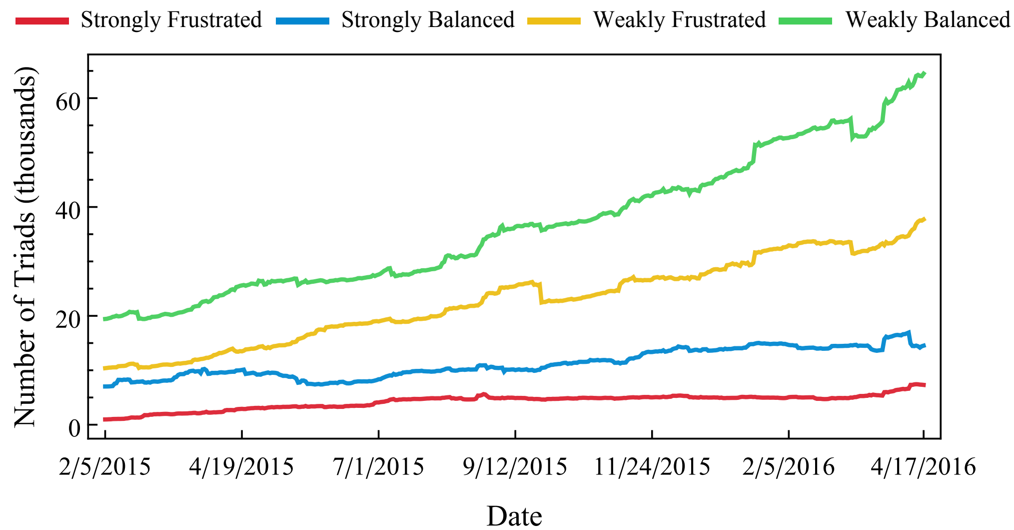

Figure A.7. The number of each triad type per day weighted by distance among alliances with more than 200 members.

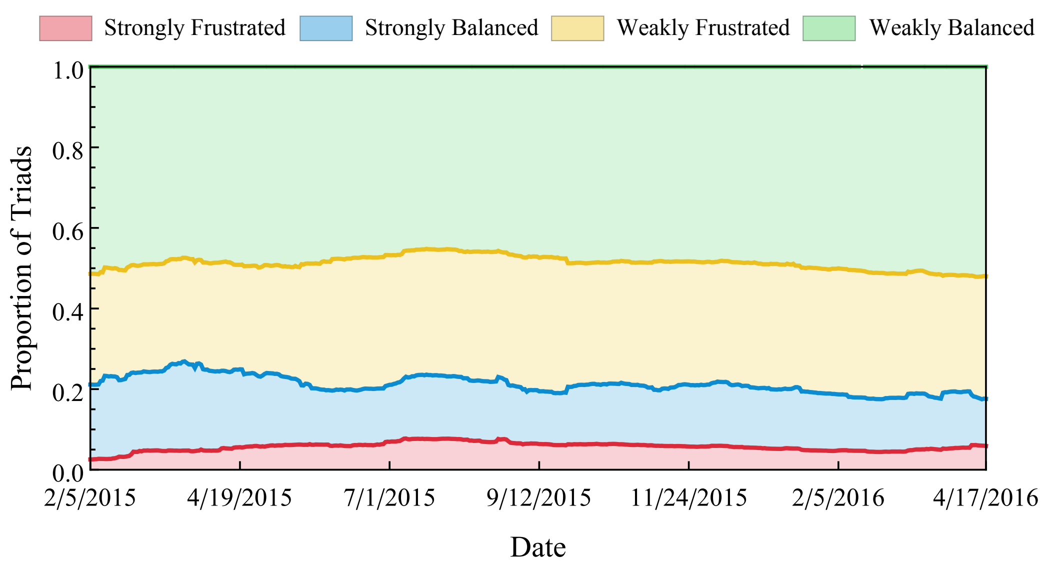

Figure A.8. The accumulated proportions of each triad type per day weighted by distance among alliances with more than 200 members.

A.5 Large Alliances - Standings-Weighted

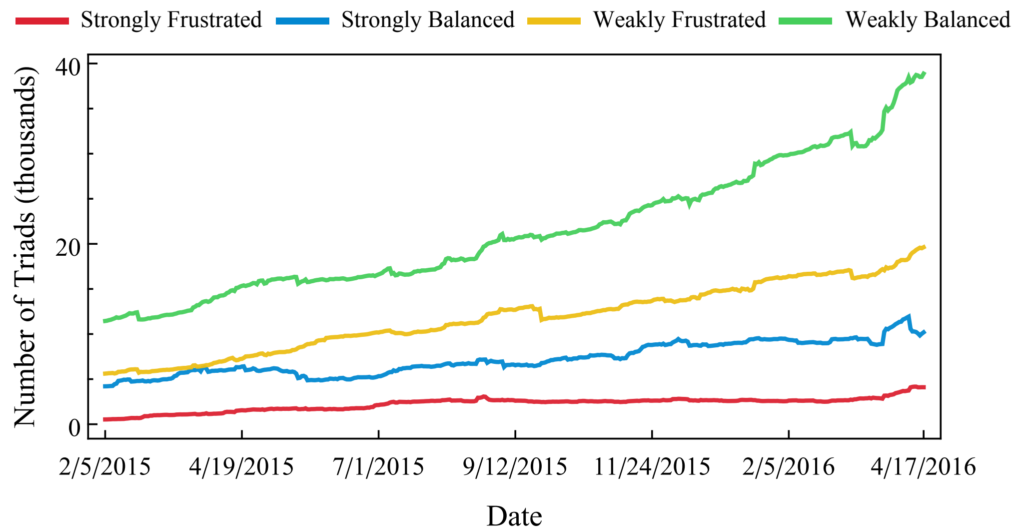

Figure A.9. The number of each triad type per day weighted by standings value among alliances with more than 200 members.

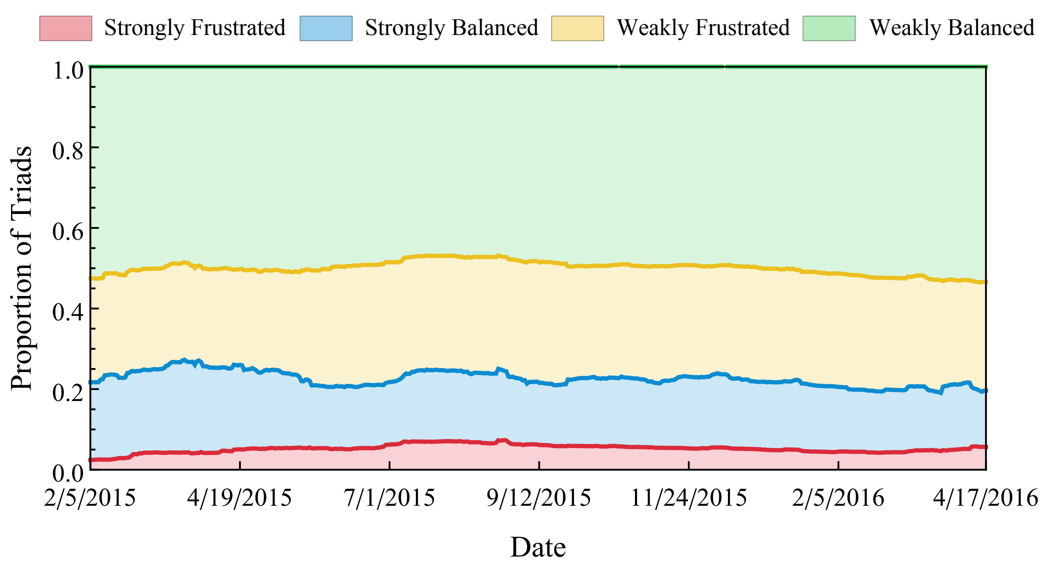

Figure A.10. The accumulated proportions of each triad type per day weighted by standings value among alliances with more than 200 members.

A.6 Large Alliances - Combined-Weighted

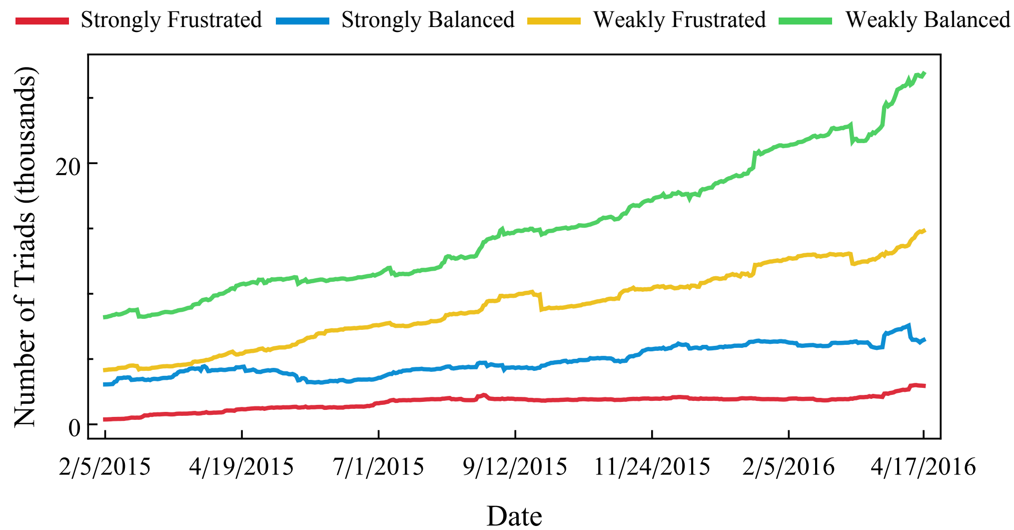

Figure A.11. The number of each triad type per day weighted by the average of all four weights among alliances with more than 200 members.

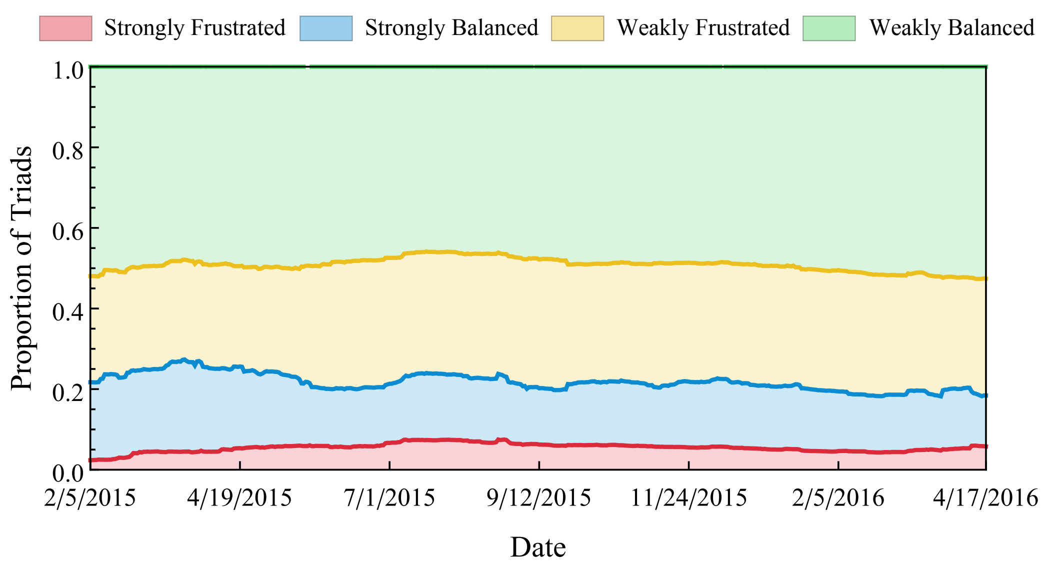

Figure A.12. The accumulated proportions of each triad type per day weighted by the average of all four weights among alliances with more than 200 members.

B Appendix: Sovereign Alliance Triad Dynamics

B.1 Sovereign Alliances - Unweighted

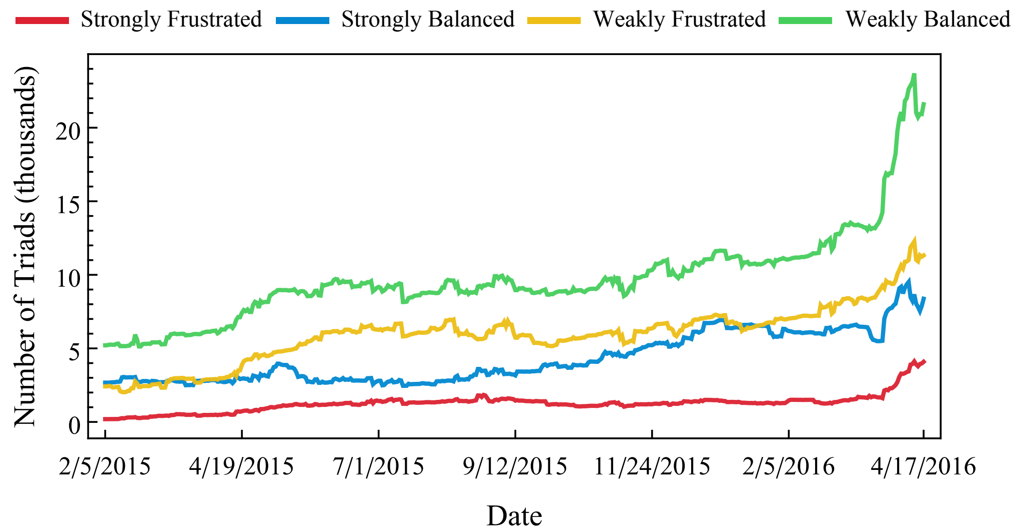

Figure B.1. The number of each triad type per day among alliances that hold sovereignty.

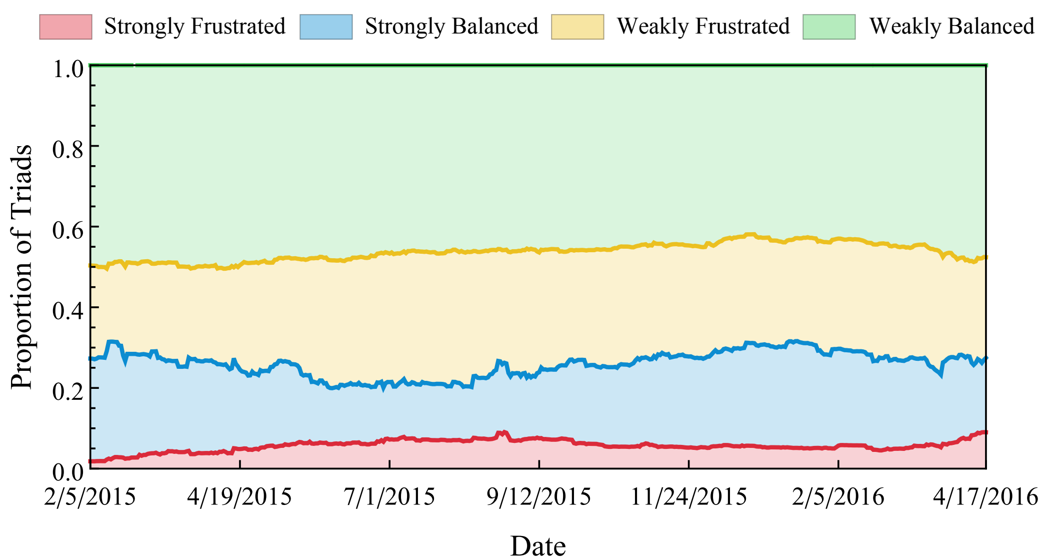

Figure B.2. The accumulated proportions of each triad type per day among alliances that hold sovereignty.

B.2 Sovereign Alliances - Member-Weighted

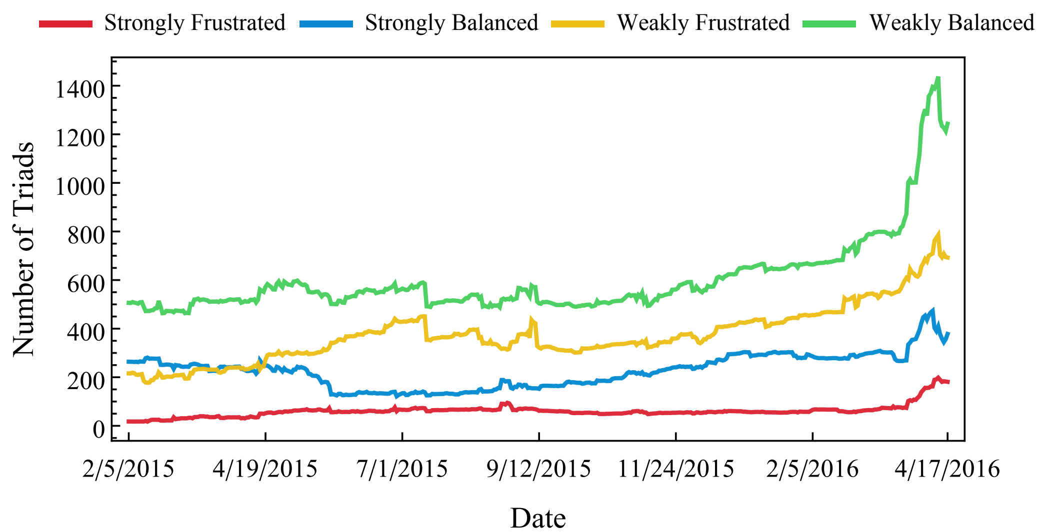

Figure B.3. The number of each triad type per day weighted by membership among alliances that hold sovereignty.

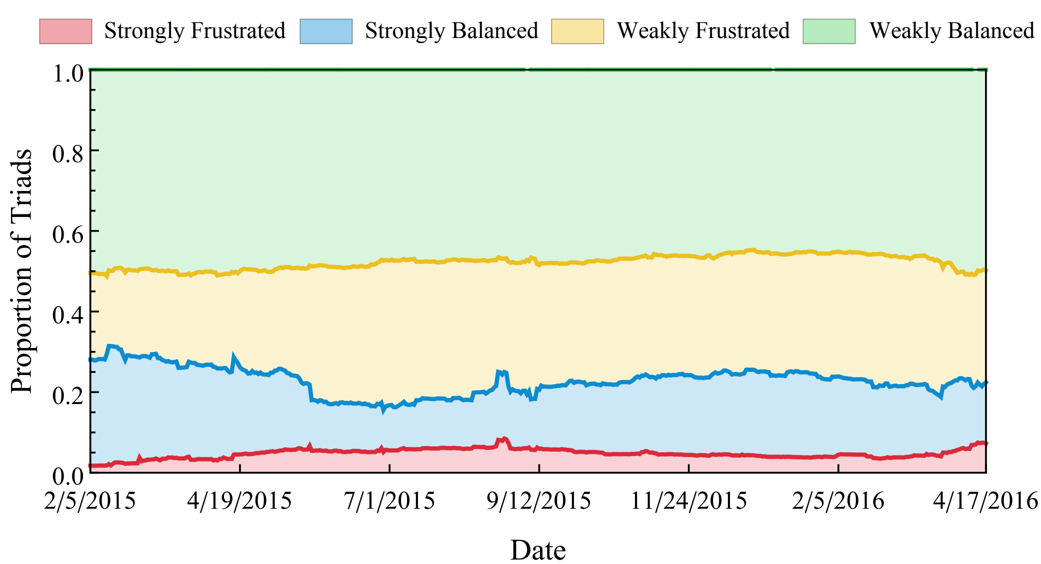

Figure B.4. The accumulated proportions of each triad type per day weighted by membership among alliances that hold sovereignty.

B.3 Sovereign Alliances - Sovereignty-Weighted

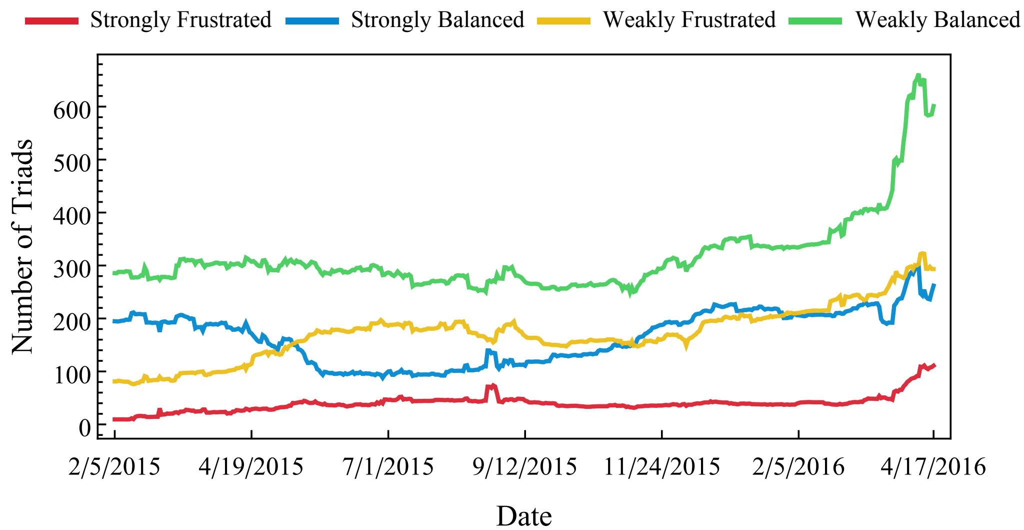

Figure B.5. The number of each triad type per day weighted by sovereignty among alliances that hold sovereignty.

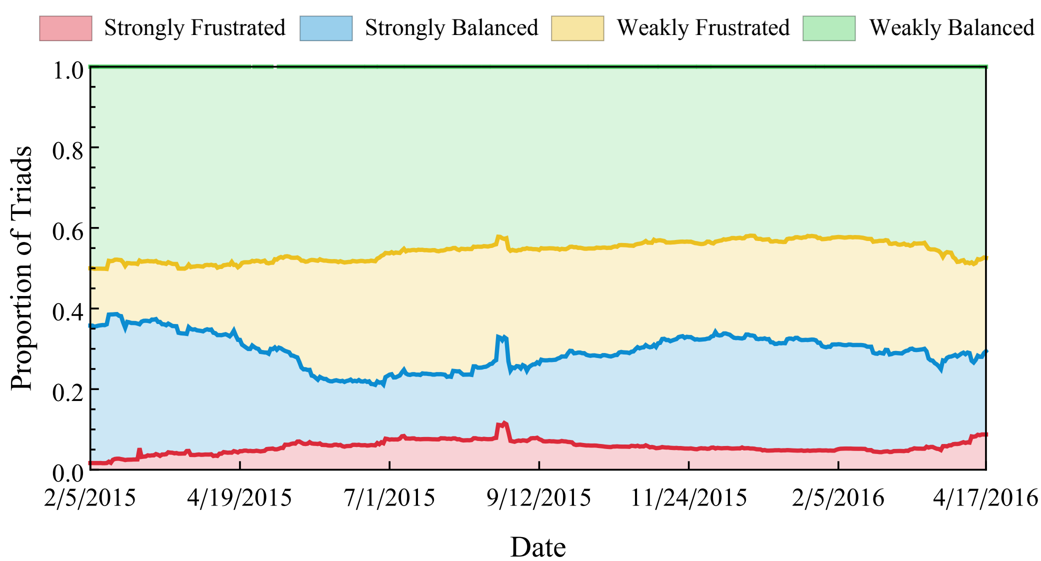

Figure B.6. The accumulated proportions of each triad type per day weighted by sovereignty among alliances that hold sovereignty.

B.4 Sovereign Alliances - Distance-Weighted

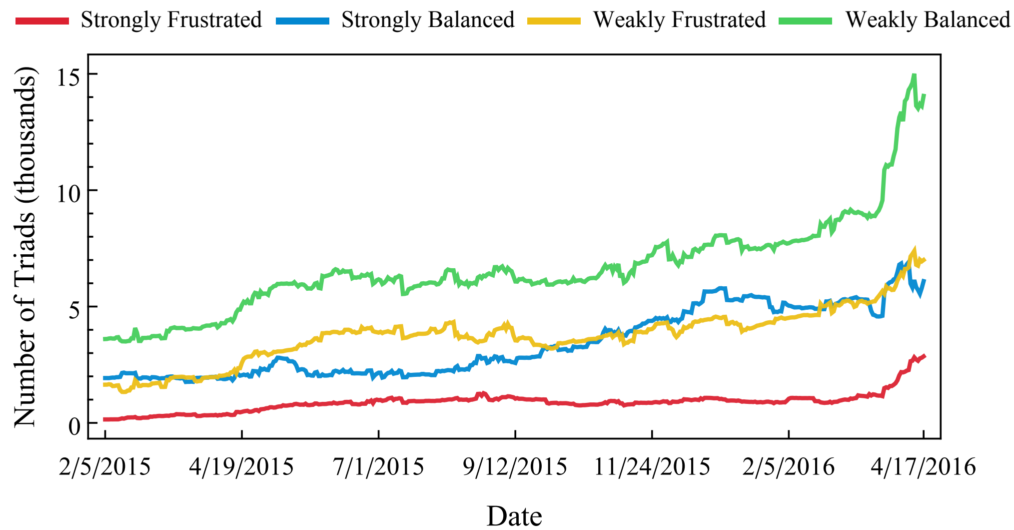

Figure B.7. The number of each triad type per day weighted by distance among alliances that hold sovereignty.

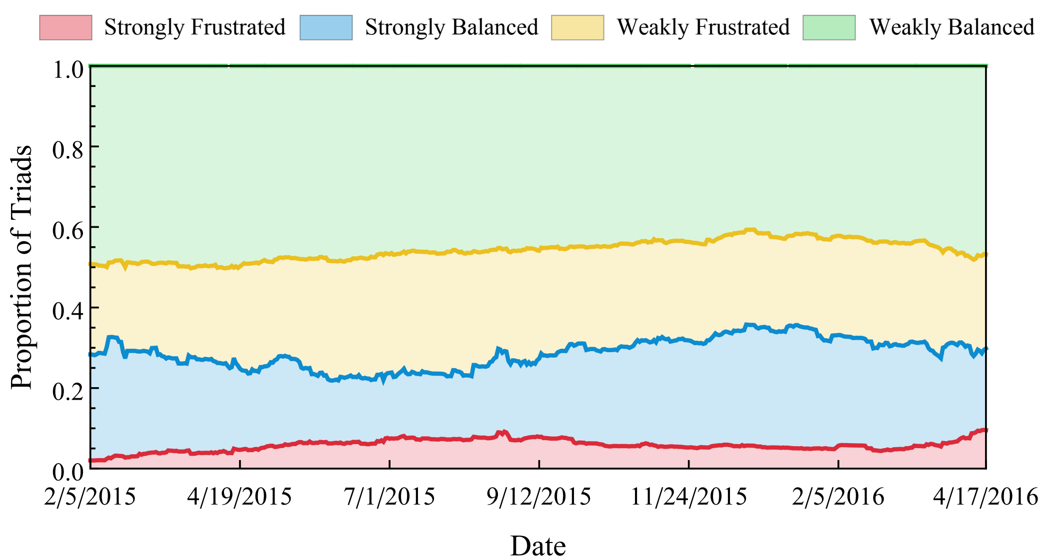

Figure B.8. The accumulated proportions of each triad type per day weighted by distance among alliances that hold sovereignty.

B.5 Sovereign Alliances - Standings-Weighted

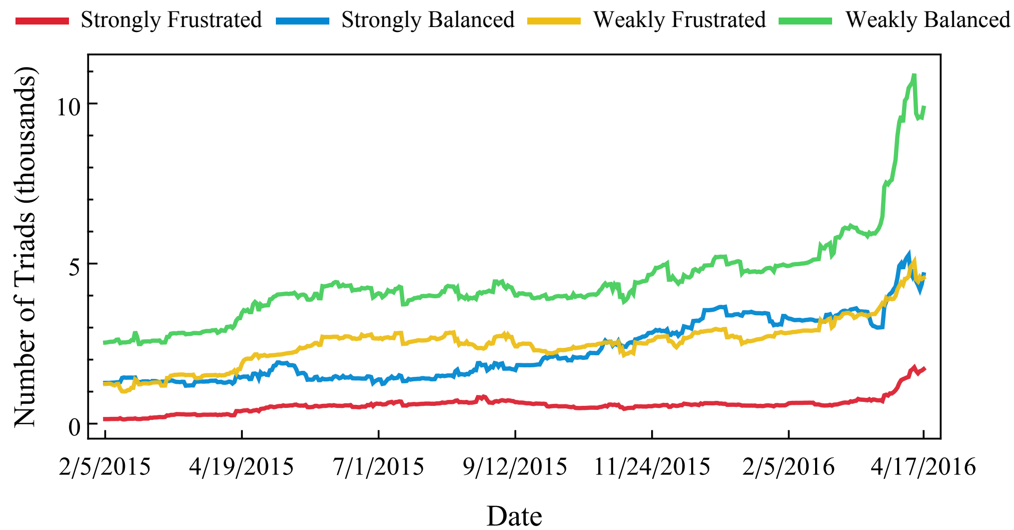

Figure B.9. The number of each triad type per day weighted by standing value among alliances that hold sovereignty.

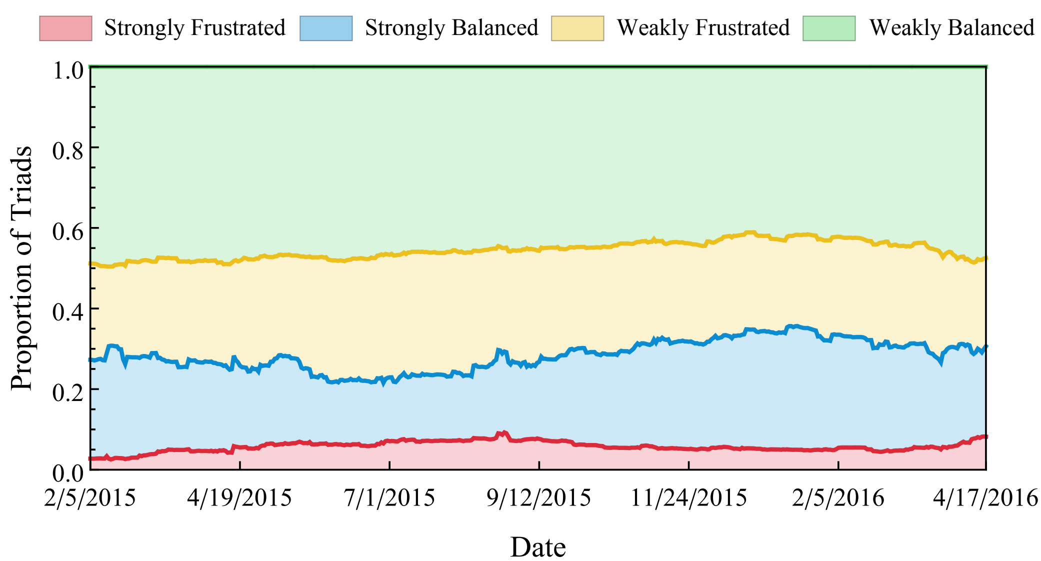

Figure B.10. The accumulated proportions of each triad type per day weighted by standing value among alliances that hold sovereignty.

B.6 Sovereign Alliances - Combined-Weighted

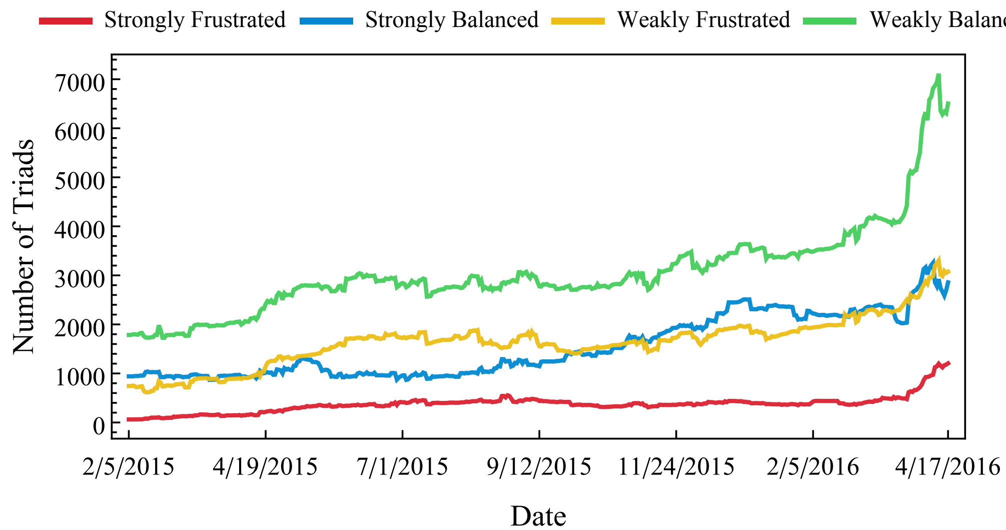

Figure B.11. The number of each triad type per day weighted by the average of all four weights among alliances that hold sovereignty.

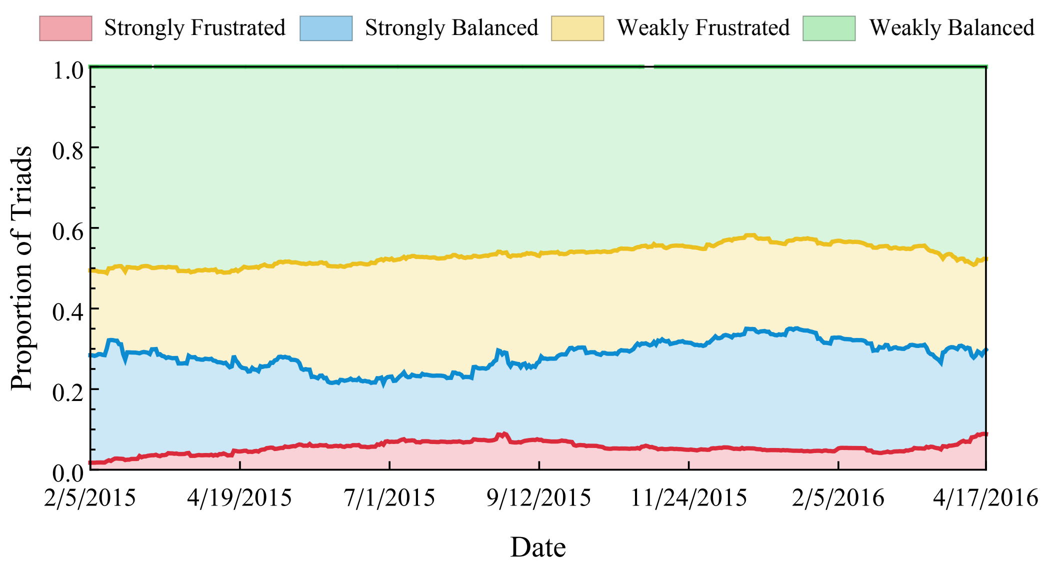

Figure B.12. The accumulated proportions of each triad type per day weighted by the average of all four weights among alliances that hold sovereignty.

C Appendix: Effects of Weights on Triad Proportions

C.1 Large Alliances

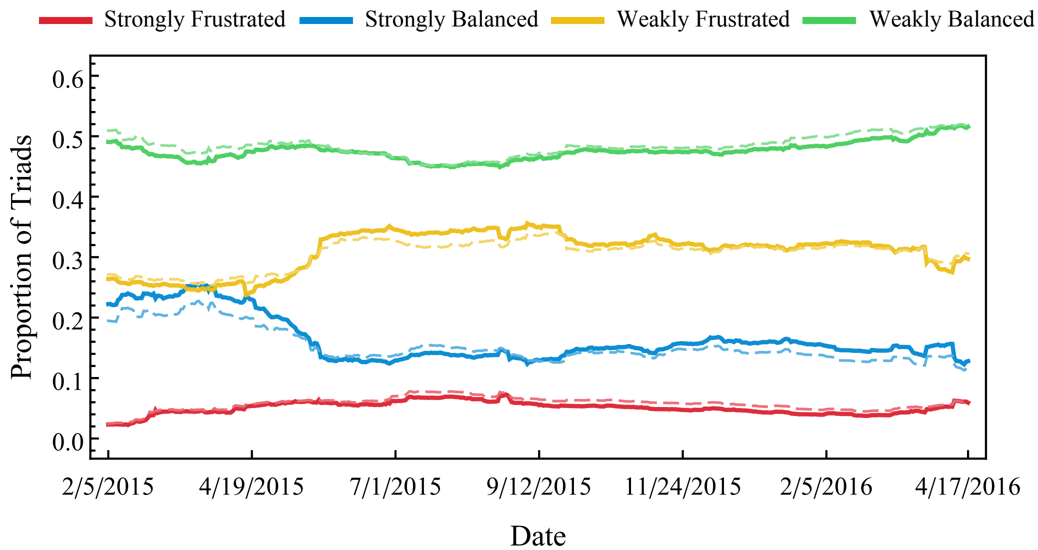

Figure C.1. The daily **membership-weighted** proportions of each triad type among large alliances (bold line) compared to the unweighted proportions (dashed line).

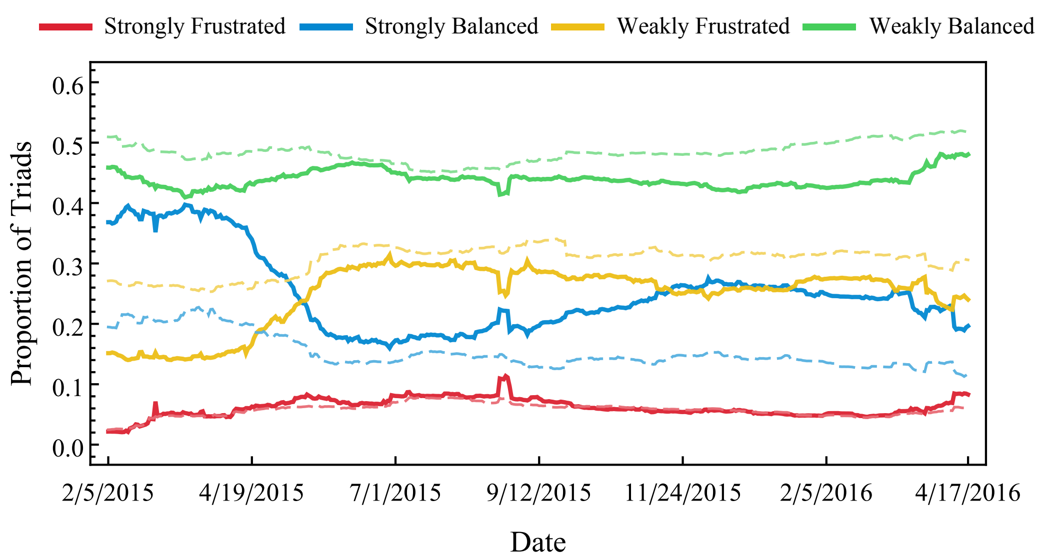

Figure C.2. The daily **sovereignty-weighted** proportions of each triad type among large alliances (bold line) compared to the unweighted proportions (dashed line).

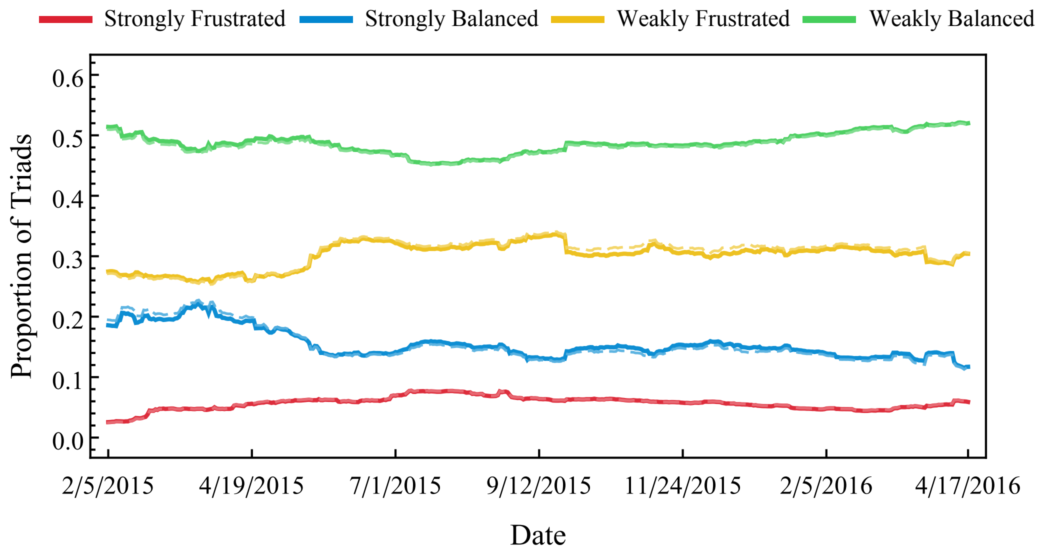

Figure C.3. The daily **distance-weighted** proportions of each triad type among large alliances (bold line) compared to the unweighted proportions (dashed line).

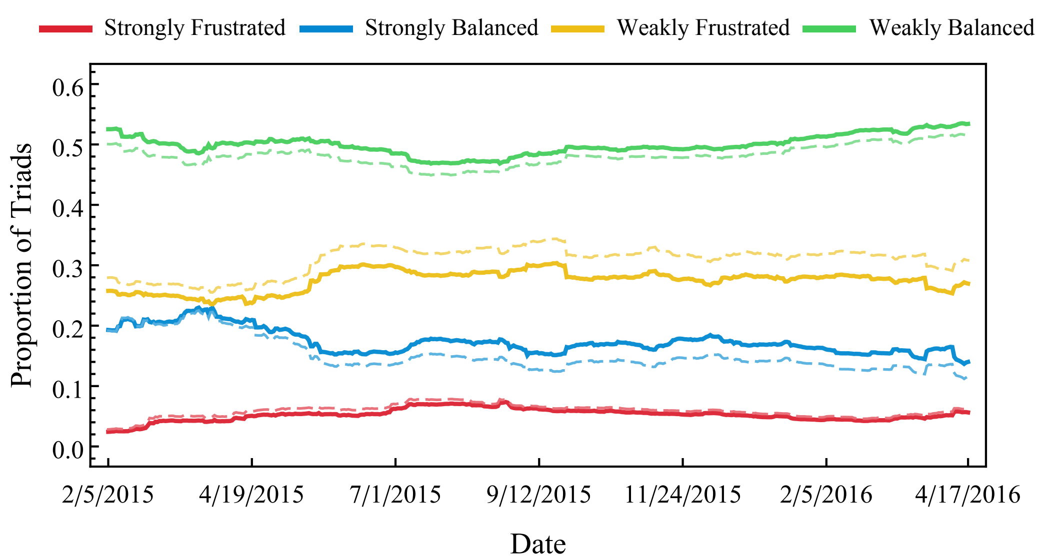

Figure C.4. The daily **standings-weighted** proportions (bold line) of each triad type among large alliances compared to the unweighted proportions (dashed line).

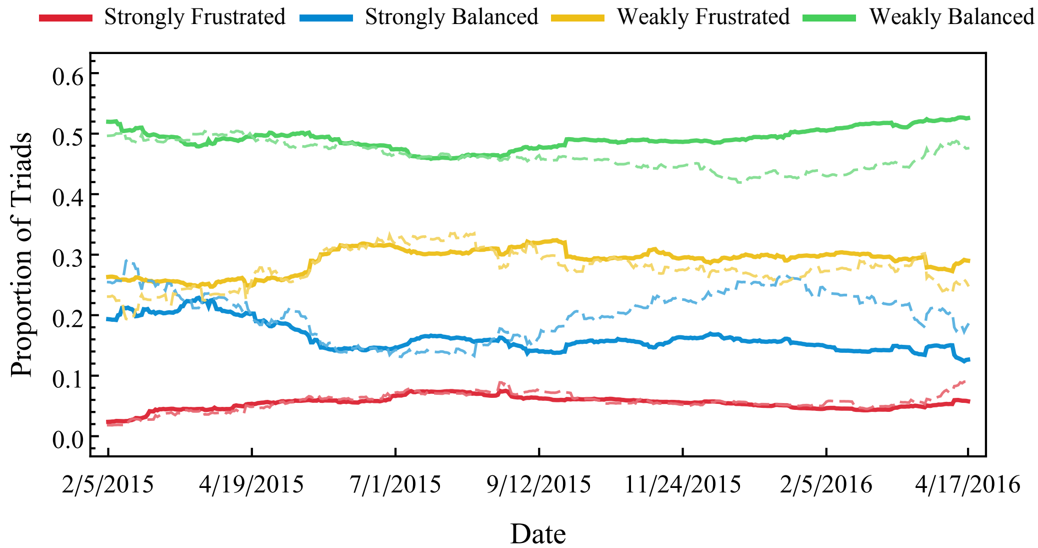

Figure C.5. The daily proportions of each triad type among large alliances using **combined weights** (bold line) compared to the unweighted proportions (dashed line).

weighting	strongly balanced	strongly frustrated	weakly balanced	weakly frustrated
Unweighted Large Triads	15.33	5.74	48.4	30.54
Member-Weighted Large Triads	16.39	5.07	47.54	31.00
Sovereign-Weighted Large Triads	25.11	6.14	43.91	24.84
Distance-Weighted Large Triads	15.51	5.69	48.68	30.12
Standing-Weighted Large Triads	17.52	5.11	50.26	27.11
Combined-Weighted Large Triads	16.33	5.47	49.16	29.04
Unweighted Sovereign Triads	20.26	5.69	46.29	27.76
Member-Weighted Sovereign Triads	18.08	4.74	47.75	29.42
Sovereign-Weighted Sovereign Triads	23.86	5.63	45.72	24.79
Distance-Weighted Sovereign Triads	22.92	5.79	45.79	25.5
Standings-Weighted Sovereign Triads	23.54	4.98	48.22	23.26
Combined-Weighted Sovereign Triads	22.98	5.43	46.78	24.81

Table C.1. The mean percentages of each type of triad for each weighting for Large and Sovereign alliances.

weighting	strongly balanced	strongly frustrated	weakly balanced	weakly frustrated
Unweighted Large Triads	15.2	5.85	48.12	30.83
Distance* Large Triads	15.48	5.82	48.23	30.47
Combined* Large Triads	16.23	5.61	48.73	29.43
Unweighted Sovereign Triads	19.69	6.3	44.07	29.94
Distance* Sovereign Triads	22.03	6.44	43.52	28.01
Combined* Sovereign Triads	22.11	6.15	44.31	27.44

Table C.2. The mean percentages of each type of triad for the alternative distance weighting and the resulting combined weighting for Large and Sovereign alliances.

C.2 Sovereign Alliances

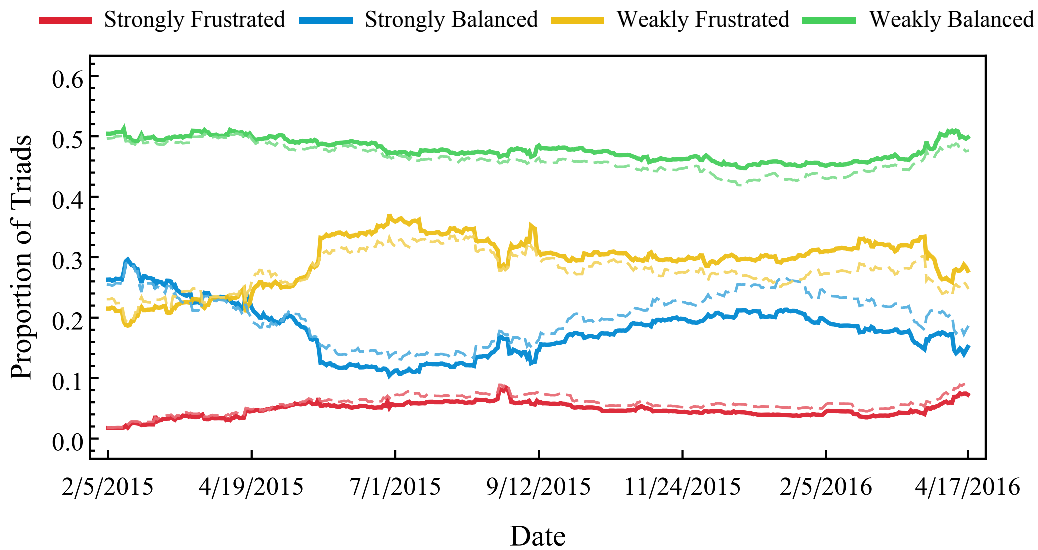

Figure C.6. The daily **membership-weighted** proportions (bold line) of each triad type among sovereign alliances compared to the unweighted proportions (dashed line).

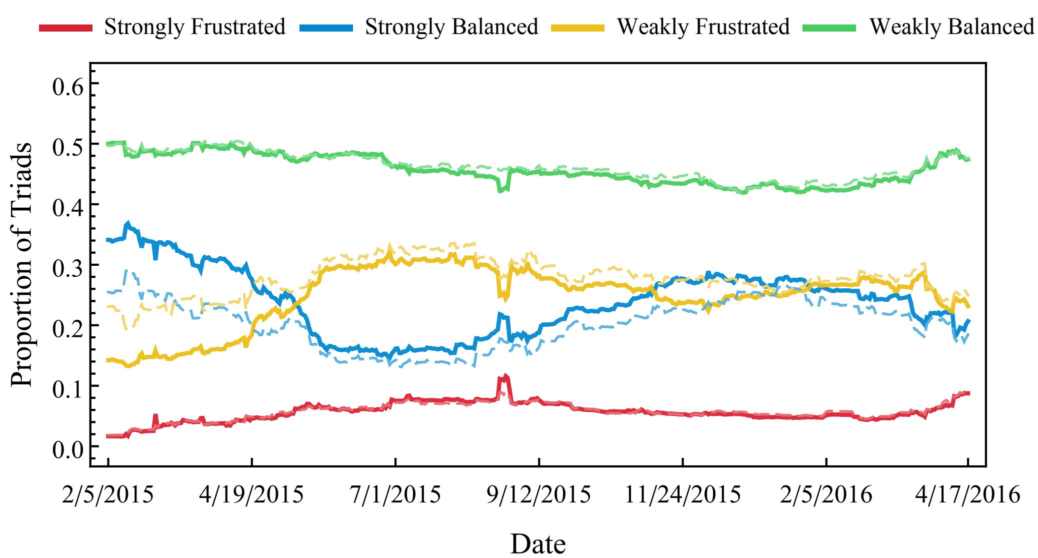

Figure C.7. The daily **sovereignty-weighted** proportions (bold line) of each triad type among sovereign alliances compared to the unweighted proportions (dashed line).

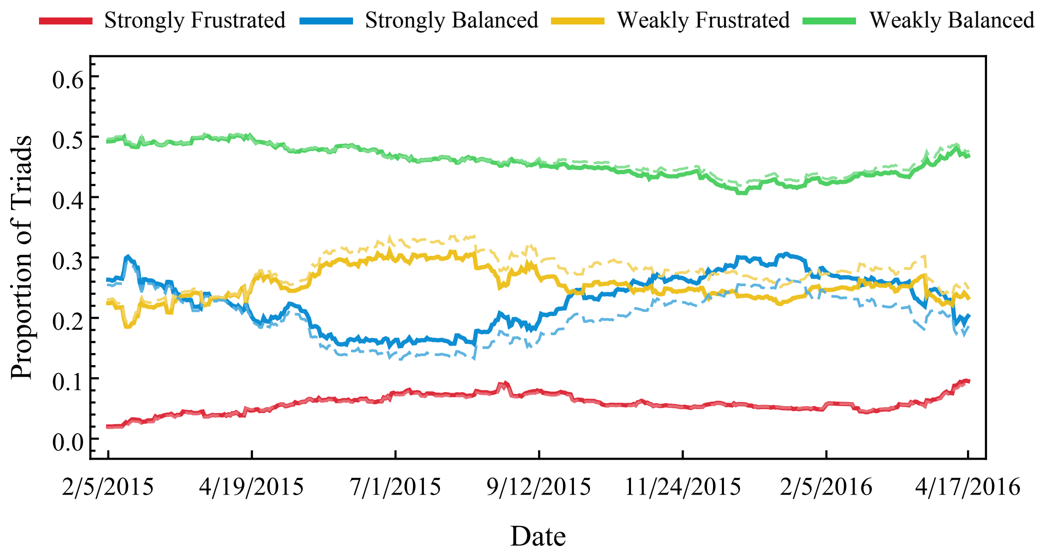

Figure C.8. The daily **distance-weighted** proportions (bold line) of each triad type among sovereign alliances compared to the unweighted proportions (dashed line).

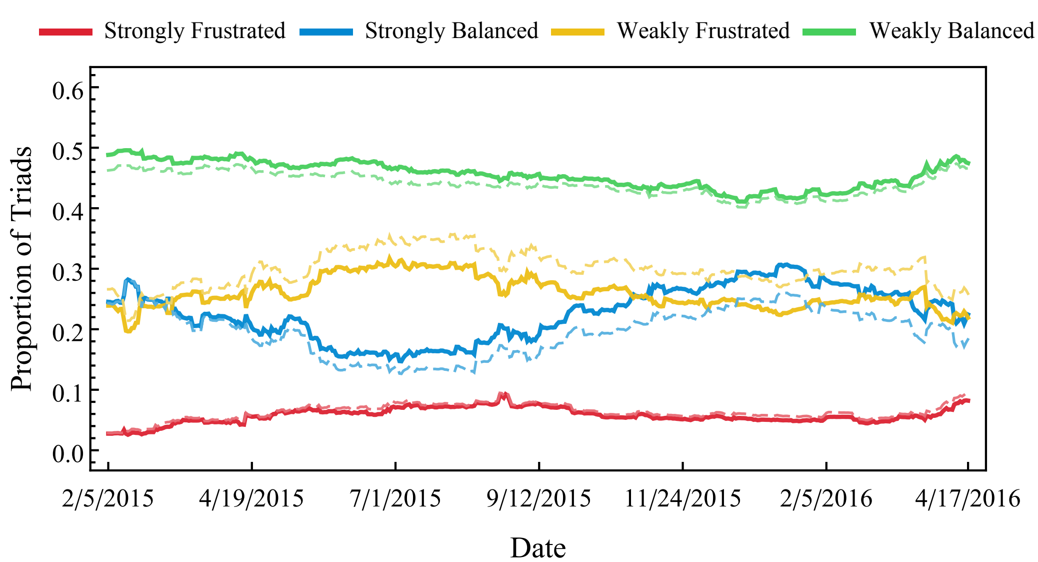

Figure C.9. The daily **standings-weighted** proportions (bold line) of each triad type among sovereign alliances compared to the unweighted proportions (dashed line).

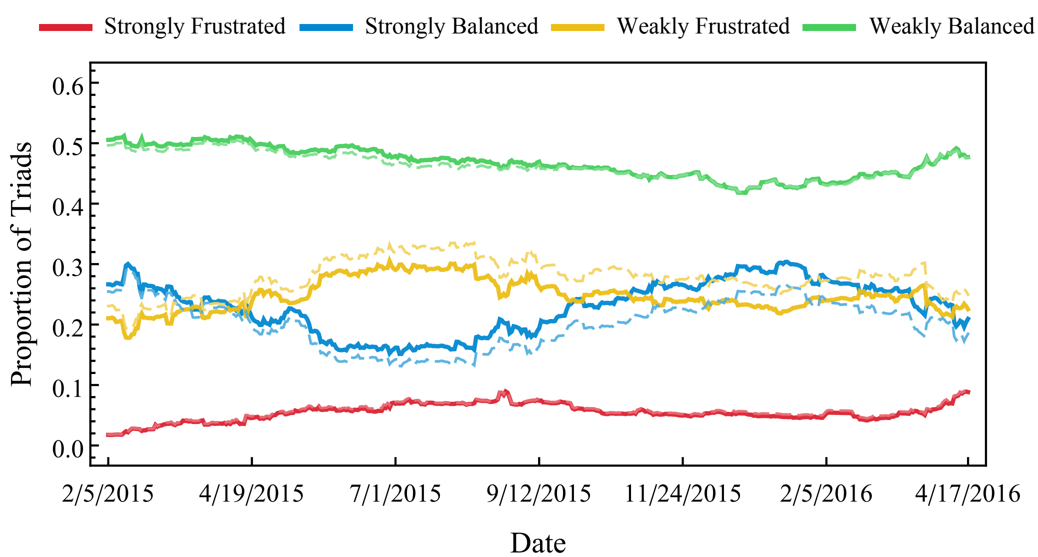

Figure C.10. The daily proportions of each triad type among sovereign alliances using **combined weights** (bold line) compared to the unweighted proportions (dashed line).

C.3 Summary Tables of the Effects of Weights on Proportions

weighting	strongly balanced	strongly frustrated	weakly balanced	weakly frustrated	sum of abs differences
membership	+1.06 ($9.662e^{-11}$)	−0.67 (0.000)	−0.86 (0.000)	+0.47 ($1.110e^{-16}$)	+3.06
sovereignty	+9.78 (0.000)	+0.4 ($9.368e^{-10}$)	−4.49 (0.000)	−5.69 (0.000)	+20.37
distance	+0.18 ($6.253e^{-8}$)	−0.05 (0.473)	+0.29 ($6.245e^{-7}$)	−0.42 (0.000)	+0.95
standing	+2.19 (0.000)	−0.63 (0.000)	+1.86 (0.000)	−3.43 (0.000)	+8.11
combined	+1.01 (0.000)	−0.27 ($2.017e^{-7}$)	+0.77 (0.000)	−1.5 (0.000)	+3.55
distance*	+0.29 ($6.253e^{-8}$)	−0.03 (0.527)	+0.11 (0.003)	−0.37 ($1.541e^{-13}$)	+0.8
combined*	+1.05 (0.000)	−0.25 ($6.245e^{-7}$)	+0.63 (0.000)	−1.43 (0.000)	+3.36

Table C.3. The mean percent change (proportions $\times 100$) between the unweighted triads and each type of weighted triad for the **large alliances**. p-values of the Kolmogorov-Smirnov two-sample test appear below each value to indicate the significance of the effect.

weighting	strongly balanced	strongly frustrated	weakly balanced	weakly frustrated	sum of abs differences
membership	−2.18 (0.000)	−0.95 (0.000)	+1.46 (0.000)	+1.67 (0.000)	+6.26
sovereignty	+3.59 (0.000)	−0.06 (0.007)	−0.57 ($1.231e^{-8}$)	−2.96 (0.000)	+7.19
distance	+2.66 (0.000)	+0.1 (0.074)	−0.5 (0.000)	−2.26 (0.000)	+5.52
standing	+3.28 (0.000)	−0.72 (0.000)	+1.94 (0.000)	−4.5 (0.000)	+10.44
combined	+2.72 (0.000)	−0.26 (0.000)	+0.49 (0.000)	−2.95 (0.000)	+6.42
distance*	+2.41 (0.000)	+0.1 (0.166)	−0.53 (0.000)	−1.98 (0.000)	+5.02
combined*	+2.56 (0.000)	−0.24 (0.000)	+0.42 (0.000)	−2.74 (0.000)	+5.96

Table C.4. The mean percent change (proportions $\times 100$) between the unweighted triads and each type of weighted triad for the **sovereign alliances**. p-values of the Kolmogorov-Smirnov two-sample test appear below each value to indicate the significance of the effect.

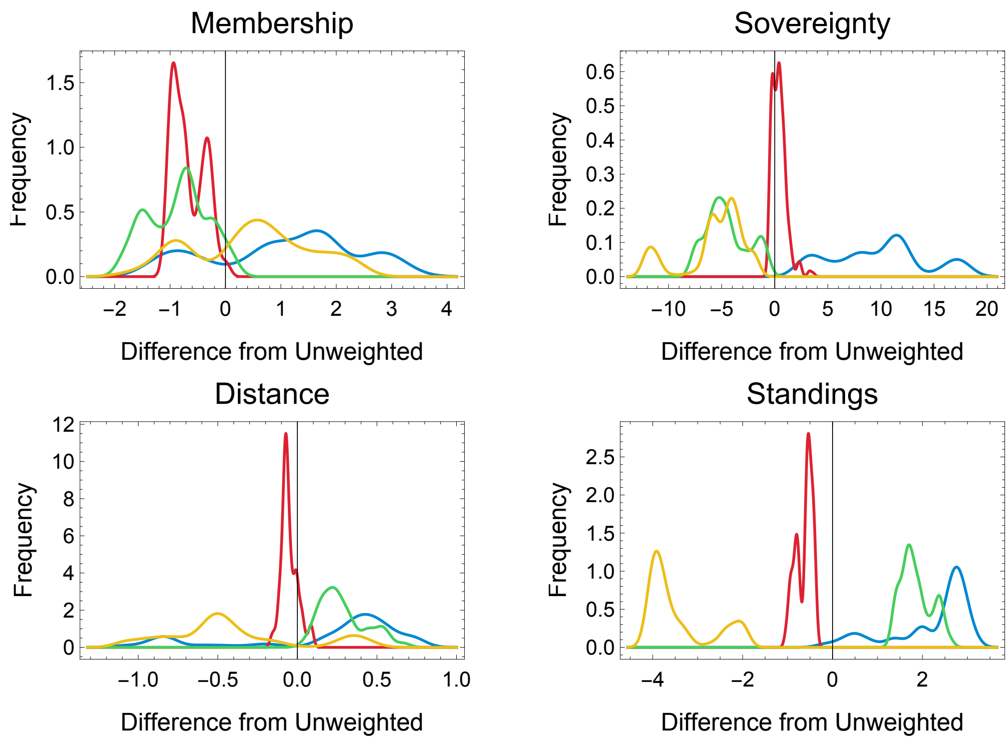

Figure C.11. Smooth histograms of the differences for each type of triad between each weighting and the unweighted series for **large alliances**. Note the non-normal and multi-modal distributions, which made using parametric methods impossible and motivated us to use the Kolmogorov-Smirnov test for significance of changes. Also notice how the strongly frustrated triads (red) show differences closest to zero.

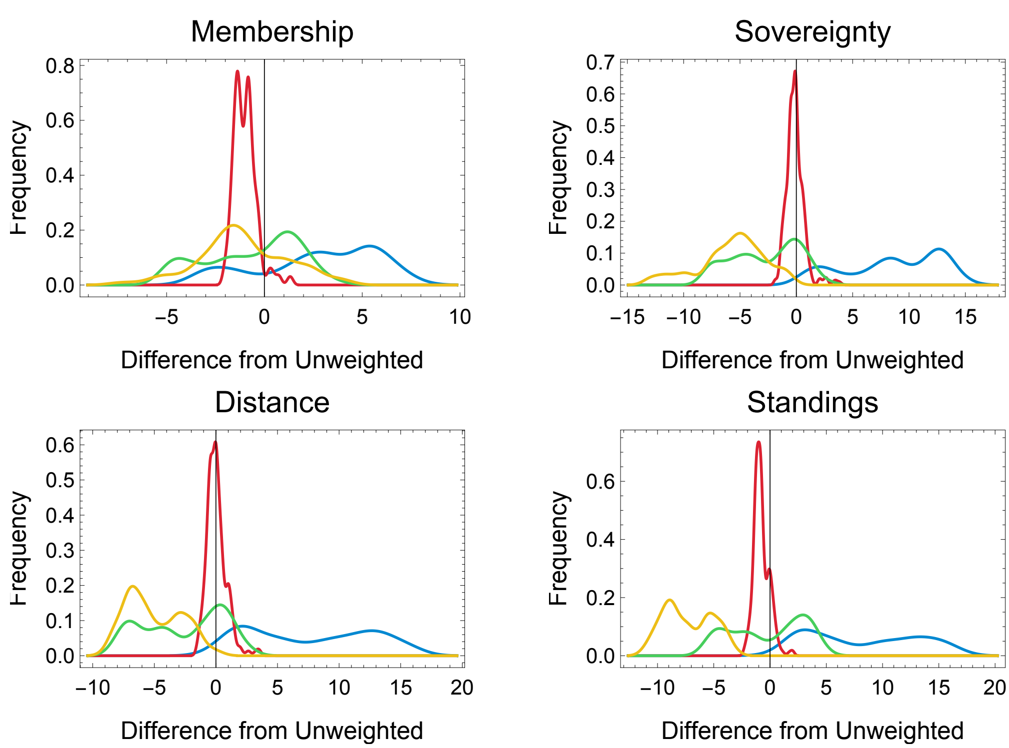

Figure C.12. Smooth histograms of the differences for each type of triad between each weighting and the unweighted series for **sovereign alliances**.

D Appendix: Large Alliance Triad Dynamics

D.1 Large Alliances - Unweighted

	strongly balanced	strongly frustrated	weakly balanced	weakly frustrated
triad creation	18.79	7.85	49.1	24.26
triad persistence	14.67	5.73	48.66	30.94
triad dissolution	20.67	11.13	44.61	23.59

Table D.1. Summary results showing the unweighted percents of the large alliance triad types when they are created, that exist in the system over time, and when they are removed. This only includes adding and removing triads through link creation and destruction; i.e., excluding nodes entering/leaving.

from	to strongly balanced	to strongly frustrated	to weakly balanced	to weakly frustrated	to nonexistent
strongly balanced	99.28	0.24	0.06	0.00	0.41
strongly frustrated	0.35	98.67	0.4	0.01	0.57
weakly balanced	0.00	0.04	99.6	0.12	0.24
weakly frustrated	0.00	0.00	0.12	99.7	0.17

Table D.2. Summary results of the unweighted percents of triad type changes including though the deletion of edges for the large alliances.

from	to strongly balanced	to strongly frustrated	to weakly balanced	to weakly frustrated	to nonexistent
strongly balanced	—	33.88	8.63	0.02	57.46
strongly frustrated	26.21	—	30.38	0.84	42.57
weakly balanced	1.2	8.91	—	29.23	60.66
weakly frustrated	0.02	0.2	41.86	—	57.91

Table D.3. Summary results of the unweighted percents of large alliance triad type changes including though the deletion of edges. Because we use daily data for the standings it is possible for triads to change multiple edge valences in one step. Although this does occur, we find that 94.0% of the changes (excluding deletion) in this table are one edge flip away.

D.2 Large Alliances - Member-Weighted

	strongly balanced	strongly frustrated	weakly balanced	weakly frustrated
triad creation	20.03	8.28	47.73	23.96
triad persistence	15.94	5.16	47.38	31.51
triad dissolution	23.5	12.64	43.63	20.23

Table D.4. Summary results showing the member-weighted percents of the large alliance triad types when they are created, that exist in the system over time, and when they are removed. This only includes adding and removing triads through link creation and destruction; i.e., excluding nodes entering/leaving.

from	to strongly balanced	to strongly frustrated	to weakly balanced	to weakly frustrated	to nonexistent
strongly balanced	99.27	0.27	0.07	0.00	0.39
strongly frustrated	0.46	98.36	0.52	0.01	0.65
weakly balanced	0.01	0.04	99.56	0.15	0.24
weakly frustrated	0.00	0.00	0.16	99.67	0.17

Table D.5. Summary results of the member-weighted percents of triad type changes including though the deletion of edges for the large alliances.

from	to strongly balanced	to strongly frustrated	to weakly balanced	to weakly frustrated	to nonexistent
strongly balanced	—	36.72	9.54	0.02	53.72
strongly frustrated	27.98	—	31.52	0.89	39.61
weakly balanced	1.48	9.89	—	33.27	55.36
weakly frustrated	0.02	0.21	47.92	—	51.85

Table D.6. Summary results of the member-weighted percents of large alliance triad type changes including though the deletion of edges. Because we use daily data for the standings it is possible for triads to change multiple edge valences in one step. Although this does occur, we find that 93.8% of the changes (excluding deletion) in this table are one edge flip away.

D.3 Large Alliances - Sovereignty-Weighted

	strongly balanced	strongly frustrated	weakly balanced	weakly frustrated
triad creation	25.5	10.73	44.19	19.57
triad persistence	25.12	6.08	43.97	24.83
triad dissolution	30.89	14.81	39.69	14.62

Table D.7. Summary results showing the sovereignty-weighted percents of the large alliance triad types when they are created, that exist in the system over time, and when they are removed. This only includes adding and removing triads through link creation and destruction; i.e., excluding nodes entering/leaving.

from	to strongly balanced	to strongly frustrated	to weakly balanced	to weakly frustrated	to nonexistent
strongly balanced	99.34	0.26	0.06	0.00	0.34
strongly frustrated	0.64	98.08	0.6	0.01	0.67
weakly balanced	0.01	0.07	99.51	0.16	0.25
weakly frustrated	0.00	0.00	0.21	99.63	0.16

Table D.8. Summary results of the sovereignty-weighted percents of triad type changes including though the deletion of edges for the large alliances.

from	to strongly balanced	to strongly frustrated	to weakly balanced	to weakly frustrated	to nonexistent
strongly balanced	—	39.23	9.65	0.02	51.1
strongly frustrated	33.32	—	31.15	0.46	35.06
weakly balanced	2.3	13.47	—	32.79	51.43
weakly frustrated	0.02	0.33	55.66	—	43.99

Table D.9. Summary results of the sovereignty-weighted percents of large alliance triad type changes including though the deletion of edges. Because we use daily data for the standings it is possible for triads to change multiple edge valences in one step. Although this does occur, we find that 94.1% of the changes (excluding deletion) in this table are one edge flip away.

D.4 Large Alliances - Distance-Weighted

	strongly balanced	strongly frustrated	weakly balanced	weakly frustrated
triad creation	18.54	7.66	49.28	24.53
triad persistence	14.96	5.66	48.93	30.44
triad dissolution	22.56	12.09	44.89	20.47

Table D.10. Summary results showing the distance-weighted percents of the large alliance triad types when they are created, that exist in the system over time, and when they are removed. This only includes adding and removing triads through link creation and destruction; i.e., excluding nodes entering/leaving.

from	to strongly balanced	to strongly frustrated	to weakly balanced	to weakly frustrated	to nonexistent
strongly balanced	99.32	0.23	0.06	0.00	0.38
strongly frustrated	0.35	98.7	0.39	0.01	0.54
weakly balanced	0.00	0.03	99.62	0.11	0.23
weakly frustrated	0.00	0.00	0.12	99.71	0.17

Table D.11. Summary results of the distance-weighted percents of triad type changes including though the deletion of edges for the large alliances.

from	to strongly balanced	to strongly frustrated	to weakly balanced	to weakly frustrated	to nonexistent
strongly balanced	—	34.38	8.91	0.02	56.69
strongly frustrated	26.92	—	30.26	0.88	41.95
weakly balanced	1.2	8.97	—	28.87	60.97
weakly frustrated	0.03	0.2	41.26	—	58.51

Table D.12. Summary results of the distance-weighted percents of large alliance triad type changes including though the deletion of edges. Because we use daily data for the standings it is possible for triads to change multiple edge valences in one step. Although this does occur, we find that 93.8% of the changes (excluding deletion) in this table are one edge flip away.

D.5 Large Alliances - Standings-Weighted

	strongly balanced	strongly frustrated	weakly balanced	weakly frustrated
triad creation	21.17	7.25	49.94	21.64
triad persistence	17.09	5.13	50.47	27.32
triad dissolution	24.43	11.57	45.36	18.63

Table D.13. Summary results showing the standings-weighted percents of the large alliance triad types when they are created, that exist in the system over time, and when they are removed. This only includes adding and removing triads through link creation and destruction; i.e., excluding nodes entering/leaving.

from	to strongly balanced	to strongly frustrated	to weakly balanced	to weakly frustrated	to nonexistent
strongly balanced	99.55	0.19	0.04	0.00	0.22
strongly frustrated	0.44	98.86	0.34	0.01	0.35
weakly balanced	0.01	0.03	99.73	0.09	0.14
weakly frustrated	0.00	0.00	0.14	99.75	0.11

Table D.14. Summary results of the standings-weighted percents of triad type changes including though the deletion of edges for the large alliances.

from	to strongly balanced	to strongly frustrated	to weakly balanced	to weakly frustrated	to nonexistent
strongly balanced	—	41.82	8.53	0.01	49.65
strongly frustrated	39.01	—	29.76	0.45	30.77
weakly balanced	2.23	12.69	—	32.69	52.4
weakly frustrated	0.04	0.28	56.46	—	43.23

Table D.15. Summary results of the standings-weighted percents of large alliance triad type changes including though the deletion of edges. Because we use daily data for the standings it is possible for triads to change multiple edge valences in one step. Although this does occur, we find that 94.8% of the changes (excluding deletion) in this table are one edge flip away.

D.6 Large Alliances - Combined-Weighted

	strongly balanced	strongly frustrated	weakly balanced	weakly frustrated
triad creation	19.53	7.56	49.43	23.48
triad persistence	15.82	5.46	49.4	29.33
triad dissolution	23.14	12	44.92	19.93

Table D.16. Summary results showing the combined-weighted percents of the large alliance triad types when they are created, that exist in the system over time, and when they are removed. This only includes adding and removing triads through link creation and destruction; i.e., excluding nodes entering/leaving.

from	to strongly balanced	to strongly frustrated	to weakly balanced	to weakly frustrated	to nonexistent
strongly balanced	99.41	0.22	0.05	0.00	0.32
strongly frustrated	0.39	98.74	0.38	0.01	0.48
weakly balanced	0.01	0.03	99.66	0.1	0.2
weakly frustrated	0.00	0.00	0.13	99.72	0.15

Table D.17. Summary results of the combined-weighted percents of triad type changes including though the deletion of edges for the large alliances.

from	to strongly balanced	to strongly frustrated	to weakly balanced	to weakly frustrated	to nonexistent
strongly balanced	—	36.62	8.84	0.02	54.52
strongly frustrated	30.63	—	30.16	0.74	38.47
weakly balanced	1.5	10.07	—	30.07	58.36
weakly frustrated	0.03	0.22	45.96	—	53.79

Table D.18. Summary results of the combined-weighted percents of large alliance triad type changes including though the deletion of edges. Because we use daily data for the standings it is possible for triads to change multiple edge valences in one step. Although this does occur, we find that 94.2% of the changes (excluding deletion) in this table are one edge flip away.

E Appendix: Sovereign Alliance Triad Dynamics

E.1 Sovereign Alliances - Unweighted

	strongly balanced	strongly frustrated	weakly balanced	weakly frustrated
triad creation	21.96	8.61	45.53	23.91
triad persistence	20.24	5.88	45.93	27.95
triad dissolution	20.43	9.17	44.23	26.17

Table E.1. Summary results showing the unweighted percents of the sovereign alliance triad types when they are created, that exist in the system over time, and when they are removed. This only includes adding and removing triads through link creation and destruction; i.e., excluding nodes entering/leaving.

from	to strongly balanced	to strongly frustrated	to weakly balanced	to weakly frustrated	to nonexistent
strongly balanced	99.24	0.3	0.07	0.00	0.39
strongly frustrated	0.57	98.03	0.7	0.01	0.68
weakly balanced	0.01	0.06	99.47	0.19	0.26
weakly frustrated	0.00	0.00	0.22	99.62	0.16

Table E.2. Summary results of the unweighted percents of triad type changes including though the deletion of edges for the sovereign alliances.

from	to strongly balanced	to strongly frustrated	to weakly balanced	to weakly frustrated	to nonexistent
strongly balanced	—	39.78	8.85	0.04	51.33
strongly frustrated	29.13	—	35.44	0.74	34.69
weakly balanced	2.17	11.98	—	36.32	49.53
weakly frustrated	0.03	0.35	56.62	—	43.00

Table E.3. Summary results of the unweighted percents of sovereign alliance triad type changes including though the deletion of edges. Because we use daily data for the standings it is possible for triads to change multiple edge valences in one step. Although this does occur, we find that 94.5% of the changes (excluding deletion) in this table are one edge flip away.

E.2 Sovereign Alliances - Member-Weighted

	strongly balanced	strongly frustrated	weakly balanced	weakly frustrated
triad creation	19.03	7.76	46.65	26.55
triad persistence	17.92	4.76	47.7	29.62
triad dissolution	24.83	13.86	44.84	16.47

Table E.4. Summary results showing the member-weighted percents of the sovereign alliance triad types when they are created, that exist in the system over time, and when they are removed. This only includes adding and removing triads through link creation and destruction; i.e., excluding nodes entering/leaving.

from	to strongly balanced	to strongly frustrated	to weakly balanced	to weakly frustrated	to nonexistent
strongly balanced	99.27	0.3	0.08	0.00	0.35
strongly frustrated	0.64	97.83	0.77	0.02	0.74
weakly balanced	0.01	0.06	99.51	0.18	0.24
weakly frustrated	0.00	0.00	0.22	99.63	0.14

Table E.5. Summary results of the member-weighted percents of triad type changes including though the deletion of edges for the sovereign alliances.

from	to strongly balanced	to strongly frustrated	to weakly balanced	to weakly frustrated	to nonexistent
strongly balanced	—	41.3	10.63	0.02	48.04
strongly frustrated	29.69	—	35.39	0.71	34.22
weakly balanced	2.35	11.39	—	37.18	49.08
weakly frustrated	0.03	0.28	60.96	—	38.73

Table E.6. Summary results of the member-weighted percents of sovereign alliance triad type changes including though the deletion of edges. Because we use daily data for the standings it is possible for triads to change multiple edge valences in one step. Although this does occur, we find that 93.9% of the changes (excluding deletion) in this table are one edge flip away.

E.3 Sovereign Alliances - Sovereignty-Weighted

	strongly balanced	strongly frustrated	weakly balanced	weakly frustrated
triad creation	24.03	9.14	45.19	21.65
triad persistence	23.86	5.63	45.61	24.9
triad dissolution	30.03	14.74	41.28	13.95

Table E.7. Summary results showing the sovereignty-weighted percents of the sovereign alliance triad types when they are created, that exist in the system over time, and when they are removed. This only includes adding and removing triads through link creation and destruction; i.e., excluding nodes entering/leaving.

from	to strongly balanced	to strongly frustrated	to weakly balanced	to weakly frustrated	to nonexistent
strongly balanced	99.34	0.27	0.07	0.00	0.33
strongly frustrated	0.68	97.95	0.67	0.01	0.69
weakly balanced	0.01	0.06	99.52	0.17	0.24
weakly frustrated	0.00	0.00	0.23	99.62	0.15

Table E.8. Summary results of the sovereignty-weighted percents of triad type changes including though the deletion of edges for the sovereign alliances.

from	to strongly balanced	to strongly frustrated	to weakly balanced	to weakly frustrated	to nonexistent
strongly balanced	—	40.66	9.82	0.02	49.5
strongly frustrated	33.29	—	32.69	0.52	33.5
weakly balanced	2.71	12.64	—	35.68	48.97
weakly frustrated	0.01	0.41	60.76	—	38.82

Table E.9. Summary results of the sovereignty-weighted percents of sovereign alliance triad type changes including though the deletion of edges. Because we use daily data for the standings it is possible for triads to change multiple edge valences in one step. Although this does occur, we find that 94.1% of the changes (excluding deletion) in this table are one edge flip away.

E.4 Sovereign Alliances - Distance-Weighted

	strongly balanced	strongly frustrated	weakly balanced	weakly frustrated
triad creation	23.75	8.7	44.9	22.65
triad persistence	23.26	5.95	45.29	25.5
triad dissolution	28.93	14.33	41.04	15.7

Table E.10. Summary results showing the distance-weighted percents of the sovereign alliance triad types when they are created, that exist in the system over time, and when they are removed. This only includes adding and removing triads through link creation and destruction; i.e., excluding nodes entering/leaving.

from	to strongly balanced	to strongly frustrated	to weakly balanced	to weakly frustrated	to nonexistent
strongly balanced	99.31	0.28	0.06	0.00	0.34
strongly frustrated	0.62	98	0.71	0.02	0.67
weakly balanced	0.01	0.07	99.49	0.18	0.25
weakly frustrated	0.00	0.00	0.22	99.6	0.17

Table E.11. Summary results of the distance-weighted percents of triad type changes including though the deletion of edges for the sovereign alliances.

from	to strongly balanced	to strongly frustrated	to weakly balanced	to weakly frustrated	to nonexistent
strongly balanced	—	40.88	9.16	0.04	49.92
strongly frustrated	30.74	—	35.27	0.78	33.21
weakly balanced	2.39	13.05	—	35.54	49.02
weakly frustrated	0.04	0.39	56.58	—	43.00

Table E.12. Summary results of the distance-weighted percents of sovereign alliance triad type changes including though the deletion of edges. Because we use daily data for the standings it is possible for triads to change multiple edge valences in one step. Although this does occur, we find that 94.3% of the changes (excluding deletion) in this table are one edge flip away.

E.5 Sovereign Alliances - Standings-Weighted

	strongly balanced	strongly frustrated	weakly balanced	weakly frustrated
triad creation	25.54	7.72	46.43	20.3
triad persistence	23.83	5.12	47.83	23.22
triad dissolution	29.62	13.1	42.16	15.12

Table E.13. Summary results showing the standings-weighted percents of the sovereign alliance triad types when they are created, that exist in the system over time, and when they are removed. This only includes adding and removing triads through link creation and destruction; i.e., excluding nodes entering/leaving.

from	to strongly balanced	to strongly frustrated	to weakly balanced	to weakly frustrated	to nonexistent
strongly balanced	99.53	0.22	0.04	0.00	0.21
strongly frustrated	0.72	98.27	0.56	0.01	0.43
weakly balanced	0.01	0.06	99.65	0.13	0.15
weakly frustrated	0.00	0.00	0.24	99.64	0.11

Table E.14. Summary results of the standings-weighted percents of triad type changes including though the deletion of edges for the sovereign alliances.

from	to strongly balanced	to strongly frustrated	to weakly balanced	to weakly frustrated	to nonexistent
strongly balanced	—	46.26	9.34	0.01	44.39
strongly frustrated	41.87	—	32.65	0.33	25.14
weakly balanced	3.96	16.6	—	36.45	42.99
weakly frustrated	0.04	0.44	68.44	—	31.08

Table E.15. Summary results of the standings-weighted percents of sovereign alliance triad type changes including though the deletion of edges. Because we use daily data for the standings it is possible for triads to change multiple edge valences in one step. Although this does occur, we find that 94.5% of the changes (excluding deletion) in this table are one edge flip away.

E.6 Sovereign Alliances - Combined-Weighted

	strongly balanced	strongly frustrated	weakly balanced	weakly frustrated
triad creation	24.22	8.31	45.55	21.92
triad persistence	23.23	5.58	46.35	24.84
triad dissolution	28.93	13.99	41.54	15.53

Table E.16. Summary results showing the combined-weighted percents of the sovereign alliance triad types when they are created, that exist in the system over time, and when they are removed. This only includes adding and removing triads through link creation and destruction; i.e., excluding nodes entering/leaving.

from	to strongly balanced	to strongly frustrated	to weakly balanced	to weakly frustrated	to nonexistent
strongly balanced	99.39	0.26	0.06	0.00	0.29
strongly frustrated	0.66	98.08	0.66	0.01	0.59
weakly balanced	0.01	0.06	99.55	0.16	0.21
weakly frustrated	0.00	0.00	0.23	99.62	0.15

Table E.17. Summary results of the combined-weighted percents of triad type changes including though the deletion of edges for the large alliances.

from	to strongly balanced	to strongly frustrated	to weakly balanced	to weakly frustrated	to nonexistent
strongly balanced	—	42.48	9.3	0.03	48.19
strongly frustrated	34.16	—	34.41	0.63	30.8
weakly balanced	2.86	14	—	35.9	47.23
weakly frustrated	0.04	0.4	60.77	—	38.79

Table E.18. Summary results of the combined-weighted percents of sovereign alliance triad type changes including though the deletion of edges. Because we use daily data for the standings it is possible for triads to change multiple edge valences in one step. Although this does occur, we find that 94.4% of the changes (excluding deletion) in this table are one edge flip away.

F Appendix: Coalition Detection and Polarization

Rank	Distance Measure	First Day Out-Edges	Last Day Out-Edges	Mean
1	Hierarchical Community*	0.895	0.675	0.785
2	Vertex Moving Community*	0.816	0.688	0.752
3	Centrality Community*	0.816	0.675	0.745
4	Spectral Community*	0.816	0.663	0.739
5	Modularity Community*	0.816	0.663	0.739
6	Normalized Squared Euclidean Distance	0.737	0.675	0.706
7	Canberra Distance	0.737	0.663	0.7
8	Euclidean Distance	0.737	0.638	0.687
9	Bray Curtis Distance	0.737	0.625	0.681
10	Squared Euclidean Distance	0.737	0.613	0.675
11	Cosine Distance	0.684	0.663	0.673
12	Clique Percolation Community*	0.816	0.448	0.632
13	Manhattan Distance	0.632	0.625	0.628
14	Hamming Distance	0.658	0.5	0.579
15	Damerau Levenshtein Distance	0.632	0.513	0.572
16	Correlation Distance	0.447	0.688	0.567
17	Chessboard Distance	0.579	0.45	0.514

Table F.1. The ranked accuracy of each method used in identifying the same coalitions as Chuggi and Sky 2017 using the rows of the directed weighted standings matrix (i.e., the out-edges). Network-based community detection algorithms are marked with an *, and three of those measures are not implemented for directed networks.

Rank	Distance Measure	First Day In-Edges	Last Day In-Edges	Mean
1	Hamming Distance	0.895	0.675	0.785
2	Canberra Distance	0.868	0.675	0.772
3	Damerau Levenshtein Distance	0.789	0.738	0.763
4	Vertex Moving Community*	0.816	0.688	0.752
5	Bray Curtis Distance	0.789	0.713	0.751
6	Manhattan Distance	0.816	0.675	0.745
7	Centrality Community*	0.816	0.675	0.745
8	Spectral Community*	0.816	0.663	0.739
9	Modularity Community*	0.816	0.663	0.739
10	Euclidean Distance	0.737	0.725	0.731
11	Squared Euclidean Distance	0.789	0.663	0.726
12	Hierarchical Community*	0.763	0.688	0.725
13	Normalized Squared Euclidean Distance	0.711	0.663	0.687
14	Cosine Distance	0.763	0.525	0.644
15	Clique Percolation Community*	0.816	0.448	0.632
16	Correlation Distance	0.421	0.663	0.542
17	Chessboard Distance	0.526	0.438	0.482

Table F.2. The ranked accuracy of each method used in identifying the same coalitions as Chuggi and Sky 2017 using the columns of the directed weighted standings matrix (i.e., the in-edges). Network-based community detection algorithms are marked with an *, and three of those measures are not implemented for directed networks.

Rank	Distance Measure	First Day Symmetric	Last Day Symmetric	Mean
1	Damerau Levenshtein Distance	0.842	0.725	0.784
2	Cosine Distance	0.763	0.775	0.769
3	Squared Euclidean Distance	0.789	0.738	0.763
4	Hierarchical Community*	0.816	0.7	0.758
5	Manhattan Distance	0.763	0.75	0.757
6	Centrality Community*	0.816	0.688	0.752
7	Euclidean Distance	0.763	0.738	0.75
8	Vertex Moving Community*	0.816	0.675	0.745
9	Spectral*	0.763	0.7	0.732
10	Normalized Squared Euclidean Distance	0.737	0.713	0.725
11	Bray Curtis Distance	0.789	0.65	0.72
12	Canberra Distance	0.763	0.663	0.713
13	Hamming Distance	0.763	0.663	0.713
14	Modularity Community*	0.816	0.575	0.695
15	Clique Percolation Community*	0.816	0.448	0.632
16	Correlation Distance	0.421	0.7	0.561
17	Chessboard Distance	0.447	0.35	0.399

Table F.3. The ranked accuracy of each method used in identifying the same coalitions as Chuggi and Sky 2017 using the unweighted symmetric version of the standings matrix. Network-based community detection algorithms are marked with an *.

Figure F.1. Plots of the adjacency matrices of alliance standings on 2/4/2015 (left) and 4/17/2016 (right) between the sovereign alliances included in (Chuggi and Sky 2017)'s alliance and coalition maps. Blocks of dark and light blue (standings of 10 and 5 respectively) represent clusters of alliances that are densely interconnected with positive links. Negative links are represented by red (−10) and orange (−5), and neutral relationships by yellow (0) cells. White space indicates unset standings. The black mesh lines indicate coalitions discovered through clustering by Hamming distance on out-edges, one of the measures we compare to the player-reported coalition data.

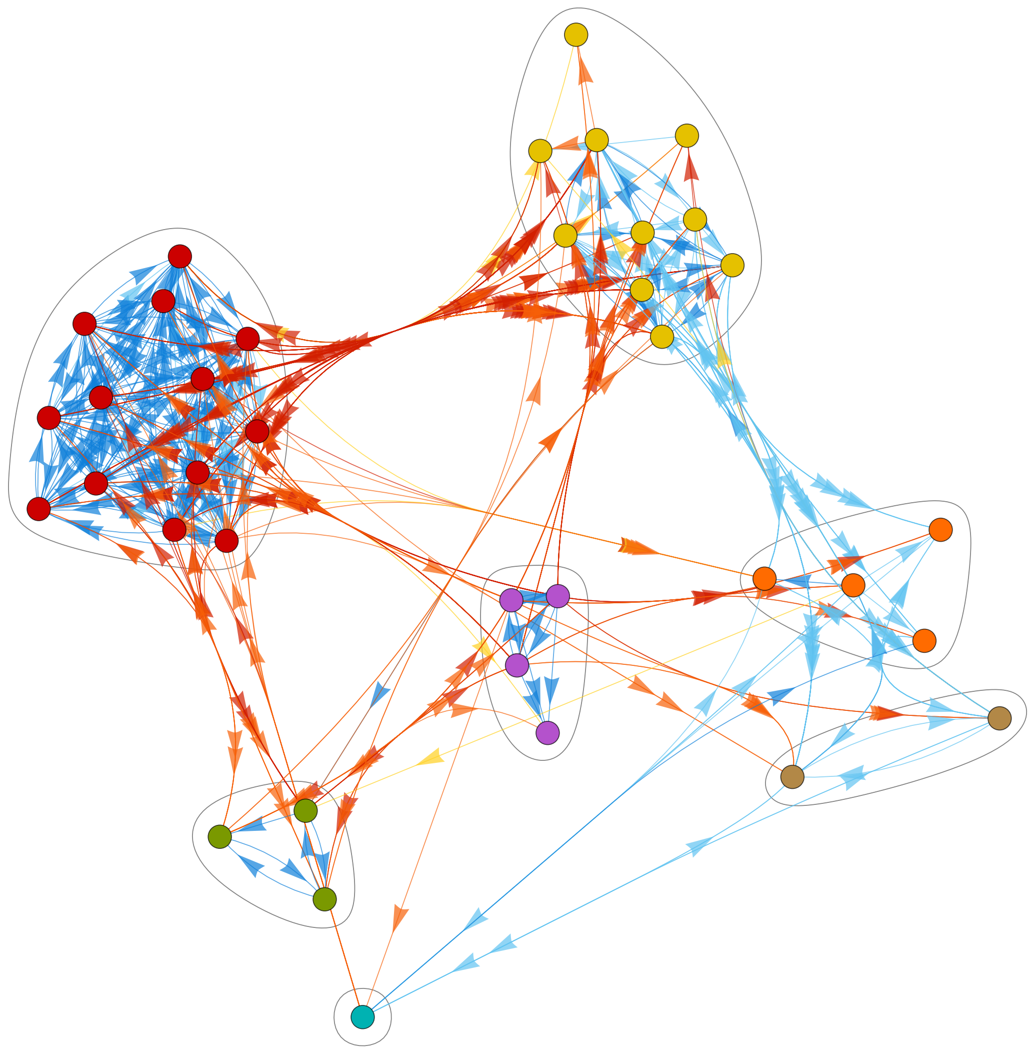

Figure F.2. A bundled-edge network diagram of the alliances in each coalition on 2/4/2015 according to Chuggi and Sky 2017. Alliance nodes are grouped by their reported coalition and the edges colored by their directed standings as in Figure F.1.

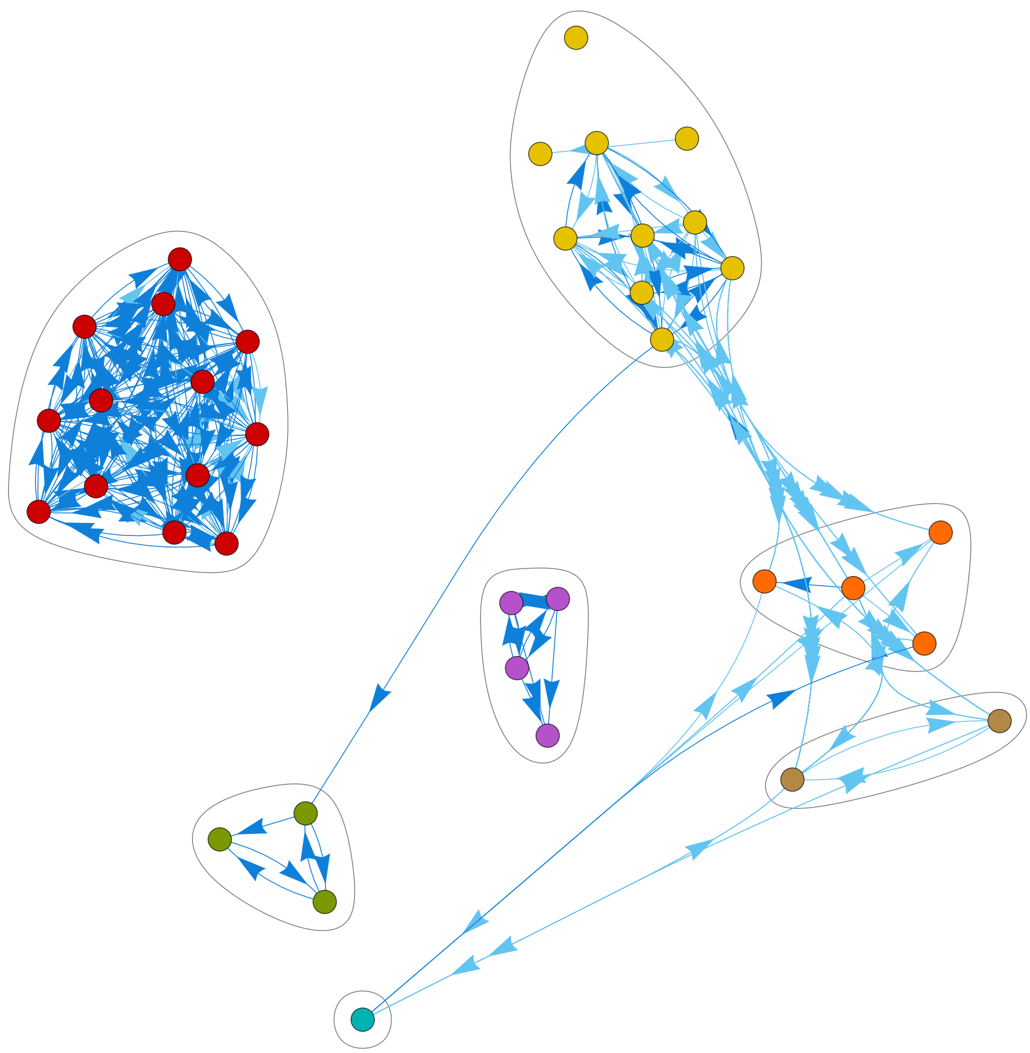

Figure F.3. The same edge-bundled network diagram as Figure F.2 showing only the positive standings. Intra-coalition edges are frequently strong (10), while inter-coalition positive edges are weaker (5, with one exception). Positive standings among coalitions imply that (1) the coalition are merging, (2) that they have a short-term arrangement, or (3) that they do not correspond to the polarized coalitions predicted by balance theory. We may consider the four coalitions with mostly positive standings among them to be in a meta-coalition which is divided into subunits for historical reasons. This feature may largely explain why the coalition detection algorithms never performed better than 90%.

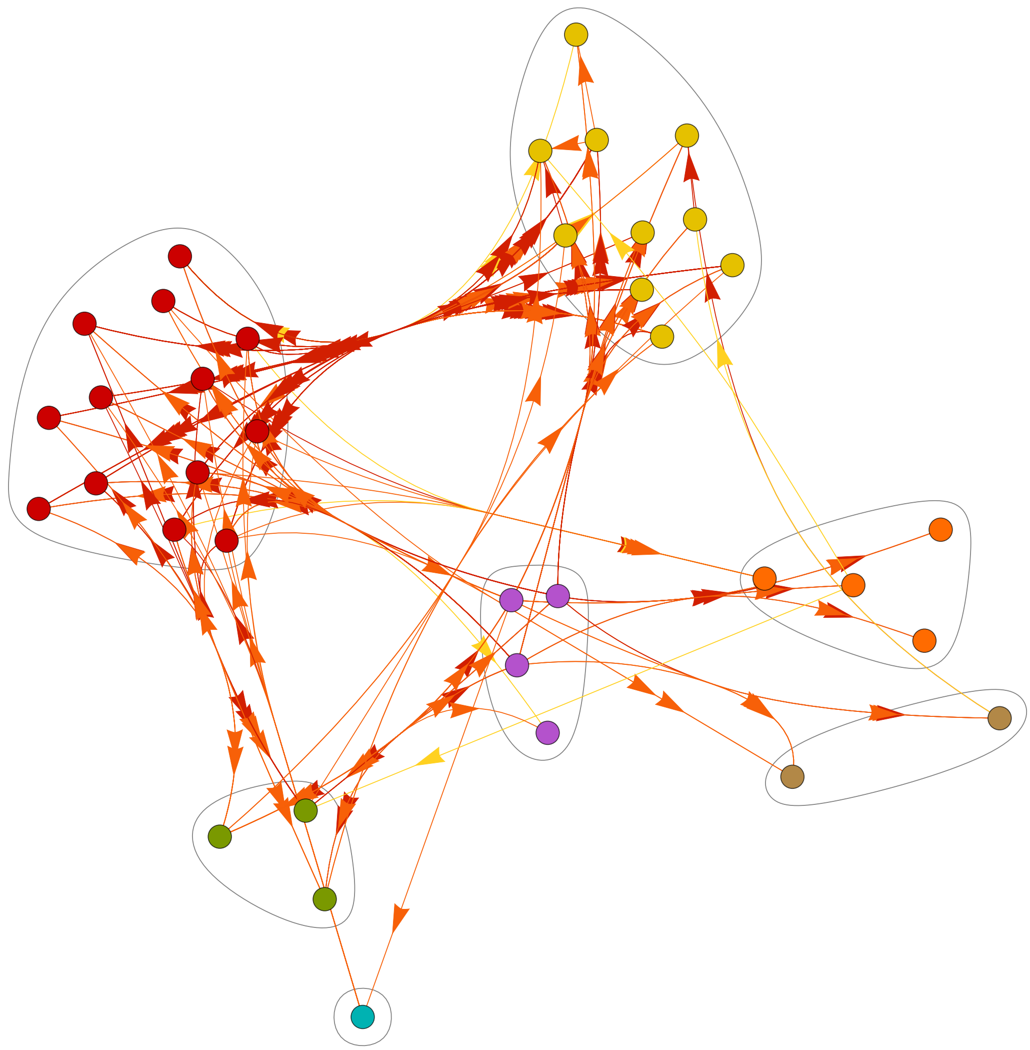

Figure F.4. The same edge-bundled network diagram as Figure F.2 showing only the negative standings. Connections between coalitions are dominated by negative or neutral standings (especially the bottom-left, bottom-right, and center). There are few negative edges within coalitions, but they do exist; this could indicate a temporary conflict, the end of bringing in a new alliance, or the beginning of a political schism.

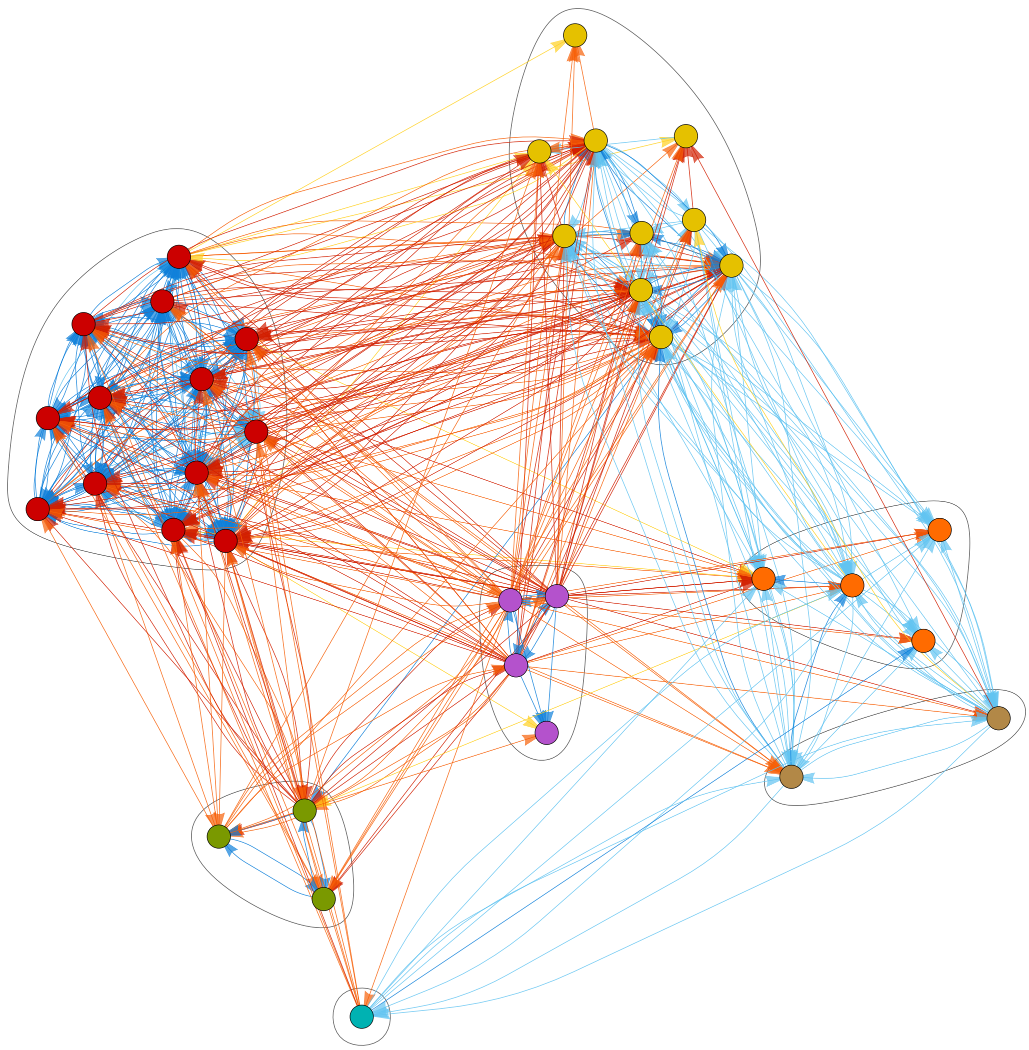

Figure F.5. The same network diagram as Figure F.2 but without bundling the edges to make the number of standings of each type clearer.

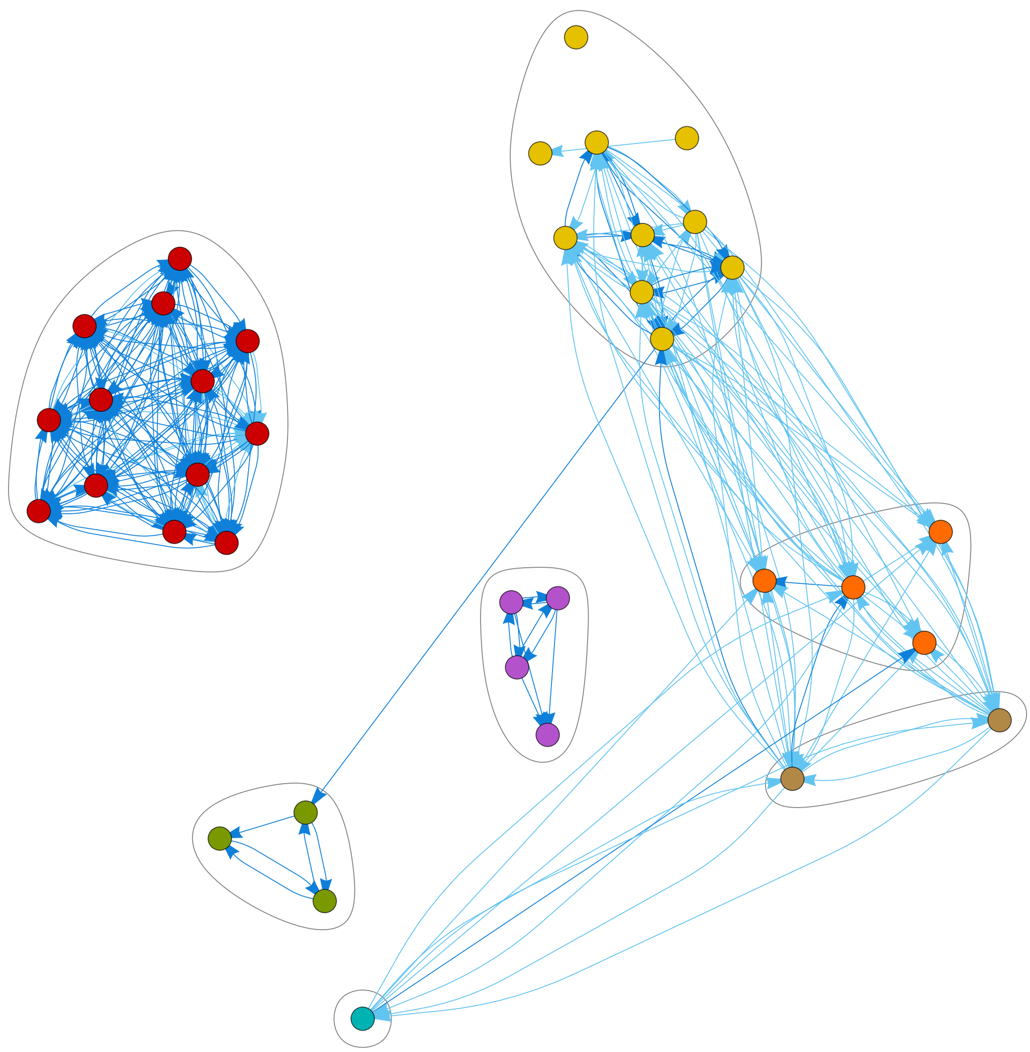

Figure F.6. The same network diagram as Figure F.3 but without bundling the edges to make the number of standings of each type clearer.

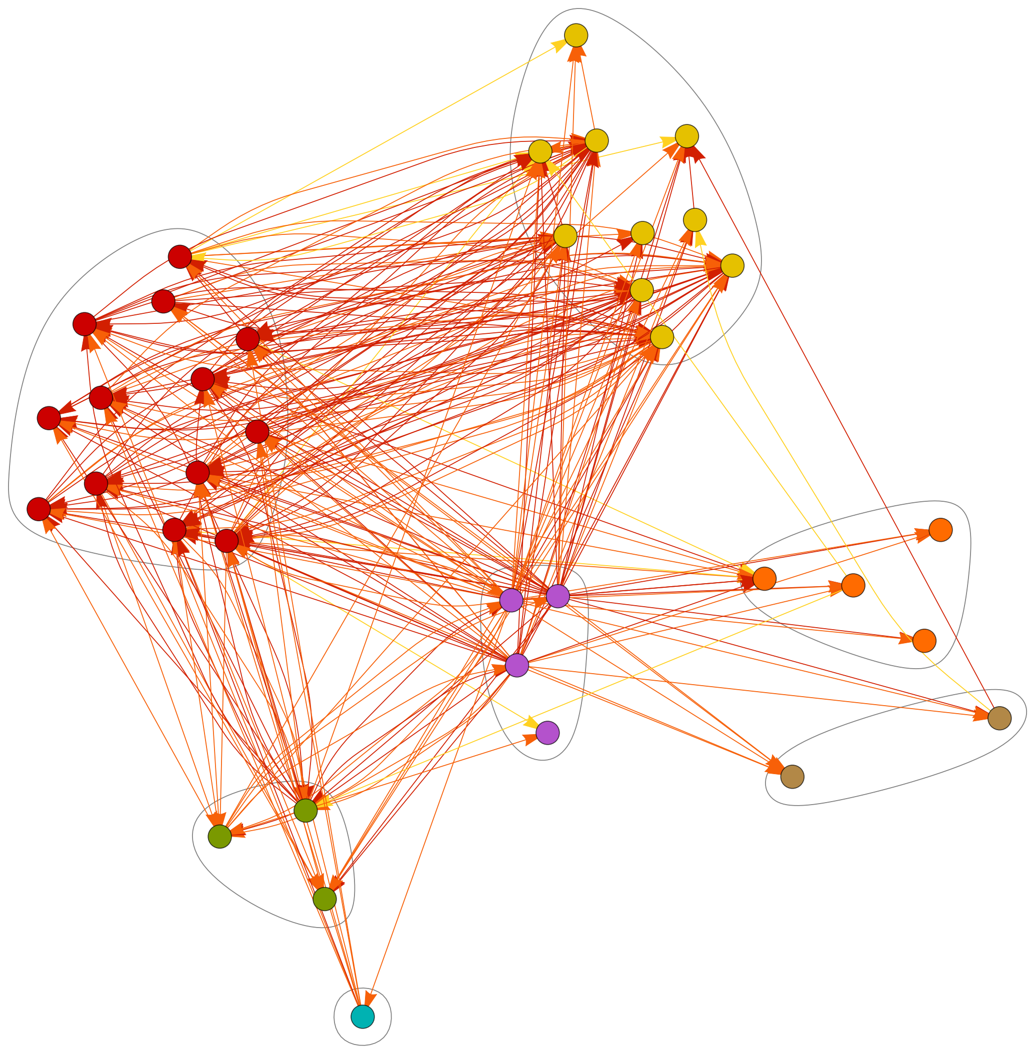

Figure F.7. The same network diagram as Figure F.4 but without bundling the edges to make the number of standings of each type clearer.

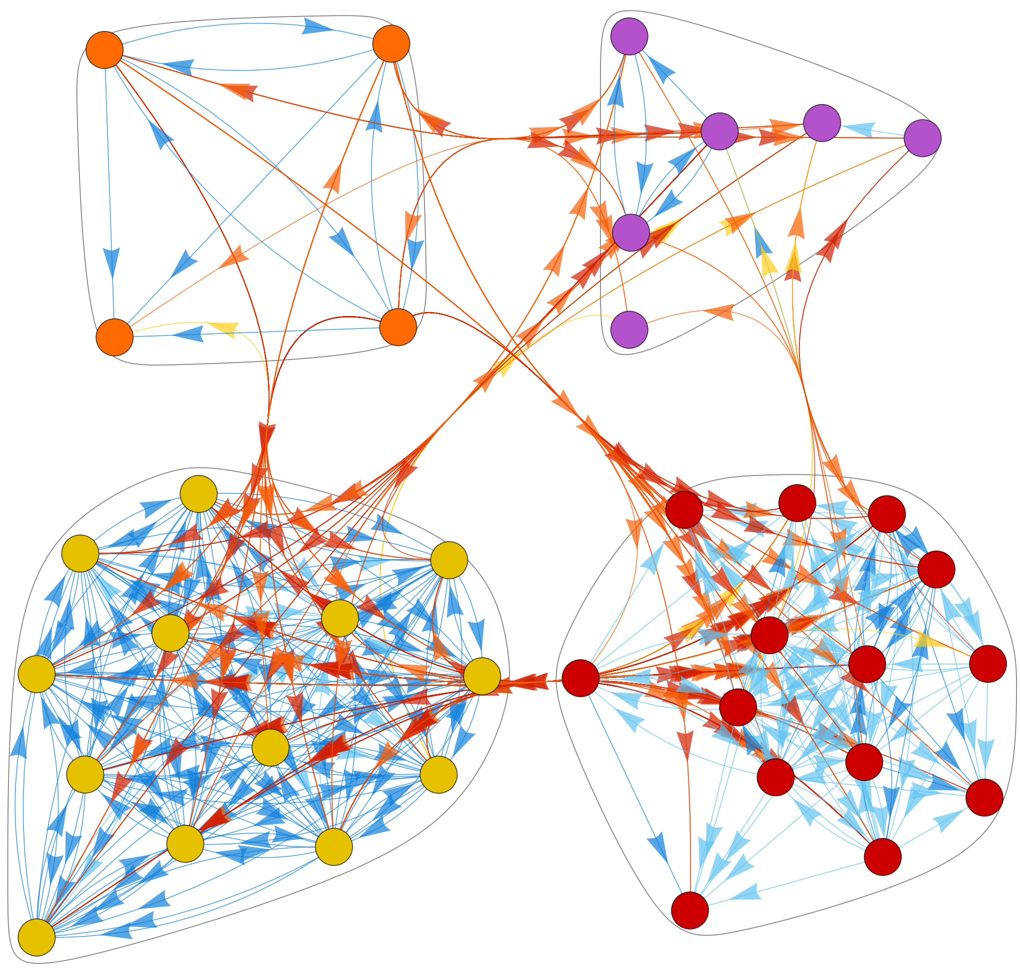

Figure F.8. A network diagram of the coalitions discovered by hierarchical clustering on the positive edges, based on the standings data on 2/4/2015. Showing both positive and negative edges.

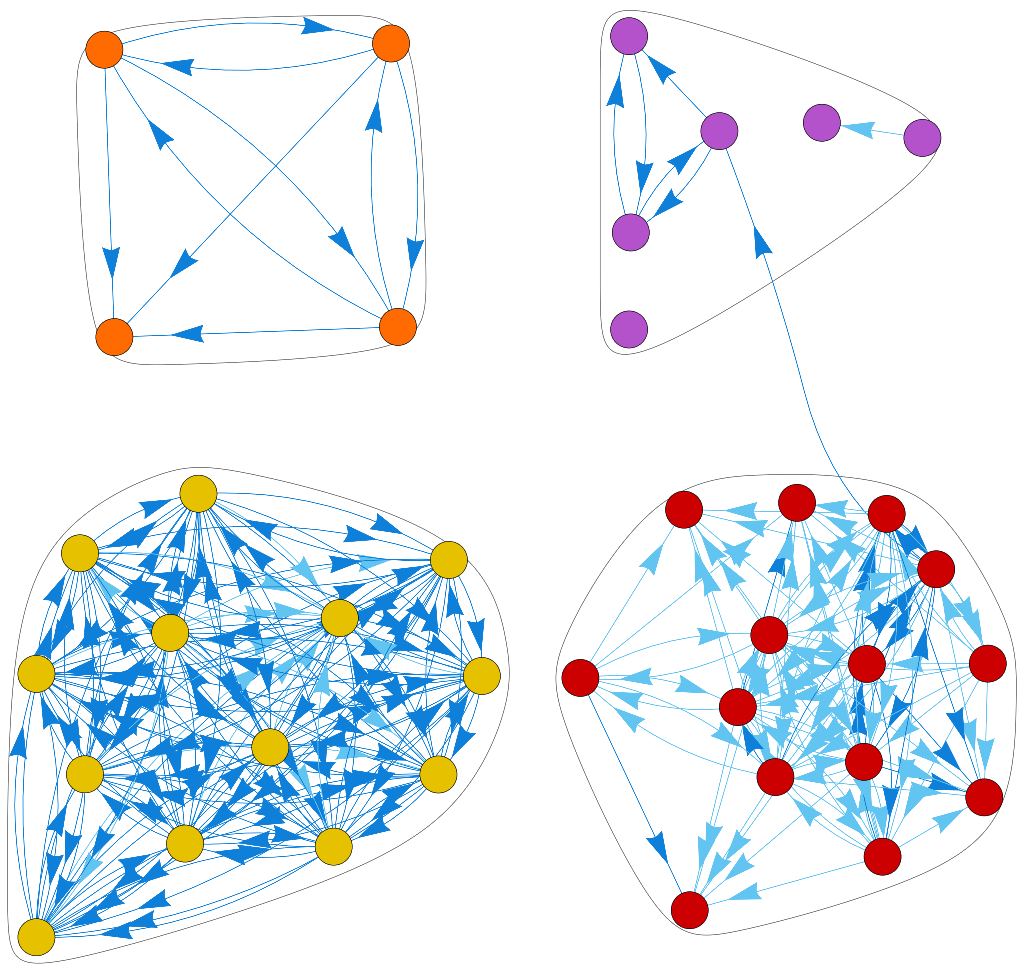

Figure F.9. A network diagram of the coalitions discovered by hierarchical clustering on the positive edges, based on the standings data on 2/4/2015. Showing only the positive edges.

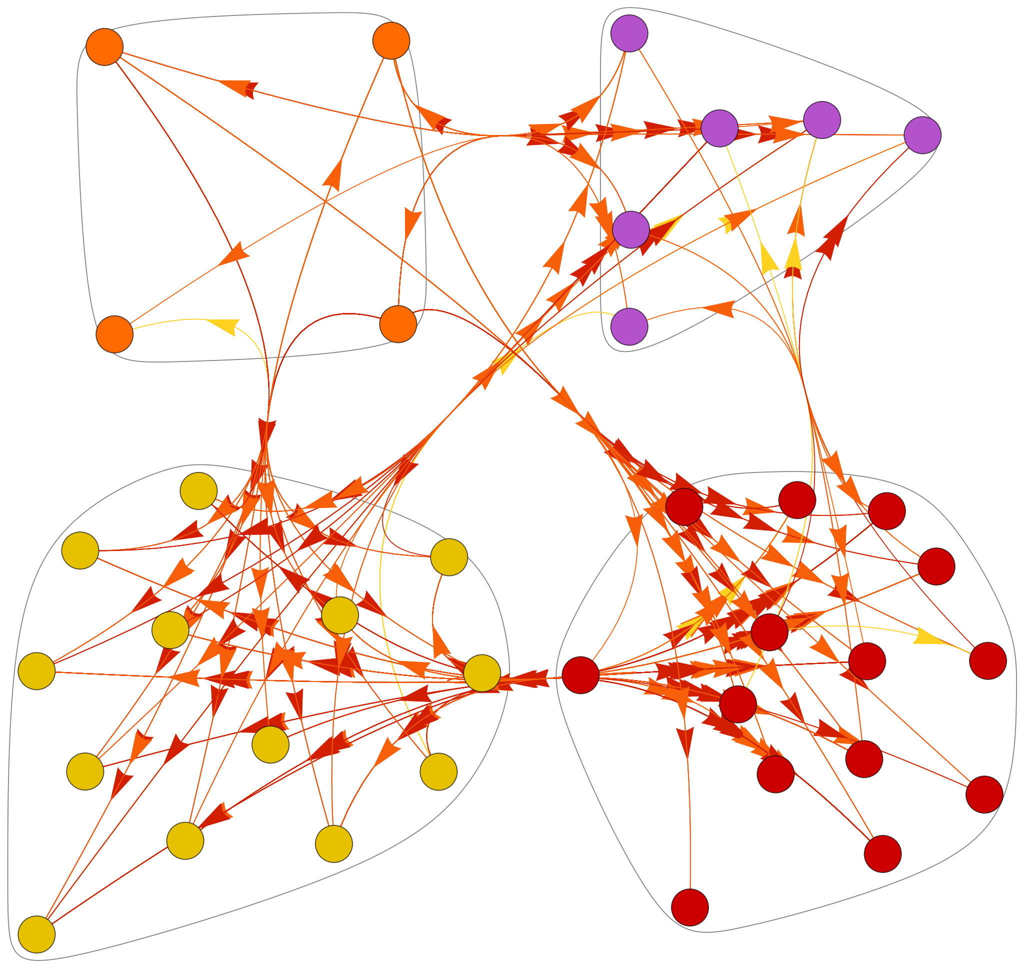

Figure F.10. A network diagram of the coalitions discovered by hierarchical clustering on the positive edges, based on the standings data on 2/4/2015. Showing only the negative edges.

G Appendix: Additional Supporting Information

G.1 Random Assignment on Large Alliance Network

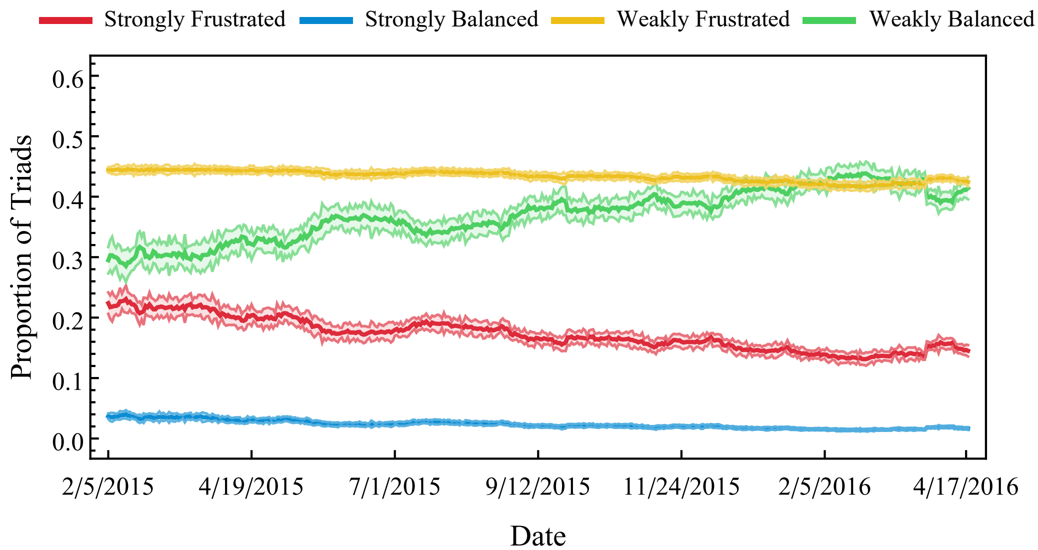

Figure G.1. The mean and three standard deviations in proportions of each type of triad across 100 samples of randomly assigning positive or negative weights while keeping both the structure of the network and the numbers of positive and negative links equal to the empirical data of the large alliances for each day.

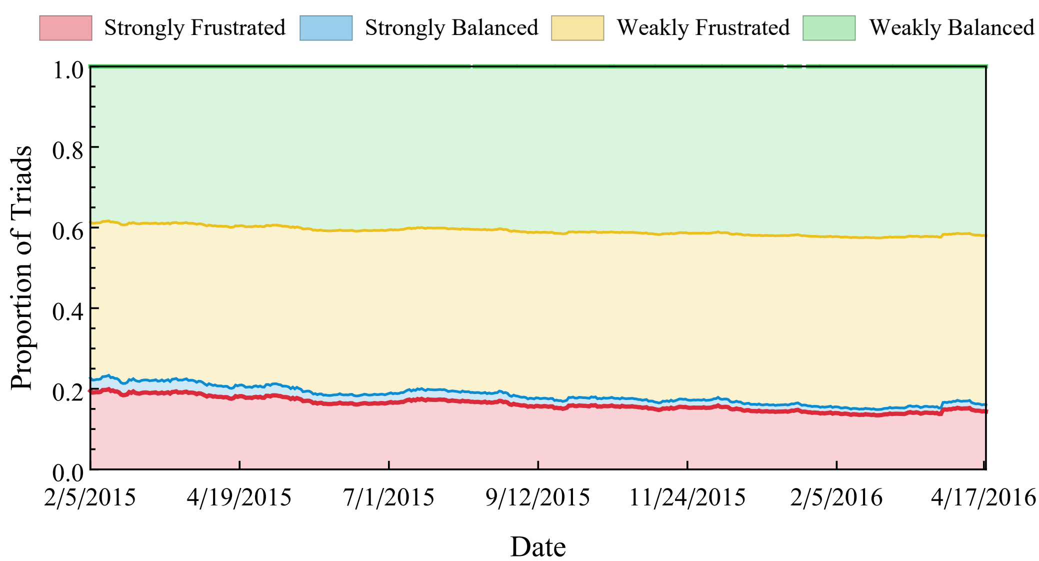

Figure G.2. The accumulated mean proportions triad types across 100 samples of randomly assigning positive or negative weights while keeping both the structure of the network and the numbers of positive and negative links equal to the empirical data of the large alliances for each day.

	strongly balanced	strongly frustrated	weakly balanced	weakly frustrated
max value	4.41	24.11	45.02	45.01
mean value	2.33	17.26	43.41	37.
min value	1.23	12.39	41.15	27.21

Table G.1. Summary results showing the maximum, mean, and minimum values for the number of each triad type across all 100 random samples and time. The maximum and minimum reveal a degree of variance not evident in the the daily plot showing three standard deviations.

G.2 Random Assignment on Sovereign Alliance Network

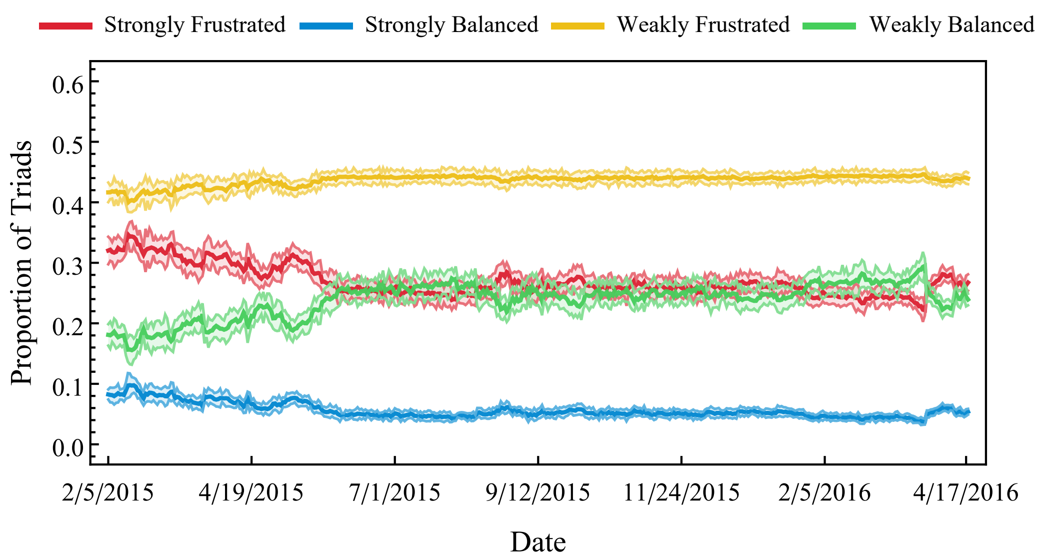

Figure G.3. The mean and three standard deviations in proportions of each type of triad across 100 samples of randomly assigning positive or negative weights while keeping both the structure of the network and the numbers of positive and negative links equal to the empirical data of the sovereign alliances for each day.

	strongly balanced	strongly frustrated	weakly balanced	weakly frustrated
max value	10.94	35.88	45.39	30.37
mean value	5.6	26.92	43.66	23.83
min value	3.44	21.02	39.08	14.24

Table G.2. Summary results showing the maximum, mean, and minimum values for the number of each triad type across all 100 random samples and time. The maximum and minimum reveal a degree of variance not evident in the the daily plot showing three standard deviations.

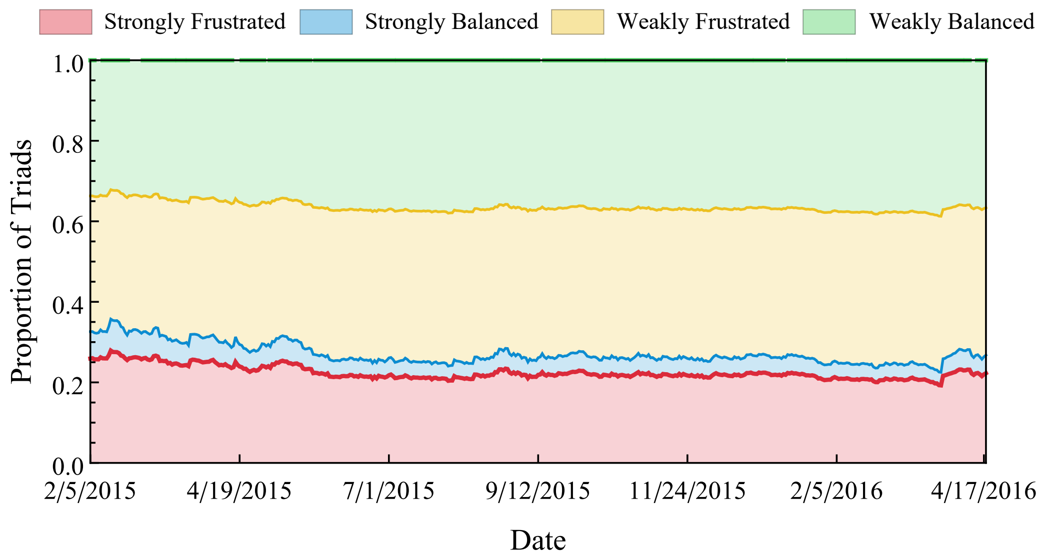

Figure G.4. The accumulated mean proportions triad types across 100 samples of randomly assigning positive or negative weights while keeping both the structure of the network and the numbers of positive and negative links equal to the empirical data of the sovereign alliances for each day.

G.3 Other Plots

Figure G.5. The number of existing large alliances per day. The number of alliances with at least 200 members grew 12% during the our analysis period, then shrank back to initial levels.

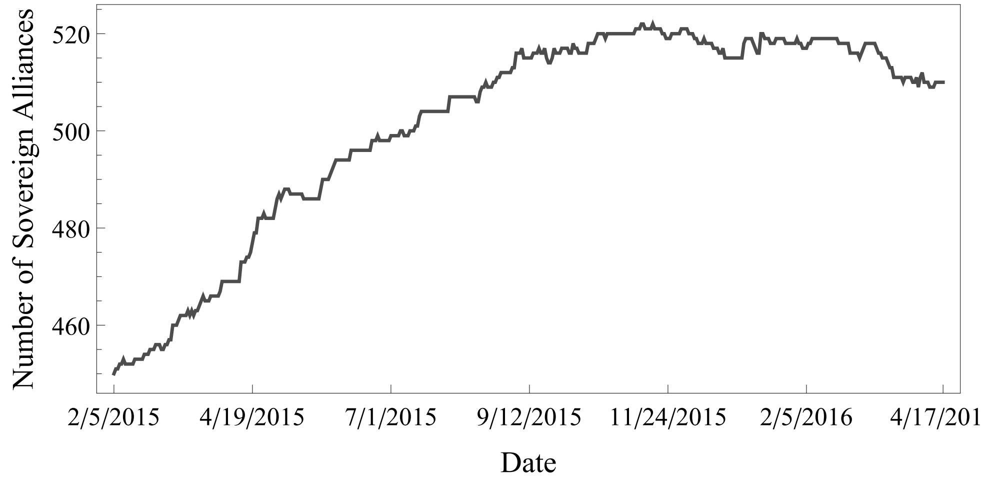

Figure G.6. The number of existing sovereign alliances per day. The number of alliances holding sovereignty over systems nearly doubled during our period of study as a result of the breakup of several large sovereign alliances (and their coalitions).

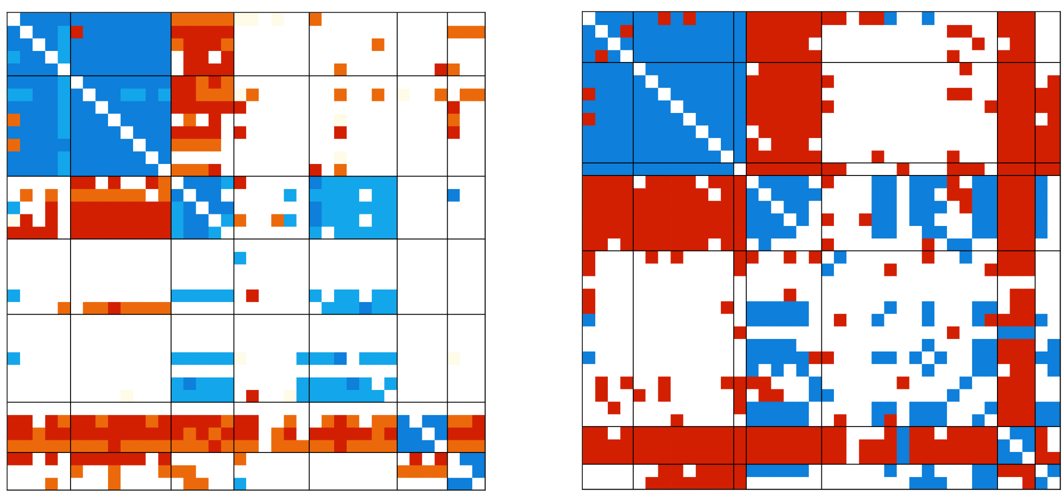

Figure G.7. Side-by-side comparison of the weighted directed (left) versus unweighted symmetric (right) standings relationships for the first day of our analysis. Here we show the coalition detection according to Canberra distance, which is the best match of the observed coalitions for the directed but not for the symmetric version.

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