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The Alignment index and its application to voting at the United Nations General Assembly

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Abstract
We propose the Alignment index as a new statistic to measure the similarity between the voting patterns of two nations. Motivated by the analysis of roll-call votes in the United Nations General Assembly, where issues are approved by large majorities, the Alignment index corrects the bias of a previous measure, called Similarity index, that in those cases is biased towards positive values, overstating similarities. One advantage of the Alignment index is that the value of zero is a clear-cut separation between aligned (similar in the broad sense) and misaligned (dissimilar) nations. One can take advantage of this property applying the Clique Partitioning model to find the voting blocs of the Assembly. In this way, the evolution during the years of the most important blocs, such as the Western societies, the Soviet bloc, the Global South, and so on, can be traced and discussed.

Keywords Voting · United Nations General Assembly · Similarity index · Clustering · Clique partitioning

1 Introduction

At the United Nations General Assembly (UNGA), nations are repeatedly asked to express their votes on issues in the form of *yes*, *no*, or *abstention* decisions. When repeated for a sufficiently long period, researchers have at their disposal many observational data by which they can infer nations' preferences and affinities. These data have been an important source of analysis for international politics: they were used to detect similarities, positions on a political space, inclinations to form blocs of homogeneous countries, and so on. One of the earliest research on voting patterns has been the discoveries of nations' blocs, see

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Ball (1951), and to do so, researchers needed to develop analytical methods to measure the voting similarities between countries. Early proposals of similarity measures were the Agreement Index, see Lijphart (1963), the Kendall's τ_b, see Bruce (1975), the Spearman's rank-order correlation coefficient, see Gartzke et al. (1998). Nevertheless, one of the most applied measure has been the Similarity index, proposed in Signorino and Ritter (1999), that will be referred later on as the *S*-index. The *S*-index converts yes-or-no votes into 0–2 numbers, with 1 the value assigned to the abstention. Given a nations pair, absolute differences between votes are calculated, and after averaging and normalizing, the *S*-index ranges between − 1 and 1. Positive values of the *S*-index are obtained when two nations mostly voted in the same way, and vice versa. The *S*-index seems quite natural, but it has a subtle and questionable consequence when the purpose of the index is to analyze voting blocs. In fact, blocs are defined as groups with high internal similarities and large dissimilarities between different blocs, but, as is the case at the UNGA, when resolutions are approved by large majorities, there are many more similar than dissimilar pairs. Nevertheless, the positive value of the *S*-index does not really reflect similar voting due to common interests or values between two nations, but rather, the inertia of the assembly to seek the largest majorities to support the resolutions. As a consequence, when applied to determine voting blocs, the *S*-index could obtain disappointing results: positive similarities outweighs dissimilarities, clustering cannot detect separate groups. In this contribution, we elaborate on this issue and we propose a method to distinguish voting similarities from the inertia of the assembly. It is just the difference between the actual value of the *S*-index and its expected value conditional to independent voting, as determined by its marginal distribution. We will call this difference the Alignment index, later on referred to as the *A*-index, as it takes into account that knowing that one nation voted *yes* increases the probability that the second nation aligned and voted *yes* as well.

We will apply the *A*-index to cluster nations according to their UNGA voting pattern and we will see that the *A*-index reveals the UNGA voting blocs more efficiently than the *S*-index. Actually, finding and interpreting voting blocs in the Assembly has been one of the earliest questions in the UN political analysis, see Ball (1951). To give an historical background, the first quantitative assessment of the presence of blocs is given in Russett (1966), in which the factor loadings of the principal component analysis are interpreted as the nations indirect membership to blocs of voters. The same approach has been applied later in Kim and Russett (1996). However, the first attempt to apply a clustering algorithm to the voting patterns is quite recent and it is presented (Macon et al. 2012). There, network theory and modularity maximization are used to detect the nations' clusters. Detecting clusters is important as they can affect and predict the transitions to democracy, the formation of defensive alliances, avoid armed conflict, and so on, see Pauls et al. (2017). In our contribution, we propose the Clique Partitioning (CP) model to cluster the UNGA nations into homogeneous blocs. Our preference on the CP model relies on some of its properties: it is an optimal partition model, resolving the doubt about what partition is best. Moreover, the number of clusters k is not fixed in advance, but it is the outcome of the optimization process, resolving the problem of determining k. Finally, outliers are automatically detected as singletons, without imposing their memberships to some cluster. Clearly, they are relevant properties when the CP is applied to voting data, as k is unknown and a single nation that vote without a clear pattern should be detected as an outlier.

Elaborating indexes reflecting voting patterns has been the issue of other contributions too. In Häge (2011); Häge and Hug (2016), it has been noted that common votes between nations can appear just by chance, and it is suggested to use Scott's π or Cohen's κ to measure the dissimilarities. The propensity of approving an issue by large majority and the following bias in the S-index was noted in Macon et al. (2012), too. There, a solution based on network theory is proposed. Nations are considered as nodes of a graph, and there is an arc between two nodes every time they voted in the same way for some amendment. Then, modularity maximization algorithms are used to find the voting blocs. In Benati et al. (2026), after extending the notion of modularity, nations are partitioned using hypergraphs clustering of the voting patterns. Finally, it should be mentioned that similarities can also be computed as by-product of the dimensional scaling method called NOMINEE. The method and its variants, see Voeten (2000) and Bailey et al. (2017), projects nations on a euclidean space and there groups of nations can be visually detected.

The paper is structured as follows: In Sect. 2, we will review some basic procedures of voting at the General Assembly, that is, how an issue can be approved. Moreover, we will describe the most common qualitative blocs that are or were used in International Politics, such as the West, the Soviet blocs, the Global South, and so on. In Sect. 3, we will illustrate our methodology. First, we define the Alignment index and compare it to other similarity measures that were proposed so far. Then, we motivate its use in a clustering model called clique partition. As will be seen, that model has some advantages, the most important are i) that the number of clusters is not fixed in advance, ii) outliers are automatically detected. Finally, we will introduce a resolution parameter to get a generalization of both the A-index and the S-index. The purpose of this parameter is to fine-tune the clustering results by emphasizing or reducing the similarities between nations. In Sect. 4, we will apply the methodology to detect the most important nations blocs that are recognizable at the UNGA from its inception to the last data available. We will see that the confrontation between the West and the Soviet bloc is recognizable for many years, from after the end of the World War II to the Fall of the Berlin Wall. In this period, the number of UN members strongly increased, but the size of blocs did not change greatly, suggesting that the non-aligned countries of those years were a movement of countries that actually acted as intermediaries between the two superpowers. After the Fall of the Berlin Wall, we recognized two periods. The first period lasted a few years after the Fall of the Wall and experienced an alignment between the West and the former Soviet bloc. Then, in the new Millennium, we observed that the West cluster is often detectable, but against an alternative bloc whose cohesion is weak. Indeed, the main countries of the BRICS and the Global South are often there, but not as systematically to form a consistent opposition. Finally, we apply the resolution limits to two of the most recent years to check the sensitivity of the clustering to the parameters. There, it can be found that the core of the Western countries can be still detected even though the plain application of the A-index failed. Finally, in Sect. 5, we conclude with some remarks.

2 A world organized around common interests and values

2.1 Voting in the general assembly at the united nations

Founded in 1945, the United Nations is an international organization which nowadays counts up to 193 Member States (United Nations 2024). Its main representative body is the General Assembly (UNGA), its center of innovation and diffusion of global policies in which international controversies and disputes take place. In the Assembly, all 193 member states enjoy equal status and they exercise their voting rights following their preferences as a sovereign entity, see Khan (2020); Lees (2023). As a consequence, votes offer an interesting insight into the states alignment in the international scenario (Pauls et al. 2017; Seabra et al. 2022). The UNGA discusses specific issues through a dedicated agenda: there are six committees corresponding to six policy areas. These are the Committee for Disarmament and International Security, the Economic and Financial Committee, the Social, Cultural and Humanitarian Committee, the Special Political and Decolonization Committee, the Administrative and Budgetary Committee, and the Legal Committee (Panke 2014). Therefore, UNGA resolutions are mainly concerned with colonialism, the Middle East, economic development, nuclear issues and disarmament, and human rights (Voeten 2013). However, the number of roll calls about an issue varies along the years, some being overrepresented compared to others, see Häge et al. (2016). Roll-call votes are the only type of vote for which the vote choice of each UN state is recorded and they consist of around 20–30% of the whole resolutions on a given year. The other ways of making decisions are 'by consensus', 'by acclamation', 'without objection' or 'without a vote'. In a roll call, a nation can cast three types of vote: agreeing, (yes), disagreeing (no), or abstaining. A fourth hypothesis is the absence, that, depending on circumstances, can be interpreted as a real abstention or a missing observation, for example due to bureaucratic impediments to voting, see Dreher and Jensen (2013) and Voeten (2013) for opposing views about the treatment of these data. Since the UNGA resolutions are non-binding, it can be claimed that, at least most of the times, the vote is sincere and it actually reflects the nation's preference. In other words, strategic voting cannot be excluded, but it is surely less common than in the United Nations Security Council (UNSC), where deliberates are binding, see Bailey et al. (2017). As voting is public and nations vote repeatedly on many issues, coordinated voting patterns are likely to emerge. Therefore, roll-call votes are helpful to assess the level of cohesion among specific regional groups, such the West and the East, the Global South or the BRICS and so on, see for example (Boockmann et al. 2011). An interesting open problem of political analysis is to determine how blocs, whose definition is basically *qualitative*, are consistent with *quantitative* blocs, that are determined by actual observation of some common behavior. In what follows, we give a brief description of the groups that we could expect to find.

2.2 The Western societies

The Western society is one of the main categories that have been used to analyze the UNGA voting. The concept is straightforward when applied to UNGA post-war period, in which the Yalta iron curtain separated the Soviet bloc from the rest of the world. In fact this separation could be easily identified at the beginning of the UNGA activity in 1947. At the time, the small number of nations that took part in the assembly made it easy to identify their voting

patterns. However, as the UN unfolded, the differences were more nuanced and less clear. Nowadays, the term Global West broadly defines a set of countries characterized by shared political, economic, and cultural values. It's a way to distinguish these countries from the rest of the world, often called the Global East or Global South, Ikenberry (2024). It is an expansive and inclusive membership association which, being multilateral and decentralized, attracts and remains open to new members. This system is not geographically defined or confined to a territorial region, rather, it is mainly characterized by shared political principles. The most influential nations within the global West are those that belong to the G7, which is an informal forum composed of the United States, the United Kingdom, Canada, Japan, France, Germany, and Italy. The G7 was established as a platform for economic and financial cooperation in response to the 1973 energy crisis, with its first summit held in 1975. Initially, it was focused on financial challenges, but it has progressively expanded its scope. Over time, the G7 has evolved into a more formal venue for tackling major global issues and played a leading role in the creation of various functional organizations to manage the economic interdependence (Ikenberry 2024).

2.2.1 The BRICS

In 2001, when the global economy was under a recession, the acronym BRIC was coined from the initials of the four largest emerging market economies: Brazil, Russia, India, and China. At the time, these countries represented about 42% of the world's population and they were thought to have the potential to drive the global economic growth, Roberto Castello Branco (2015). In 2010, the Federal Republic of South Africa was invited to join the group, transforming BRIC into BRICS. The alliance continued to grow, and as of 2024, it has welcomed new members, including Iran, Ethiopia, Egypt, and the United Arab Emirates, while as of 2025, it has welcomed Cuba and Peru, covering about 36% of global GDP, the 37% of the world trade, about half of the world population and the 40% of the global oil production. At present, the group is considered as a potential alternative to the existing global order represented by the G7. The BRICS countries shared not only their status as rising economies, but also a desire to play an active role within the international context. This motivation led their foreign ministers to convene before the 61st United Nations General Assembly to discuss their votes and explore the possibility of expanding their multilateral cooperation (Duggan 2015).

2.2.2 The G77 and the global South

In the post-colonial period, the enlargement of the UN lead to the emersion of a new cleavage, represented by the North-South divide, potentially opposed or different to the traditional East-West divide, see Voeten (2000). The institutional expression of the South is the G77, which was established in 1964 at the end of the first session of the United Nations Conference on Trade and Development (UNCTAD). The G77 was founded after the experience of the Non-Aligned Movement, but it pursued a more ambitious purpose. The Non-Aligned Movement aimed at promoting political independence and cooperation among not-aligned states, while the G77 aimed at favoring economic cooperation between all the developing countries to obtain the fairest global commercial conditions. Nowadays, the G77 serves as the key platform for the Global South within the UN system, allowing member states to

collectively address issues and negotiate on a unified front. The Global South includes both authoritarian regimes and democracies. Its opposition to aspects of the international order, claimed to be framed around the Western interests, is based on a shared ideology about the International politics developed during the process of decolonization, see Lees (2023). Furthermore, the Global South nations are recognized to have driven the human rights agenda within the UNGA, particularly regarding issues of racial discrimination (Schabas 2022).

3 The alignment index

3.1 From similarity to alignment

The following statement is trivial: If in many resolutions two nations vote in the same way, then they are similar. However, voting in the same way is not enough to determine whether or not their preferences align. If in the Assembly there is a tendency to vote with overwhelming majorities, then two nations vote in the same just for inertia. In this case, their similarity does not imply that they agree on the most contested issues and a more accurate analysis should follow. In the less frequent case that one nation is disagreeing, what is the vote of the other nation? Did it follow the first nation in the opposition, or did it stay on the other side of the fence? In other words, in the most contested issues, did they align their votes or not?

Voting on resolutions in the UNGA allows for three alternatives: approval, rejection, and abstention. On this data, one can calculate the similarity index, that is, the *S*-index, proposed in Signorino and Ritter (1999). Its definition is the following: votes are coded with a variable $X = \{1, 2, 3\}$, corresponding to approval, abstention, rejection. Having a set K_{ij} of resolutions in which both nation *i* and *j* participated, let x_{ik} and x_{jk} be the vote of nation *i* and *j* on resolution *k*. Then the *S*-index is:

$$s_{ij} = 1 - \frac{\sum_{k \in K_{ij}} |x_{ik} - x_{jk}|}{|K_{ij}|} \tag{1}$$

The index assumes that, in a single roll call, the strongest difference between two nations is when they voted in opposite way, while abstention is treated as a milder form of disagreement. Then, the differences are summed for all votes $k \in K_{ij}$ and subtracted to 1. In this way, the index s_{ij} ranges from 1, when nations *i* and *j* always vote in the same way, to -1, when the two nations always vote in opposite direction. The logic of the S-index is straightforward, but it can induce a bias. If the assembly is characterized by decisions approved by large majorities, then finding dissimilar voting can be rare. In fact, to find two dissimilar nations, that is, two nations with $s_{ij} < 0$, we must have patterns in which negative and positive votes are at least sufficiently balanced. If dissent is rare, most of the times the agreement between two nations appears just by chance, but the value of s_{ij} is biased towards positive values, indicating an unjustified similarity.

It has been noted that the similarity between voting patterns should be corrected by probabilistic considerations, for example see Häge (2011); Häge and Hug (2016), where the Scott's τ and the Cohen's κ are proposed to measure the similarity. Here, we propose a correction of the *S*-index that considers the conditional probabilities of observing two aligned votes. Let $X_i = yes$ be the event that nation *i* will vote *yes* (and similarly for *no* and *abstain*

votes), then the following conditional probabilities characterize the voting alignment of the *yes* vote between nations *i* and *j*:

$$\Pr[X_i = yes | X_j = yes] = \begin{cases} 1, & \text{maximum alignment;} \\ \Pr[X_i = yes], & \text{independent voting;} \\ 0. & \text{maximum misalignment.} \end{cases} \tag{2}$$

Similarly, using the same conditional probabilities, we can define the alignment of the *no* vote or of an *abstain* decision. The conditional probabilities can be estimated from observed voting. Let K_i be the set of roll calls in which nation *i* participated, and *Y* the subscript label of the *yes* vote, then the marginal probability of *i* voting *yes* is:

$$p_{i,Y} = \Pr[X_i = yes] \simeq \frac{\#[\text{i voted yes}]}{|K_i|}. \tag{3}$$

Similarly, we can define $p_{i,A}$ and $p_{i,N}$ to estimate the marginal probabilities of *i* voting *abstain* and *no* respectively. Finally, from Eq. 3, it can be estimated what is the joint probability $p_{ij,YY}$ that two nations *i* and *j* both will vote *yes* under the hypothesis of independent voting: it is $\Pr[X_i = yes \cap X_j = yes] \simeq p_{ij,YY} = p_{i,Y}\, p_{j,Y}$. Clearly, we can calculate all the other joint probabilities in case of independence. They are $p_{ij,AA}$ and $p_{ij,NN}$ as the probabilities that *i* and *j* both will vote *abstain* and *no*, and finally, the probabilities that they vote differently: $p_{ij,YA}, p_{ij,YN}, p_{ij,AY}, p_{ij,AN}, p_{ij,NY}, p_{ij,NA}$. Using these probabilities, we can calculate the hypothetical value of the *S*-index in Eq. 1 under the condition of independent voting. It is:

$$s^0_{ij} = 1 - 1(p_{ij,YA} + p_{ij,AN} + p_{ij,AY} + p_{ij,NA}) - 2(p_{ij,YN} + p_{ij,NY}), \tag{4}$$

Clearly, there is no reason that this quantity should be zero. Two nations can vote independently, and therefore showing no peculiar alignment even though their *S*-index resulted positive (or negative). However, to let their vote coordination emerge, it is sufficient to compare the actual *S*-index with its theoretical counterpart S^0. We will call this difference the Alignment index, later on *A*-index, and for two nations *i* and *j* it is calculated as:

$$a_{ij} = s_{ij} - s^0_{ij} \tag{5}$$

To make a numerical example, suppose that during 100 roll calls nations *i* and *j* voted *yes* 80 times, voted *no* 20 times. However, when they disagreed, they do it in opposite way: they both voted *yes* 60 times, while in 20 roll calls *i* voted *yes* when *j* voted *no*, and vice-versa, in 20 roll calls *i* voted *no* when and *j* voted *yes*. This a clue that they should hold different views and interests in the political arena, and we wish an index capable to recognize it. Working out the calculation, we can see that there is a fraction of 0.6 roll calls in which they vote the same way, and in a fraction of 0.4 they disagree, so that there is a difference of 2 between their votes. Therefore the *S*-index is $s_{ij} = 1 - 0.8 = 0.2$: as a positive value, it indicates similarity between the two nations, but it does not consider that when they disagree, they do it in the opposite way. However, considering the marginal voting distribution, we have $p_{i,Y} = p_{j,Y} = 0.8$ and $p_{i,N} = p_{j,N} = 0.2$. Then, the observed joint probabilities of a yes-

no vote or a no-yes vote are both $p_{ij,YN} = p_{ij,NY} = 0.20$. This value is to be confronted with the theoretical value of independent voting of $p_{i,Y} * p_{j,N} = p_{i,N} * p_{j,Y} = 0.16$. Therefore, we find that according to Eq. 5 $a_{ij} = -2 * (0.04 + 0.04) = -0.16 (< 0.0)$. The negative value of the alignment is a more accurate picture of the opposite way by which the two nations expressed their disagreement.

3.2 A worked example

In the following, using some numerical simulations, we will illustrate the differences between the A- and the S-index. To summarize our findings, we will see that there are two extreme cases in which the outcomes are identical or opposite, while in intermediate cases the $A-$ index recognizes differences between nations that are more pronounced than what is recognized by the $S-$index. The reason is due to voting inertia: that is, if the assembly (and therefore nations) tends to support issues with overwhelming majorities, then differences between nations are more revealed when they disagree rather than when they disagree.

If it is assumed that marginal and joint vote probabilities are estimated from the same roll-call votes, so that $K_i = K_j = K_{ij}$ in Eqs. (1) and (3), then the general structure that is necessary to calculate the A-index is summarized in Table 1.

Here we give a worked example to illustrate the full details of the calculation.
In given period, the assembly voted on 240 resolutions. Two nations, *r* (Row) and *c* (Column), expressed the following votes:

	Yes	Abst	No	
Yes	120	10	40	170
Abst	10	10	10	30
No	40	0	0	40
	170	20	50	240

From a qualitative point of view, it can be seen that most of the times they voted in the same way: they both supported the resolutions 120 times and the abstained 10 times, therefore, 130 times voted in the same way, 110 times voted differently. However, one may recognize that when they rejected a resolution, they did it for opposite reasons, they never jointly opposed a resolution (the No-No occurrences are 0), but rather, there are a sum of 80 votes in which Yes-No or No-Yes pairs are expressed. Let's see how these differences are recognized by the indices.

Table 1 Necessary data to calculate the A-index

(a) Penalty terms of the A-index

	Yes	Abst	No
Yes	0	1	2
Abst	1	0	1
No	2	1	0

(b) Probability terms of the A-index

	Yes	Abst	No	
Yes	p_{YY}	p_{YA}	p_{YN}	$p_{Y,\cdot}$
Abst	p_{AY}	p_{AA}	p_{AN}	$p_{A,\cdot}$
No	p_{NY}	p_{NA}	p_{NN}	$p_{N,\cdot}$
	$p_{\cdot,Y}$	$p_{\cdot,A}$	$p_{\cdot,N}$	1.0

Regarding the *S*-index, and observing the relative frequencies of voting, calculation begins with the observed data here reported (numbers are not fully consistent due to rounding):

	Yes	Abst	No	
Yes	0.500	0.042	0.167	0.708
Abst	0.042	0.042	0.042	0.125
No	0.167	0.000	0.000	0.167
	0.708	0.083	0.208	1.000

Yes-No differences counts for dissimilarity of 2; while Abstention versus and Yes or No counts for a dissimilarity of 1, therefore:

$$s_{rc} = 1 - 1(0.042 + 0.042 + 0.042 + 0.000) - 2(0.167 + 0.167) = 0.206$$

Regarding the *A*-index, firstly we must consider the expected values of the vote frequencies on the condition of independent voting. For the given marginals, the theoretical frequencies are:

	Yes	Abst	No	
Yes	0.502	0.059	0.148	0.708
Abst	0.089	0.010	0.026	0.125
No	0.118	0.014	0.035	0.167
	0.708	0.083	0.208	1.000

Therefore the theoretical *S*-index in case of independent voting is:

$$s^0_{rc} = 1 - 1(0.059 + 0.089 + 0.026 + 0.014) - 2(0.148 + 0.118) = 0.280.$$

As a result, the *A*-index is:

$$a_{rc} = 0.206 - 0.280 = -0.074.$$

The relevant issue is that in the first case we had a positive value, that is, broadly speaking, the opinions of *r* and *c converge*, while in the second case we had a negative value, that is, the opinions of *r* and *c diverge*. Actually, it is not a theoretical puzzle, but rather, it depends on how vote differences are taken into account. In the first case, no standardization is attempted, while, in the second case, the differences are standardized by the inertia of the assembly. As we will see, the second opportunity is better if our purpose is to detect groups of homogeneous voters in the assembly.

3.3 A comparison between scenarios

In the following, to simplify calculations, we assume that the two nations never abstained, so that the relevant probabilities are summarized in the following two-ways table:

	Yes	No	
Yes	p_{YY}	p_{YN}	$p_{Y,\cdot}$
No	p_{NY}	p_{NN}	$p_{N,\cdot}$
	$p_{\cdot,Y}$	$p_{\cdot,N}$	1.0

After some calculation, it can be found that the *S*-index can be written as:

$$s_{ij} = 1 - 2(p_{YN} + p_{NY}) \tag{6}$$

while the A-index can be written as:

$$a_{ij} = 2(p_{Y,\cdot}p_{\cdot,N} + p_{N,\cdot}p_{\cdot,Y} - p_{YN} - p_{NY}) \tag{7}$$

The two formulas will be applied to the following scenarios.

Scenario 1: Disputed votes. In this scenario, issues are strongly contested. They are approved or rejected by a strict margin, and nations vote Yes and No with the same frequencies. In this simulation, we consider two nations that voted yes or no with the same marginal probability of 50% and their difference emerges on the frequencies in which they voted in opposite way, that is, the probability of Yes-No or No-Yes. The two-ways table is characterized by marginal probabilities $p_{Y,\cdot} = p_{N,\cdot} = p_{\cdot,Y} = p_{\cdot,N} = 1/2$ (and the same for column), while the probability of opposite votes Yes-No or No-Yes is the parameter $p_{YN} = p_{NY} = x$ for $0 \leq x \leq 1/2$. Therefore, data can be arranged in the following table:

	Yes	No	
Yes	$1/2 - x$	x	1/2
No	x	$1/2 - x$	1/2
	1/2	1/2	1

Letting x range from 0 to 1/2, we can observe the variation of the difference between nations from agreement to disagreement. It can be worked out that the S-index = $1 - 2(x + x) = 1 - 4x$, while the A-index = $2(1/4 + 1/4 - x - x) = 1 - 4x$. Therefore in this scenario the value of the A-index coincide with the S-index. Their plots are reported in the straight lines of Fig. 9a, where it can be seen that they range from 1, perfect similarity and alignment, to − 1, perfect dissimilarity and misalignment. The value of $x = 1/2$ is the threshold that separate similarities from dissimilarities, both for the S-index and for the A-index.

Scenario 2: Large majorities, but opposite disagreement. In this scenario, issues are less disputed, so that in the two-ways table the marginal probabilities of voting Yes is greater than 1/2. Then we consider two nations for which, as before $p_{YN} = p_{NY} = x$, but the two nations never disagree together, that is, $P_{NN} = 0$. Therefore, data can be arranged in the following table:

	Yes	No	
Yes	$1 - 2x$	x	$1 - x$
No	x	0	x
	$1 - x$	x	1

As before, x is allowed to range between 0 and 1/2. We have that S-index = 1–4x and A-index = $2(2x(1 - x) - 2x) = -4x^2$, their plots are reported in Fig. 9b. There it can be seen that the outcomes of the two indexes are completely different. The S-index remained the same as in Fig. 9ba, revealing again that the threshold $x = 1/2$ separates similar from dissimilar nations. Conversely, the A-index is always negative, pointing to misaligned voting even when the value of x is close to 0 and both nations voted Yes-Yes most of the times! To explain this difference, when the nations voted Yes-Yes, the S-index recognizes a similar vote, while the A-index recognizes the tendency of the assembly to approve unanimously. In the latter case, the dissent between nations is less frequent, so that the cases in which they voted in opposite way is revealing of their differences.

Scenario 3: Varying majorities, varying dissent. Scenario 1 and 2 are the extreme cases in which in which the indexes are the same or completely different. However, most of the times, the difference between the $A-$ and $S-$index is milder, because some times nations voted No-No too. In this simulation we keep as before $p_{YN} = p_{NY} = x$, while the proportion of Yes-Yes over the No-No votes is controlled by the coefficient k. The resulting two-ways table is:

	Yes	No	
Yes	$k(1-2x)$	x	$k+x(1-2k)$
No	x	$(1-k)(1-2x)$	$1-x(1-2k)k$
	$k+x(1-2k)$	$1-x(1-2k)-k$	1

Note that in Scenario 1 it was assumed that $k = 1/2$, while in Scenario 2 $k = 1$, so that an intermediate level of k, $1/2 < k < 1$ is also an intermediate scenario between 1 and 2. For example, considering $k = 3/4$, then the resulting $A-$ and $S-$indexes are reported in Fig. 9c. It can be see that the $S-$index remains the same straight line as before, while the $A-$ index is an arc of parabole slightly below the line. Moreover, It can be seen that the $A-$ index becomes negative for a value of x that is smaller than what happens for the S-index. It is so because the $A-$ index, as in Scenario 2, recognize the inertia of the assembly of approving an issue by large majorities. Therefore, to summarize our findings, the $A-$ index recognizes a difference between nations that is more pronounced than what is recognized by the $S-$index.

3.4 The clique partitioning model to cluster the UNGA

The A-index has a value of 0 that clearly separates aligned from misaligned nations. In the following section, we present how to take advantage of this property to detect the clusters of nations that voted in the most aligned way. The model that we are using is the Clique Partitioning (CP). The CP is a clustering model whose inputs are the alignments a_{ij} between every pair $i, j \in N$. For a given subset $C \subseteq N$, the group alignment is $a(C) = \sum_{(i,j)\in C} a_{ij}$ and it is the measure of the whole homogeneity of C: the highest is the value, the most aligned are the nations of C. According to the CP model, the best partition $P = \{C_1, \ldots, C_k\}$ is the one that maximizes the overall index of alignment, that is, the argument that solves the CP problem: $\max_P \sum_{C_k \in P} a(C_k)$.

The CP problem can be expressed as Integer Linear Programming (ILP). Let x_{ij} be a binary variable, taking value 1 if nations i, j are located in the same cluster, 0 otherwise. Then the optimal partition P is obtained through the following optimization model:

$$\max_x \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} a_{ij} x_{ij} \tag{8}$$

$$x_{ij} + x_{jk} - x_{ik} \leq 1 \text{ for all } i < j < k; \tag{9}$$

$$x_{ij} - x_{jk} + x_{ik} \leq 1 \text{ for all } i < j < k; \tag{10}$$

$$-x_{ij} + x_{jk} + x_{ik} \leq 1 \text{ for all } i < j < k; \tag{11}$$

$$x_{ij} \in \{0,1\} \text{ for all } i,j; \tag{12}$$

The objective function (8) tends to put similar nations into the same cluster, while dissimilar ones are most likely put in different clusters. Note that to obtain meaningful clusters, it is important that parameters a_{ij} are balanced between positive and negative values, as is the case of the A-index. Constraints (9, 10, 11) refer to the transitivity property: if i and j are in the same cluster, and j and k are in the same cluster too, then i and k must also be in the same cluster. Finally, constraints (12) impose binary values to variables x_{ij}.

The CP model has some interesting properties. Firstly, the number of clusters k must not be fixed in advance, as for the k-means model, but they are the outcome of the optimization model. Secondly, the CP model is robust to the presence of outliers, as they are automatically detected as singleton. Since k is not fixed, singletons are not artificially inserted in a homogeneous group, biasing the corresponding A-index. As we will see, these properties are important in voting data, as the correct number of clusters vary with time, and sometimes nations appear as singletons between blocs.

3.5 Comparison between the alignment and the modularity index

The idea of the A-index is to compare the actual data against a null hypothesis. This intuition has been used in other applications before, the most important is the modularity function. Th modularity is a statistic that is used in network analysis to detect communities, see Newman and Girvan (2004); Agarwal and Kempe (2008). In its simplest form, for a given a graph $G = (V, E)$, let $e_{ij} = 1$ if $(i, j) \in E$, $e_{ij} = 0$ otherwise, let d_i be the degree of vertex i. For a given node partition $P = \{C_1, \ldots, C_t\}$, the modularity function is defined as:

$$m(P) = \frac{1}{2|E|} \sum_{C_k \in P} \sum_{(i,j) \in C_k} (e_{ij} - \frac{d_i\, d_j}{2|E|}). \tag{13}$$

The term e_{ij} is the actual binary value of an arc, while the second term is its expected value under the hypothesis of the configuration model, that is, a model in which the hypothetical graph has the same node degrees, but arcs are located randomly. The network community structure is revealed by the maximization of the modularity function, that, is solving $\max_P m(P)$, that is equivalent to the CP model, see Agarwal and Kempe (2008). Modularity is the statistic that has been used in Macon et al. (2012) to detect the nations blocs of the UNGA. Nations are networks nodes, and voting data are the arcs: there is an arc between a node pair every time the node/nations voted in the same way, that is, yes-yes, no-no, abstain-abstain. However, when applied to community detection (and also to UNGA data, see Macon et al. (2012)), it has been recognized that modularity suffers from the so-called resolution limit, that is, it tends to combine smaller communities into larger ones, without detecting their own specificity. To overcome this drawback, see Fortunato and Barthélemy (2007); Lancichinetti and Fortunato (2011); Xiaoyan et al. (2020), a variation of modularity has been proposed, emphasizing more diversity between vertices using a parameter λ to correct the modularity function. In this case, the generalized modularity function is:

$$m_\lambda(P) = \sum_{C_k \in P} \sum_{(i,j) \in C_k} (e_{ij} - \lambda \frac{d_i\, d_j}{2|E|}). \tag{14}$$

Here, a value $\lambda > 1$ increases the diversity between the vertices, while a value $0 \leq \lambda < 1$ increases their similarity. It can be seen that the same logic can be applied to the A-index to define a *generalized* alignment index:

$$a_{ij}^{\lambda} = s_{ij} - \lambda\, s_{ij}^{0}. \tag{15}$$

It is interesting to observe that the case of $\lambda = 1$ corresponds to the A-index, that is, Eq. (5), while the case of $\lambda = 0$ corresponds to the S-index, that is Eq. (1). Therefore, varying λ and using parameters a_{ij}^{λ} in the objective function (8), communities at various resolution levels can be obtained. As can be seen, this methodology is useful when the most relevant communities are still not easily detectable from the plain application of the A-index.

4 Community detection at the UNGA

4.1 Roll call statistics

We use data on the assembly roll call votes available from Voeten et al. (2009), version 32. This database records the nations' choices in every disputed roll-call vote of the Assembly from years 1946 to 2022. The number of nations that were members of the United Nations varies with time, as can be seen in Fig. 1. There were 55 nations in 1946, and they steadily increased to reach 193 nations in 2011. The number of disputed votes recorded in the database varies per year, see Fig. 2. It can be seen that great oscillations appeared during the Cold War and before 1970, with two peaks of more than one hundred resolutions in the years 1949 and 1961. However, in some years, voting has been more unanimous, with less than 10 disputed roll calls in years 1951 and 1965. From 1970 onward, the number of disputed votes increased to more than one hundred in years from 1978 to 1989, to decrease next to an average of 89 votes in the last 30 years. In the database, the issue of the vote is recorded, considering six main categories: the Palestinian conflict, nuclear weapons, disarmament,

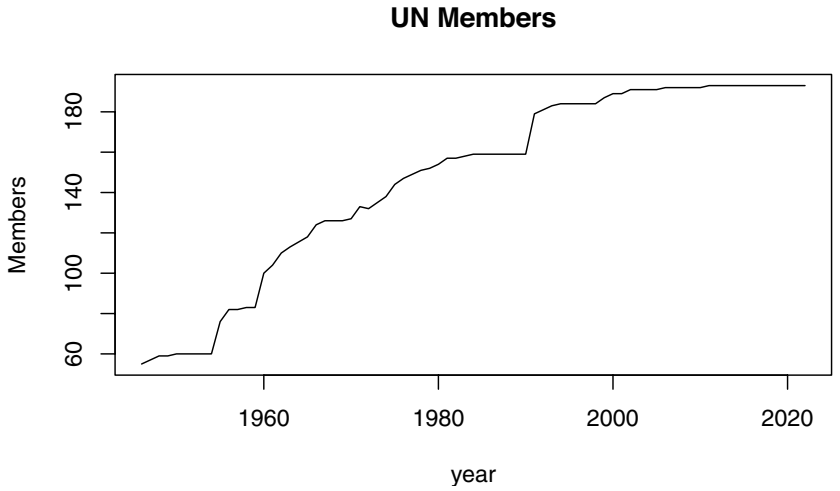


Fig. 1 Number of nations members of the UN

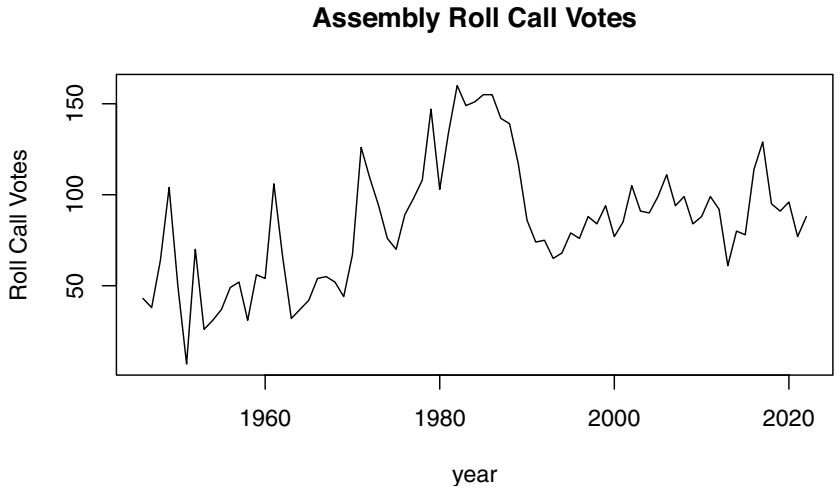


Fig. 2 Number of contested resolutions

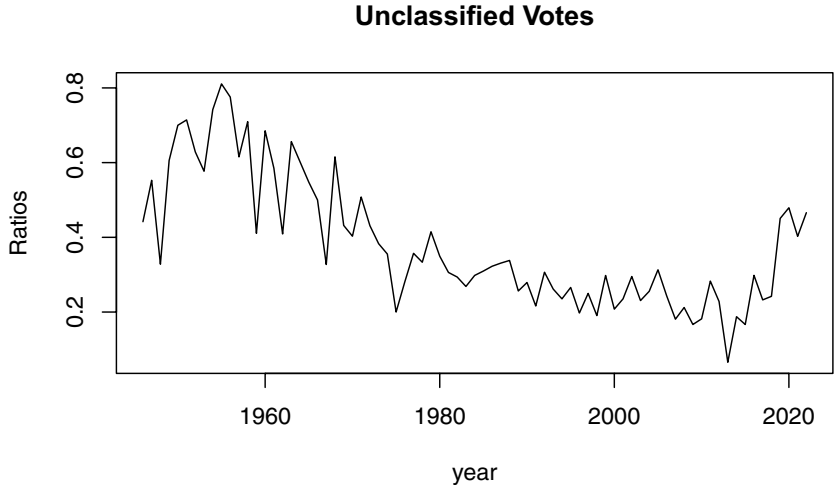


Fig. 3 Ratios of unclassified resolutions

colonialism, human rights, and economic development. The number of disputed votes on these issues is reported in Voeten (2012), Fig. 1. However, many votes are not classified in any of these categories, as can be seen in Fig. 3.

For every roll call, the dataset reports the nations' vote or their absence. Therefore, the analysis should consider how to treat the absent nations. Being absent can be considered as the expression of a vote of abstention, or, as it has been pointed out by Voeten (2012) absences can have bureaucratic causes. For example, it can be due to government turnovers that lead states to temporarily have no UN delegation. Unfortunately, this distinction is not available in data and, given that a choice must be made, an absence is treated as a missing observation. Later, we will motivate this assumption from an operational perspective, too.

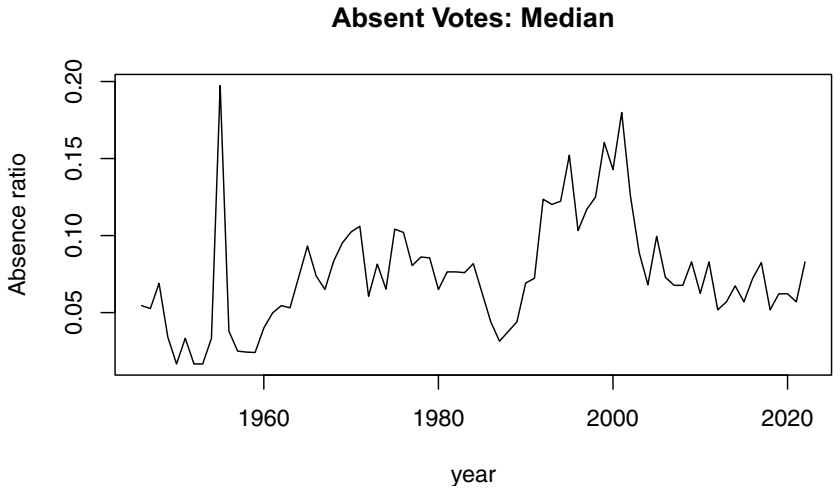


Fig. 4 Ratios of absent votes

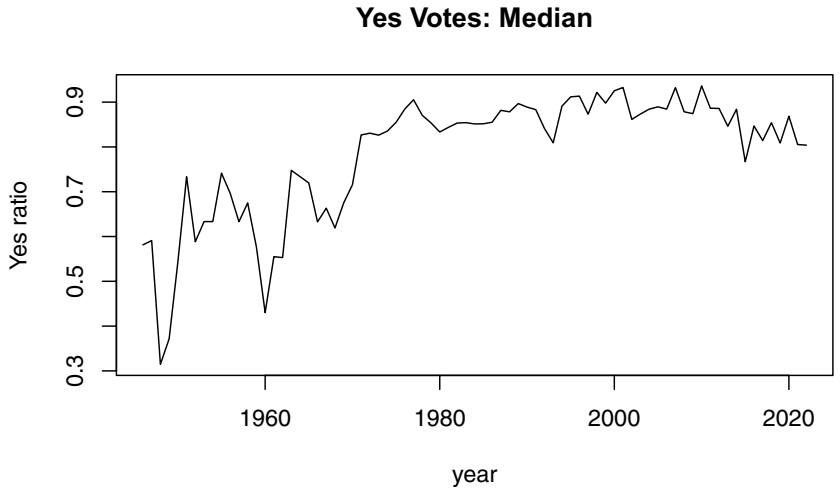


Fig. 5 Ratios of yes votes

However, absent votes are not a negligible quantity, as can be seen in Fig. 4. There, the median of the ratio of absent nations is reported, and it can be seen that in some years its median is above 10 percent.

After discarding the absences, we can calculate how disputed is a roll call. We calculated the ratio between the approval and total expressed votes. In Fig. 5, it can be seen that roll call votes were heavily disputed in the early years of the Assembly, while roll calls occurred from 1980 onwards had a percentage of yes votes that was over 70% in its median value. This confirms our motivation about the use of the A-index, as most of UNGA votes are *yes*.

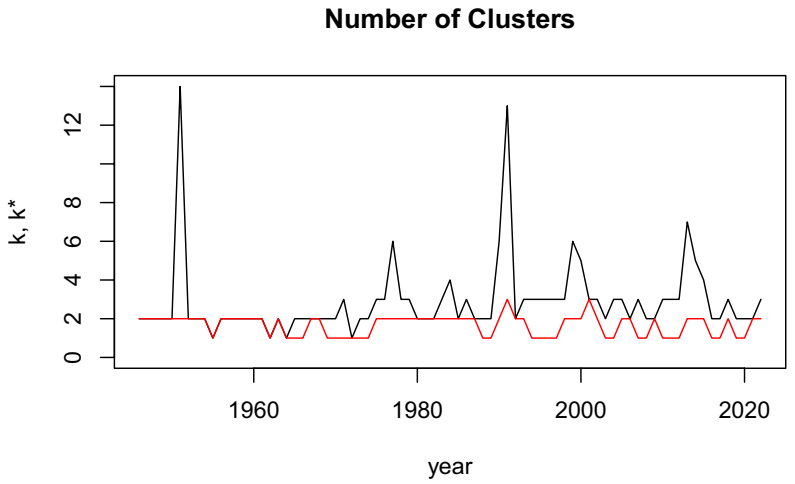


Fig. 6 Number of clusters detected by clique partitioning, using the A-index and with absent nations not recoded

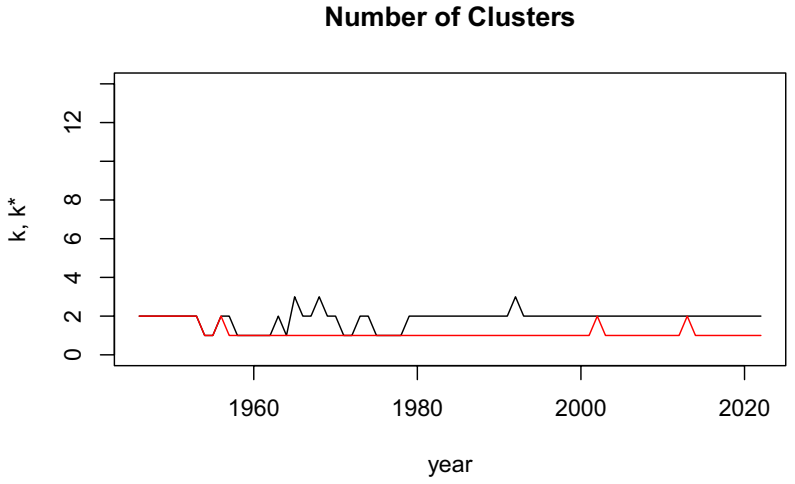


Fig. 7 Number of clusters detected by clique partitioning, using the S-index. Black line: raw data; red line: after removing outliers

4.2 Community detection in assembly votes

Disputed roll call votes of every year were used to estimate the *S*-index s_{ij} and the A-index a_{ij} for all pairs of nations i, j. The A-index is calculated in two versions, one in which absent nations are considered as a missing vote, the other in which an absent nation has been considered as an abstention vote. Next, the Clique Partition model is solved, the outcomes are the groups of nations that voted in the most coordinated way in that year. The number of clusters that are detected in the three versions of clusterings are reported as a black line in Figs. 6, 7 and 8. As mentioned, the outcome includes the detection of outliers, that is,

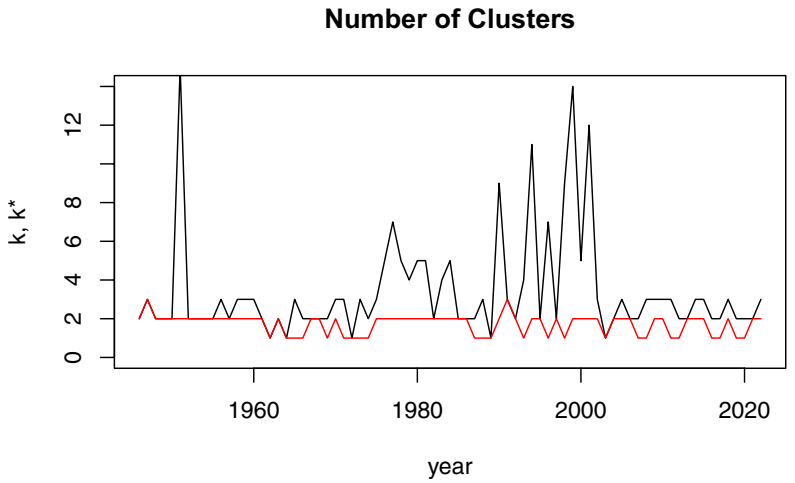


Fig. 8 Number of clusters detected by clique partitioning, using the A-index and absent nations recoded as abstention votes

nations that do not fit into any of the largest groups, therefore, the raw number of group k includes singletons too. This outcome confirms one of the advantages of the CP model, that is, k is not fixed in advance and outliers are automatically detected. It can be seen that in most cases the model can detect two or more groups, as in only a few years no structure has been identified. However, singletons and groups that are composed of up to four nations arenot very informative and can be discarded. As a result, the filtered values k^* of the net numbers of detected clusters is reported as the red line in Figs. 6, 7 and 8. There, it can be seen that the number of clusters has been reduced to a maximum of three.

The first comparison is between the clustering results of the $A-$index (the version with absent nations) and the $S-$index. The number of the detected clusters is reported in Figs. 6 and 7. It can be seen that, while in many cases the $A-$index could find at least two clusters, the S-index could detect at least two clusters very rarely, and most of them before 1960 during the years of the Cold War. Moreover, very few outliers were detected, confirming the intuition on which we developed our contribution. That is, the $S-$index is biased towards positive values, it emphasizes similarities, it could lead to misleading results when it is used for clustering. The second comparison is between the two versions of the $A-$index, with or without the absent nations. The number of the detected clusters is reported in Figs. 6 and 8. There it can be seen that the number of times in which the two models detected at least two clusters is similar, but apparently in the version without absent votes there are more outliers. Actually, this is the case, Fig. 6 accounts for 141 outliers , while Fig. 8 accounts for 162 outliers. Therefore the model in which absent data are not replaced obtained a slightly more accurate clustering. In summary, the model could recover two groups in 47 years and three groups in 3 years, and in 28 cases was unable to determine a separation between nations. When two clusters are detected, usually the smallest group is two thirds of the largest, and when there is a third group, it is made up of a few nations. Finally, the analysis of the outlier countries reveals no structure. As a whole, 72 countries were detected as outliers at least once, but only 12 of them were detected more than 3 times. The maximum has been obtained by Dominica, outlier in 7 classifications. Next, Equatorial Guinea and Kiribati

were outlier in 5 classifications. It is interesting to note that the only big nation detected as outlier more than once has been the United States, in years 1988, 2004, and 2007.

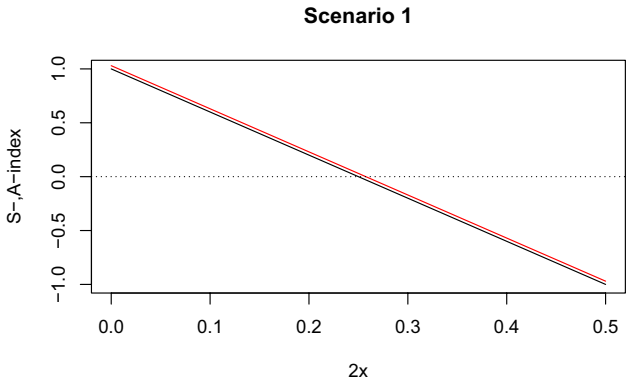
When only one group is detected, results can be fine-tuned using the generalized alignment 15, as it will be seen later. It is worth to note that when we re-run the CP model using the *S*-index (1) , results were very different. In most cases, all nations belong to the same group, with some exception, in which a some outlier or very small groups are detected. One of these small groups is composed by the United States and Israel alone, a fact that will be commented next. However, from the methodological point of view, this experiment shows that the *A*-index is more capable of identifying different groups than the *S*-index. (Fig. 9)

It is interesting to see how the composition of the clusters evolved over time, and see if the most relevant groups of nations that we discussed in Sect. 2 are recognizable as voting blocs. From Figs. 10 and 11 it can be seen that two blocs are detected in the period from 1946 to 1963, except for years 1955 and 1962. The nations that are always included in one of the two blocs are reported in Table 2. It can be seen that they can be easily interpreted as the cores of the East/West separation of the Cold War period. The United States and Russia are in opposite blocs, and the nations of their groups are their Western and Eastern allies.

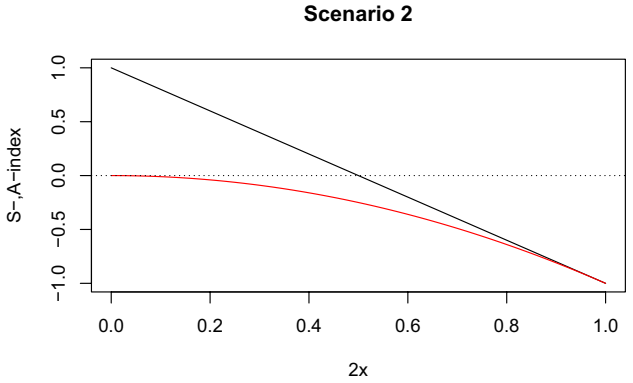
In the whole period 1947–2022, given its status as a super-power, it is interesting to see who aligned with the United States. We may guess that they are the main representative of the Western bloc, but it would be incorrect. There are three years, namely, 1988, 2004 and 2007, in which the US appeared as outliers. In these three years the CP model could not find relevant clusters: all nations were grouped together against a few outliers. Further analysis revealed that the average alignment between the US and the rest of the nations is negative. For at least one year, 2004, the reason of the separation of the United States from the rest of the world is their support to Israel, as the two nations formed a very small cluster. This small group suggests that in those years a break in the Western nations could have been emerged in issues related to the Middle East.

However, when two large clusters are detected by the CP model, the US are within one of them. Therefore, to simplify the terminology, we will refer to it as the Western bloc. Similarly, the alternative bloc will still be referred to as the East even though the term is somewhat vague, as its composition is less stable than the West, as will be seen next. The clusters size in the years in which two groups are detected can be seen in Fig. 10. After the Second World War, the size of the Western bloc was larger than the Eastern, but the latter gained momentum: there are two years during the post-colonial period, 1953 and 1954, in which the Eastern bloc turn out the largest. It was a temporary effect, because, in the following years and as the sixties unfolded, the Western bloc still covered the majority of the nations. From 1963 to 1974 there are only two years in which two blocs are detected, but cata on those years confirm the largest size of the Western bloc. Next, from 1975 to 1993, the Western bloc is still ahead of the Eastern, but it seems that distances were reduced. From 1998 onward, we had again sparse data, but remarkably, most of the time the Eastern bloc is greater than the Western, pointing to the possibility that the size of the UNGA alliances has changed.

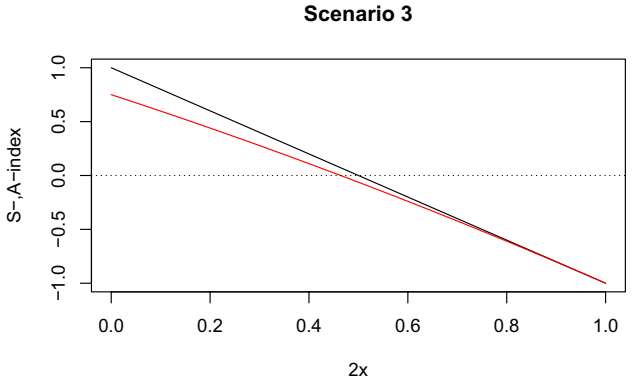
An important cluster statistic is how strong is the whole alignment of the nations within a cluster, that can be referred to as the group cohesion. The group cohesion statistic is calculated by the average of the pairwise alignments a_{ij}, on the condition that i and j belong to the same group. Western and Eastern cohesion are reported in Fig. 11, drawn as black and red line respectively, that are compared with the global average cohesion drawn in blue



(a)



(b)



(c)

Fig. 9 The S-index (black line) and the A-index (red line) under three different scenarios

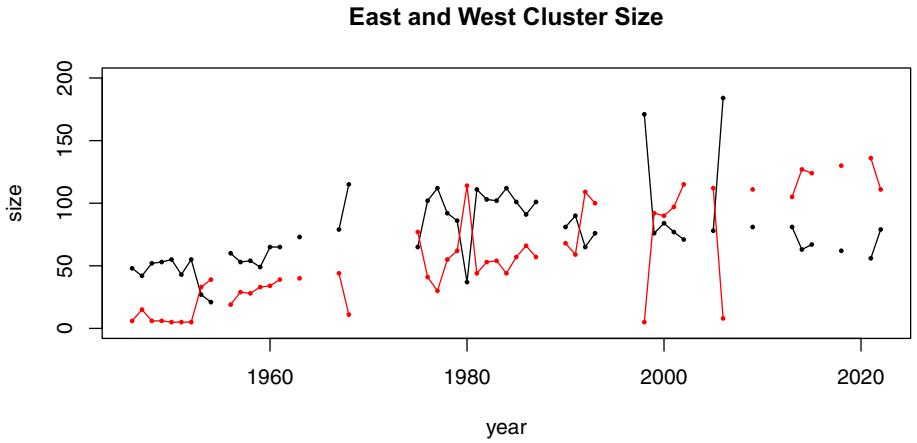


Fig. 10 Cluster size. Black line: the Western bloc; red line: the Eastern bloc

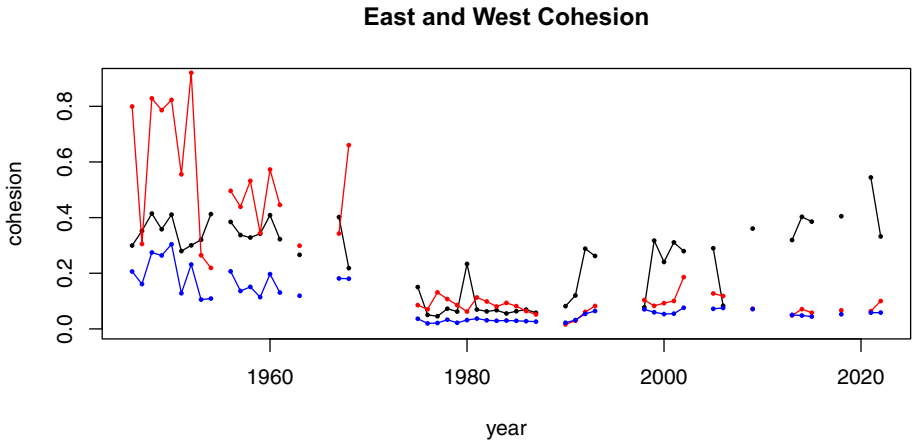


Fig. 11 Clusters cohesion. Black line: the Western cohesion; red line: the Eastern cohesion

Table 2 UNGA voting blocs, years 1946–1963

Western bloc	Eastern bloc
United States	Russia
Canada	Poland
Panama	Czechoslovakia
Brazil	Ukraine
Netherlands	Belarus
South Africa	
Turkey	
Australia	
New Zealand	

(calculated considering all nations within the same group). In that figure, some regular patterns can be observed. During the Cold War, but before 1968, we observe disciplined patterns. Both the Western and the Eastern bloc are characterized by high level of cohesion, as is proved by the fact that the red and the black line are way above the blue line, suggesting high reciprocal alignments within groups. Then, in the period between 1976 and 1987, the global cohesion of the system had decreased (the blue line), the West and East decreased too, still they are well separated, suggesting that during these years greater discrepancies emerged between the nations of the same bloc. Then, from 1998 onward, it can be seen that cohesion among the West increased, while the cohesion of the East is remarkably lower, to the point that in many years it is only slightly larger than the global. This suggest that even though the Eastern bloc has increased its size, still its internal alignment is sparse. It suggests that, while the West aligned its vote for most of the UNGA resolutions, the East did it only for some specific issues, and they are less capable to coordinate their voting with the same ability of the Western world.

Finally, we can look at the clusters compositions for different periods. In Fig. 12 and Table 2 the cores of the West and the East blocs are reported. Cores are the nations that were always detected in the same bloc for the considered period. It can be seen that the core of the East is consistent with the nations that were freed by the Soviet Union, while the core of the West is composed by the most faithful allies of the United States. Remarkably, there are English-speaking countries like Australia, Canada and South-Africa, with Turkey, the important OTAN ally. It is worth to note that only one European country appears, that is the Netherlands, showing that in some years other European countries like France and Great Britain showed some level of discrepancy with the US.

In Fig. 13 and Table 3, the bloc cores for the years from 1975 to 1987 are reported. As before, cores are defined by the nations that always appeared in the same cluster. The West/East patters are still evident, as we can recognize the United States with its allies, mostly European nations, confronted with Russia and its satellites, including post-colonial nations like Cuba and Congo. It is interesting to observe that the main countries of the G77 group (see Sect. 2) are not detected in any of the groups, neither they are detected as an autonomous cluster. Most likely, and as their name suggests, non-aligned countries expressed intermediate positions between the two super-powers.

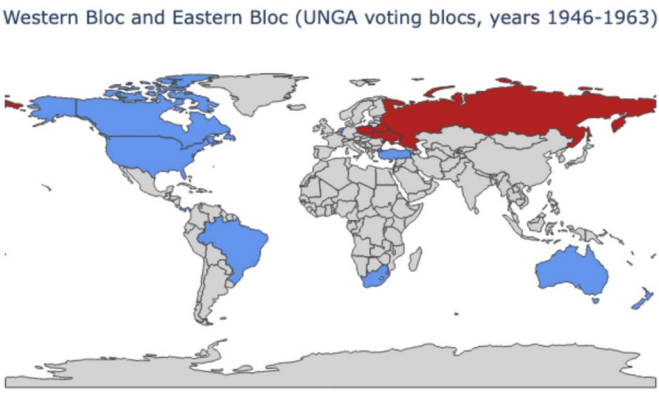


Fig. 12 Voting blocs during the cold war

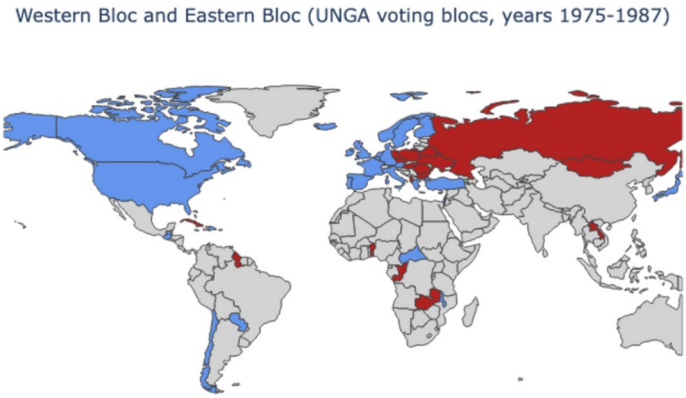


Fig. 13 Voting blocs during the decline of East bloc

Table 3 UNGA voting blocs, years 1975–1987

Western bloc	Eastern bloc
United States	Russia
Canada	Cuba
Dominican Republic	German Democratic Republic
Guatemala	Guyana
Paraguay	Czechoslovakia
Chile	Poland
United Kingdom	Hungary
Ireland	Albania
Netherlands	Bulgaria
Belgium	Romania
Luxembourg	Ukraine
France	Belarus
Spain	Congo - Brazzaville
Portugal	Cape Verde
West Germany	Benin
Austria	Zambia
Italy	Mongolia
Greece	Laos
Finland	
Sweden	
Norway	
Denmark	
Iceland	
Central African Republic	
Malawi	
Eswatini	
Turkey	
Israel	
Japan	
New Zealand	
Fiji	

In Fig. 14 and Table 4, we can see the state of the world after the fall of the Berlin Wall, in years from 1990 to 1993. The blocs certify the end of the confrontation between the United States and the Soviet Union, dissolved in 1991. Even before the dissolution, in year 1990, Russia belongs to the core of the Western allies, jointly with some of its former allies of the East Europe. A new nation cluster emerged, formed mainly by African and Asian countries. It is difficult to interpret the group, namely, if it is the expression of a regional bloc or the prelude of a new economic or political alignment, lead by India and China. Indeed, this bloc was short-lived, as in the following years we cannot identify a cohesive bloc alternative to the West.

In Fig. 15 and in Table 5, we have tried to summarize the detected clusters from 1998 to 2022. In that period, the World order moved further away from the ideological blocs of the previous periods, and while a bloc of Western societies was still recognizable, its alternative is less evident. As before, the core of the Western bloc has been identified with the nations that were always included in it during the period. Conversely, if we use the same methodology, then we cannot identify the alternative, as no nation was always included in it. Actually, it can be recognized that the most important emerging countries were often included in the alternative bloc, but not as systematically as it happened with the East during the Cold War. This fact is also reflected by the cohesion values that are observed in Fig. 11. In fact, the cohesion of the alternative bloc is much less than the West, and only a few marginal points more than the global cohesive index. In the second column of Fig. 5 we report how many times the most important BRICS countries have been found in the alternative bloc. On a total of 14 clustering, for 12 times China and India are in the alternative blocs, 10 times South-Africa, 9 times Russia, 7 times Brazil. This suggests that despite all efforts to reach a joint vision of international relations, the BRICS countries are still behind the cohesion that the Western countries are still showing nowadays.

Even though the most important BRICS countries, that is, China, India, Russia, South-Africa, India and Brasil, do not show cohesion as a whole in the last twenty years, still they may have found common ground in some specific issues. Therefore, it is worth to explore the clustering structure that emerges for specific themes. A specific subset of resolutions and amendments are defined as: *important for the U.S.A.*. The source of this classification is the U.S. State Department in reports entitled Voting Practices in the United Nations. This classification is available until year 2017, so starting from 1998, we could select 235 roll-call

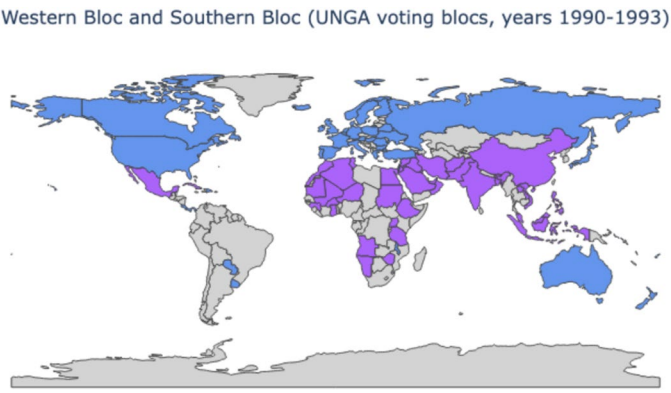


Fig. 14 Voting blocs after the fall of the Berlin Wall

Table 4 UNGA voting blocs, years 1990–1993

Western bloc	Southern bloc
United States	Cuba
Canada	Trinidad Tobago
Dominican Republic	Mexico
Dominica	Mali
Costa Rica	Mauritania
Panama	Niger
Paraguay	Guinea
Uruguay	Burkina Faso
United Kingdom	Ghana
Ireland	Uganda
Netherlands	Tanzania
Belgium	Ethiopia
Luxembourg	Angola
France	Zimbabwe
Liechtenstein	Namibia
Spain	Comoros
Portugal	Morocco
Germany	Algeria
Poland	Tunisia
Austria	Sudan
Hungary	Iran
Italy	Iraq
Malta	Egypt
Greece	Syria
Bulgaria	Jordan
Romania	Saudi Arabia
Russia	Kuwait
Ukraine	Bahrain
Belarus	United Arab Emirates
Finland	Oman
Denmark	Afghanistan
Iceland	China
Malawi	India
Turkey	Bhutan
Israel	Pakistan
Japan	Bangladesh
Australia	Maldives
New Zealand	Laos
Solomon Islands	Vietnam
Fiji	Malaysia
Samoa	Brunei
Sweden	Philippines
Norway	Indonesia

votes. Most resolutions were on Human Rights (125 resolutions) and the Middle East (57 resolutions). Applying the A-index and the clique partitioning model to these data, we found two clear cohesive clusters that are reported in Fig. 16. There, it can be seen that Western

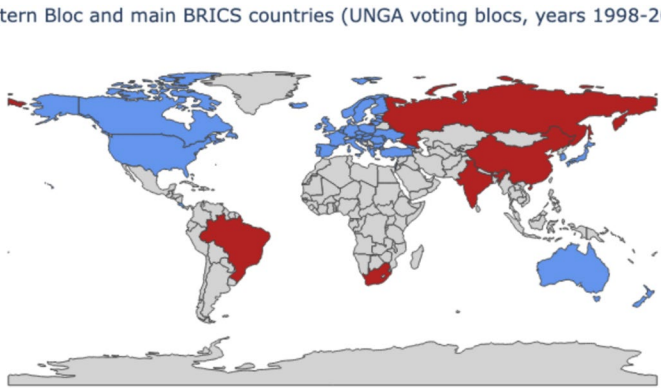


Fig. 15 Core and peripheral nations in the new millennium

countries are faced with a specific alternative bloc, which includes the five most important BRICS and the other developing countries that are most attracted to their orbit.

A second classification scheme of resolutions and amendments refers to the issue at stake. Running the clique partitioning on these data from 1998 to 2022 we found the following structures:

- Middle East: one small cluster composed by Israel and the United States is opposed by the rest of the world.
- Nuclear weapons: Two main clusters, but China and Russia voted with the Western countries.
- Disarmament: Two main clusters, but Brazil and Russia voted with Western countries.
- Human rights: Two main clusters: the Western and the BRICS countries.
- Post-colonialism: One large cluster is opposed by China and some other African and Asian countries.
- Economic development: One large cluster.

As a conclusion, we may observe that while during the Cold War voting revealed a strong ideological separation between the East and the West, in recent days the difference between the Western societies and the BRICS countries are more nuanced, and rooted on convenience rather than ideology.

4.3 Sensitivity to the absent nations

It has been assumed that absent nations were considered as missing data, rather than an abstention votes. Even though some literature agreed with this view, see Voeten (2012), it is worth to explore how the results that were presented so far are robust to the hypothesis. Therefore, we compared the clusterings obtained under the two assumptions: one in which absent votes are missing, that will be referred to as M1, and the other in which the absent nation is replaced by an abstention vote, referred to as M2. Actually, most of the times the resulting clusters are quite similar, but there were some cases in which the differences were remarkable.

Table 5 UNGA voting blocs, years 1998–2022

Western bloc	Main BRICS countries
United States	China (12)
Canada	India (12)
Costa Rica	South Africa (10)
United Kingdom	Russia (9)
Ireland	Brazil (7)
Netherlands	
Belgium	
Luxembourg	
France	
Monaco	
Liechtenstein	
Spain	
Andorra	
Portugal	
Germany	
Poland	
Austria	
Hungary	
Czechia	
Slovakia	
Italy	
San Marino	
Malta	
Albania	
North Macedonia	
Croatia	
Slovenia	
Greece	
Cyprus	
Bulgaria	
Moldova	
Romania	
Estonia	
Latvia	
Lithuania	
Ukraine	
Georgia	
Finland	
Sweden	
Norway	
Denmark	
Iceland	
Turkey	
Israel	
South Korea	
Japan	
Australia	
New Zealand	

Table 5 (continued)

Western bloc	Main BRICS countries
Marshall Islands	
Micronesia (Federated States of)	

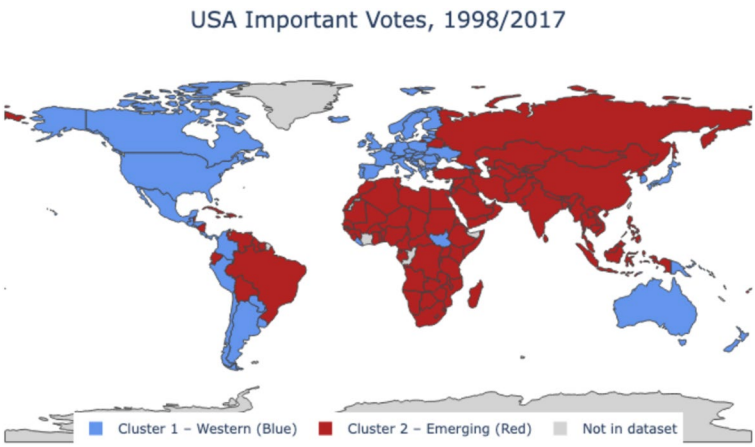


Fig. 16 Voting blocs in the new millennium on issues important for the USA

First of all, after discarding the outliers, M1 recognized at least two groups in 49 occurrences, while M2 in 53 occurrences. They *both* recognized at least two groups in 46 cases. Therefore, there was 10 years in which only one of the two methods found some cluster, but the other not. Next, we considered the clusterings obtained in the 46 occurrences in which both models recognized some structure. For each of these years, we compared the two clusterings through the Adjusted Rand Index (ARI). The ARI considers how many times the countries pairs are assigned differently, that is when one method assigned them into different clusters, while the other method put them into the same cluster. Then this number is corrected by a factor that considers the possibility that assignments may be the same just by chance. The resulting index, the ARI, ranges from -0.5 to 1. A value around 0 means that the two clusters are quite different, while the two clusterings are considered similar if the ARI is over 0.7. The distribution of the ARI's that were obtained in 46 years is reported in Fig. 17. It can be seen that most of the times the ARI is referring to similar pairs, to the point that for 15 times the ARI is 1: the two clusterings are exactly the same. However, there are seven cases in which the ARI is close to 0. Actually, the discrepancies are not so strong to invalidate the results presented previously. However, it cannot be claimed that the way in which absent nations are treated in inconsequential. As a general conclusion, we should outline that the clustering that we obtained are sensitive to data. First, every year the number of resolutions that are voted on is not large, so we cannot invoke any law of large numbers to claim that clusters are indisputable. Moreover, the ratio of issues that are voted every year changes, and so we could find different patterns of alignments just for the issues that are voted more frequently. However, even after all these warnings, it remains true that the combination of the A-index with the CP model has been capable to give a quantitative ground to some useful analysis about the countries blocs of the International Relations.

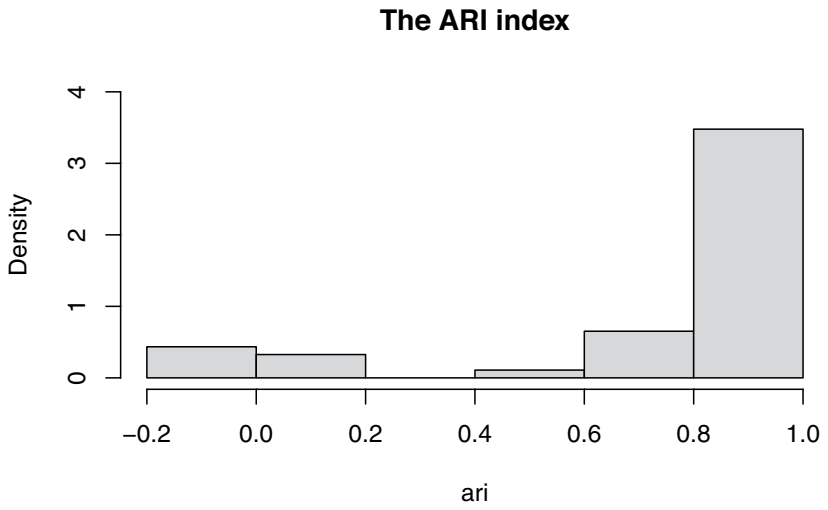
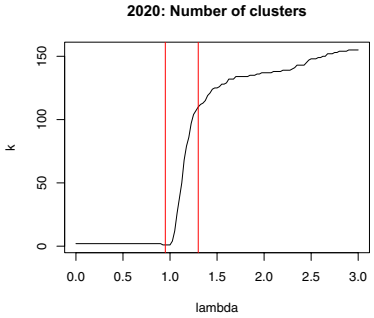


Fig. 17 The ARI index comparing two clusterings: the one in which absent nations are treated (1) as missing data, (2) as abstention votes

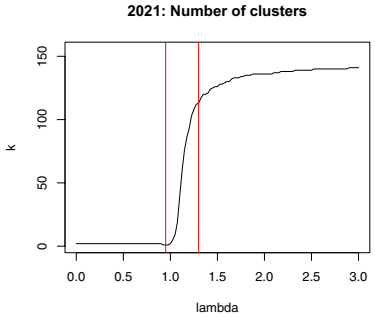
4.4 Sensitivity to the resolution limit

It can be seen that in Fig. 11 there are some discontinuities, because in some years two large groups can be detected, while in other years they are not apparent. However, one may suppose that the structure of the alignments did not drastically change from year to year, rather, it is only more difficult to detect it numerically. To this purpose, one can try to fine-tune the analysis using different values of λ in Eq. 15, to see what groups can emerge for varying values of λ, testing more or less remarkable differences between the $S-$index and the $A-$index.

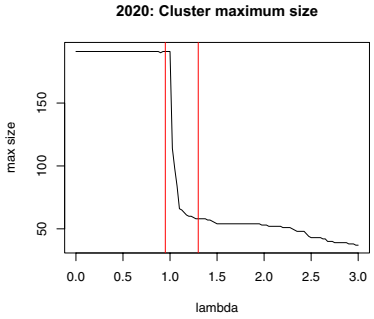
To show the clustering behaviour of the CP using the resolution parameter λ, we selected years 2020 and 2021, In year 2021 we found two clusters, while in 2020 only a single large cluster has been determined. As can be seen, by fine-tuning the value of λ, we will discover that the outcomes of the two years are very similar, and indeed, by lightly perturbing the value of λ, two groups can de detected in 2020, too. Moreover, the two groups of 2020 and 2021 are quite similar. We run the CP using alignment values from $\lambda = 0$, corresponding to the A-index, to $\lambda = 3$, (the value $\lambda = 1$ correspond to the A-index) and we expect that, as alignments between nations decrease with λ, the number of clusters will increase. In Fig. 18, we have reported some statistics about clustering in year 2020 and 2021. These statistics are: the number of clusters detected, the maximum size of the detected clusters, the number of outliers, and the clustering entropy. The red vertical lines are drawn for the values $\lambda = 0.95$ and $\lambda = 1.30$. It can be seen that before 0.95, the results are still the ones that are obtained with the S-index, that is, with $\lambda = 0$. We observe in the two cases that only one large group is detected, with the presence of two outliers in 2021. For values greater than 0.95, we begin to observe the effect of the alignment: the large group is split into two and more groups, letting emerge the clusters that most voted in coordinated way. The outcomes are very sensitive to the *lambda* values within the range [0.95, 1.30]. It can be seen that the number of clusters sharply increases, as does the number of outliers, while, for $\lambda \geq 1.30$,

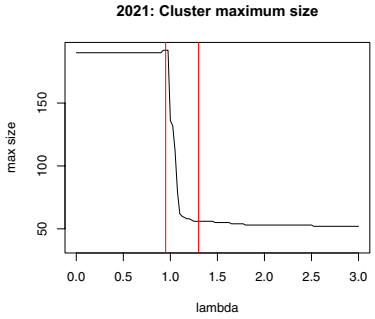


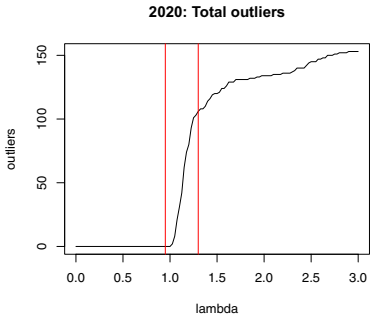
(a) Number of clusters in year 2020.

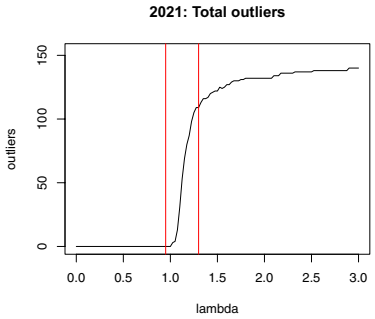


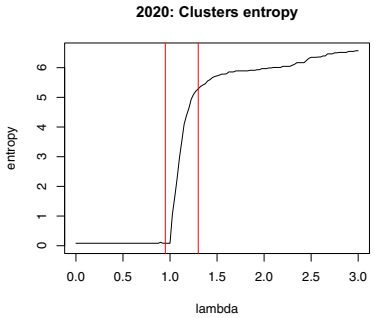
(b) Number of clusters in year 2021.











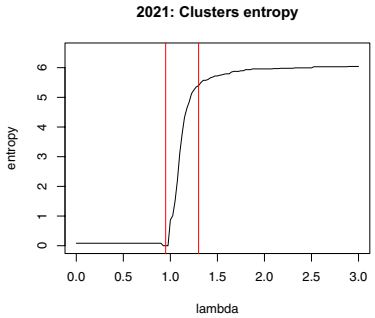


Fig. 18 Comparison of some clusters statistics on year 2020 and 2021, for varying values of the resolution parameter λ

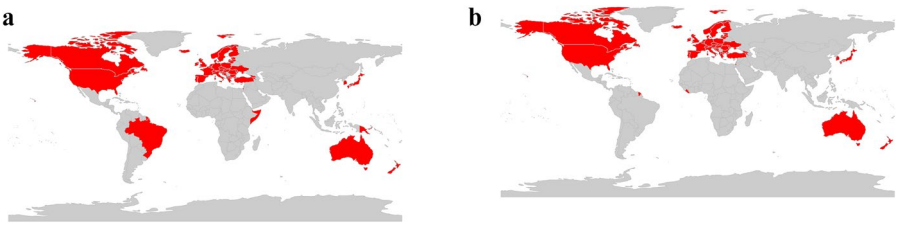


Fig. 19 **a** UN nations core in year 2020. **b** UN nations core in year 2021

the system seems to stabilize. That is, groups are more and more separated, but at a slower pace. The result is also supported by the graph of the entropy: we can see that it sharply increases and then stabilizes. In qualitative terms, we have observed that in all cases only one large group is recognizable, resulting from core of the West bloc drawn in Fig. 15. The size of the core varies with λ, as can be seen in the histogram about the maximum cluster size in Fig. 18, but, from the value $\lambda = 1.30$ onward, the largest group is composed of around 50 nations. More precisely, for $\lambda = 1.30$ the core is composed of 58 nations in year 2020, 56 nations in year 2021. In Fig. 19a and b the countries that belong to the two cores are reported. Results are easily recognizable, as in both maps the main Western countries are detectable. The main difference is the presence of Brazil and Somalia in the Western core in 2020. As a conclusion, it can be seen that, if the resolution limit is modified, then different levels of alignments are detectable, but all of them have some common features. In this case, we could identify the nations that were most able to coordinate their votes, forming a consistent core of the most influential UNGA voters. Therefore, for the years 2020 and 2021, even though the plain application of the A-index gave contrasting results (as in one year two blocs were detected, no bloc in the other year), still a careful tuning of λ revealed a regular pattern. As a general rule, one may use the λ parameter to see if the same bloc structure that is revealed by the $A-$index in a given year can be also recovered in a contiguous year in which no cluster has been detected.

5 Conclusion

In this paper, we proposed a new index to measure the similarity between voting patterns, called the Alignment index. It consists of the difference between an actual voting similarity and an hypothetical similarity conditional to independent voting. With respect to the S-index, the A-index adjusts the bias that can emerge when similarity comes out just by chance, that happens when voting bodies support an issue with large majorities. We apply the A-index to detect voting patterns in the UNGA and we found that clusters of countries with similar voting behavior are better recognized by the A-index than by the S-index and therefore, from the qualitative point of view, we could detect four main periods of the UNGA voting blocs. In the first period, years 1946/1963, blocs are composed around the allies of the United States and the Soviet Union. In the second period, during the decline of the Soviet Union, the cores of the blocs remained similar, even though the number of UN members almost doubled, and new alliances emerged in the International arena. Remarkably, short after the Fall of the Berlin Wall, the East/West blocs collapsed because at the

time Russia aligned with the West, revealing a new temporary cleavage between the North and the South. However, the North/South blocs lasted only a few years, because in the new millennium, we have seen the West bloc to re-emerge, but without a clear opposition of organized countries. In other words, BRICS countries were not consistently found among the opponents of the West, unless we limit our analysis to some peculiar issue, such as the theme of the Human Rights. This last finding is also confirmed by the clustering sensitivity analysis carried out through the resolution limit as, in year 2020 and 2021, we found that the common core of the most aligned nations is composed mainly by the Western countries.

Future research may consider that our introduction of the Alignment index has been mainly numerical and devoted to applications, and we left aside all the inferential issues that can emerge. However, they can be developed to consider how reliable a clustering can be under different modification of the roll-call votes. For example, one could develop bootstrapping techniques to asses the variability of the $A-$ and $S-$ index and to determine interval estimates of the statistics, as in a similar vein has been proposed in the field of the Belief networks, see Boutyline and Vaisey (2017). Next, political analysis can take advantage of this findings to analyze the evolution of the political networks in the international relations. We think that these statistics can be very useful to ground the qualitative analysis with some evidence provided by numbers.

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Data availability The programs coded to carry out this research are under improvment to be made them available through the CRAN public archive. In the meantime, they are freely available from the authors.

Declarations

Conflict of interest The authors declare no conflict of interest.

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