Evolution of Spatial Political Community Structures in Sweden 1985–2018

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Abstract. Understanding how the electoral behaviour of a population changes in a country is key to understand where and why social change is happening. In this paper, we apply methods from network science to the study the middle-long-term evolution of Swedish electoral geography. Sweden is an interesting case since its political landscape has significantly changed over the last three decades with the rise of the Sweden Democrats and the Green Party and the fall of the Social Democrats. By partitioning the Swedish municipalities according to their similarity in voting profiles, we show that Sweden can be divided into three or four main politico-cultural communities. More precisely, a transition from three to four main politico-cultural communities is observed. The fourth community emerged in the early 2000s, and it is characterized by a large vote-share for the Sweden Democrats, while almost all other parties underperform.

Keywords: Electoral geography · Swedish parliamentary elections · Network science · Community detection · Partition · Fragmentation · Convergence · Evolution

1 Introduction

Understanding where and why political change is happening in a country is fundamental issue in political geography. In this paper, we propose to use methods from network science to help characterize where political change is happening. Every country is divided into administrative regions such as municipalities or counties. The main idea of this work is to represent a country as a network of its administrative regions connected by a weighted edge measuring their similarity in political/electoral behaviour. The resulting network can be analyzed using standard network science methods, such as community detection.

In this paper, we focus on the Swedish case. Over the last three decades, the Swedish political landscape has significantly changed with the rise of the Sweden Democrats who rise from nothing to reach about 18% and the fall of the Social Democrats from about 45% to below 30%, but the geographical patterns of electoral behaviour have remained fairly stable. Henrik Oscarsson and Sören

R. M. Benito et al. (Eds.): COMPLEX NETWORKS 2020, SCI 944, pp. 275–285, 2021.
https://doi.org/10.1007/978-3-030-65351-4_22

Holmberg have studied various perspectives on Swedish elections and electoral behavior within the framework of the Swedish National Election Studies Program (SNES). As for the political geography in Sweden, they suggest two dividing lines that pervade the electoral behavior: one between the North and the South and one between cities and the countryside [16, p. 247]. Although regional variation of electoral behavior in Sweden is quite weak compared with many other European countries [12] and may even have decreased for some parties during the 20th century [8, p. 220], there are still clear differences between different parts of Sweden.

According to the literature, the electoral geography in Sweden has been quite unchanged over the years and the following patterns are generally described:

- Strong support for the Left Party (V) and the Social Democratic Party (S) in the northern parts of Sweden [3,9,10,14–17].
- Strong support for the Center Party (C) in smaller cities and on Gotland [9,15,16].
- Strong support for the Green Party (MP) in Stockholm and other university cities [9,15].
- Strong support for the Sweden Democrats (SD) in Scania and Blekinge [15, 18–20].
- Strong support for the Liberal Party (L) in larger cities and on the West Coast (for instance Gothenburg) [9,15].
- Strong support for the Moderate Party (M) in the three largest cities (Stockholm, Gothenburg, and Malmö) [9,15].
- Strong support for the Christian Democrats (KD) in Småland and Norrland [9,15,16].

Regarding the evolution of the electoral geography in Sweden over time, there are not many studies concerned with the issue. One important observation is that the Sweden Democrats (SD), which is a relatively new (established 1988) party, started growing rapidly since 1998 [18–20]. Another important study is by Oscarsson et al. [15], where the geographical convergence of party support was studied by calculating the evolution of the coefficient of variation measure (CV). The CV is defined as $\frac{\sigma}{\mu}$, where μ is the mean vote share of a party and σ its standard deviation. CV is a measure of dispersion and a high value for a certain party indicates a large variation in support for the party between the regions of Sweden. Oscarsson et al. [15] discuss the evolution of the CV for each party since 1991, noting in particular that S and M have the smallest coefficients, thus, the smallest regional differences in support.

One drawback in the state-of-the-art approach to Swedish electoral geography is that it normally focuses on one specific election or on the change from one election to the next, ignoring a longer perspective. Furthermore, it is common to simply present the locations where a certain political party has its strongest and weakest support [16]. Sometimes more sophisticated methods are used, e.g., the regression-analysis-based method employed by Lidström [14]. However, these studies are often performed in a party-by-party fashion, and do not provide an integrated view of electoral behavior. It appears that an integrated approach to

the topic would be advantageous not least when analysing the factors underlying the political divisions.

In this study, an alternative methodology to investigate electoral geography, based on network science [13], is used. The analysis provides a partition of Swedish municipalities into "communities" based on the similarity in their inhabitants' electoral behavior. The term "community" is here employed as in network science rather than in political sciences or in sociology. In the functional network analysis [13] performed here, "connections" signify similarity in electoral behavior. Communities, in turn, reflect the regions where electoral behavior is relatively homogeneous. Such a method provides a way to investigate subnational politico-cultural geography. In contrast to a party-by-party analysis, this approach also takes into account the full spectrum of possible electoral choices, including abstention, blank votes, and invalid votes. Furthermore, since this analysis can be performed for successive elections, it allows us to study the evolution of the communities identified.

This paper is organized as follows. Section 2 presents the data and methodology used in this study. Section 3 presents the results and Sect. 4 provides some discussion and concluding remarks.

2 Data and Methodology

2.1 Data

For this project, the results of parliamentary elections in Sweden from 1985 to 2018 at the municipal level are used [21–26]. The choice of the level is motivated by it being coarse enough for the maps to be informative, yet fine-grained enough to provide some reasonable insights.

Note that the map of municipalities has changed a little during the study period: their number increased from 284 to 290. The creation of new municipalities occurred without exception as a division of one municipality into two or three new ones. The changes were handled by assuming homogeneity in electoral behavior before the division and using the finer decomposition when comparing partitions into communities.

The vote-share distribution characterizing a municipality i is represented as an 11-dimensional vector $\mathbf{v}_i$, comprising the following choices: The Social Democratic Party (S); The Moderate Party (M); The Sweden Democrats (SD); The Green Party (MP); The Center Party (C); The Left Party (V); The Liberals (L, formerly FP); The Christian Democrats (KD) ; Others (minor parties) ; Invalid or blank vote; Abstention.

The components of the vote-share vector are obtained by computing the percentage of votes for each option in each municipality.

2.2 Methods

In order to partition Sweden into politico-cultural communities we perform a functional network analysis similar to that presented in [7], where bipartisanship

in Spanish election was analyzed. The authors of that study extracted the functional network measuring the similarity of electoral behaviour between municipalities using the cosine similarity measure, however discussing the resulting partition only shortly. In this paper, an improved version of their methodology is applied to Swedish parliamentary elections.

The functional network associated with a given election can be specified by a matrix S_{ij}, where the elements S_{ij} represent similarity in electoral behavior, represented by the vote-share vectors $\mathbf{v}_i$ and $\mathbf{v}_j$, between two municipalities i and j. The nodes of this network are the Swedish municipalities, and the edges are weighted by the similarity between municipalities. The degree of similarity between two municipalities i and j is given by the Bhattacharyya coefficient (BC) [2] as

$$S_{ij} = \mathrm{BC}(\mathbf{v}_i, \mathbf{v}_j) = \sum_k \sqrt{\mathbf{v}_{ik}\mathbf{v}_{jk}}\,. \tag{1}$$

This coefficient is an approximate measure of the overlap between two probability distributions, here, two vote-share distributions. Its values vary between 0 and 1, reaching 0 when there is no overlap between the distributions. It increases with the number of parties present in both municipalities and with the amount of overlap in the vote shares for a party. In our dataset, all choice options are present in every municipality, which yields generally high values of the coefficient. Other choices are possible for the similarity measure. In [7], the cosine similarity is used. We argue that a similarity measure taylored to comparing probability distribution is more natural. We tested both the BC and the Jensen-Shannon similarity measure [6] and found that the partition decomposition was undistinguishable between the two. We decided to use the BC as it is computationally cheaper.

Using BC as a similarity measure, Sweden was partitioned into politico-cultural communities, each consisting of a number of municipalities, at the times of each of the ten parliamentary elections held in Sweden between 1985 and 2018. The partition was performed applying the Louvain community detection algorithm [4], which aims at maximizing (in terms of robustness) the modularity of a partition of a network.

In order to compare the partitions at different times it is necessary to quantify the difference between partitions. This is done using the normalized mutual information (NMI) measure [5,11]. The NMI is based on the confusion matrix $\mathbf{N}$, where the rows correspond to the communities detected in partition A and the columns to those detected in partition B. The elements of $\mathbf{N}$, N_{ij} represent the number of nodes (here: municipalities) in community i of partition A that are also present in community j of partition B.

Let c_A and c_B be the number of communities found in partitions A and B, respectively. We denote the sum over row i of the confusion matrix $\mathbf{N}$ by $N_{i\cdot}$ and the sum over column j by $N_{\cdot j}$ so that N is the total number of municipalities (the sum of all elements of matrix $\mathbf{N}$). With these definitions, the NMI measure

is given by

$$\mathrm{NMI}(A,B) = \frac{-2\sum_{i=1}^{c_A}\sum_{j=1}^{c_B} N_{ij}\log\left(\frac{N_{ij}N}{N_{i\cdot}N_{\cdot j}}\right)}{\sum_{i=1}^{c_A} N_{i\cdot}\log\left(\frac{N_{i\cdot}}{N}\right)\sum_{j=1}^{c_B} N_{\cdot j}\log\left(\frac{N_{\cdot j}}{N}\right)}. \tag{2}$$

The values of the NMI measure vary between 0 and 1, being 0 when the two community structures are independent and 1 when they are identical.

The partitions can be visualized by projecting the network onto the map of Sweden and coloring the municipalities according to their community. Note that municipalities belonging to the same community are not necessarily geographically adjacent, since the criteria of grouping them together is based on similarity in voting only. The largest communities with large geographical overlaps between successive elections have been identified as being "the same" community. This leads us also to study the change in the community structure over time. For example, the evolution of the size of the major communities can be expressed by the number of municipalities within them. Over time, this number changes, providing some insights into the overall dynamics of the main communities.

In order to complete the analysis, electoral behavior in each community is studied by computing the average vote-share distribution in each of the major communities as the average of the vote-share distribution of all municipalities in respective community. This is called the prototypical vote-share distribution of a community. The similarity measure used to construct the functional network is then also used to estimate the similarity between the communities, as well as their evolution. In addition, electoral behavior in the major communities is characterized using standardized support scores. These are computed by the formula $\frac{(\mu_C - \mu)}{\sigma}$, where μ_C is the prototypical vote-share of Community C, μ is the mean vote-share of all Swedish municipalities, and σ is the standard deviation of that. Thus, the score measures the over/underrepresentation of a party in a community with respect to the national municipality average. Finally, the evolution of the number of communities identified by the Louvain algorithm is accounted for.

3 Results

Applying functional network analysis to the ten Swedish parliamentary elections between 1985 and 2018, a partition of the country into politico-cultural communities was obtained for each election. The maps of the partitions are displayed in Fig. 1. In each of them, the four largest communities are colored; municipalities outside these are grey.

We identify four main communities:

North. The community displayed in green in Fig. 1 that covers most of the North of Sweden as well as some coastal municipalities in the South East.

Urban. The community displayed in yellow in Fig. 1, covering the major Swedish cities, Stockholm, Gothenburg, and Malmö, along with many municipalities around them.

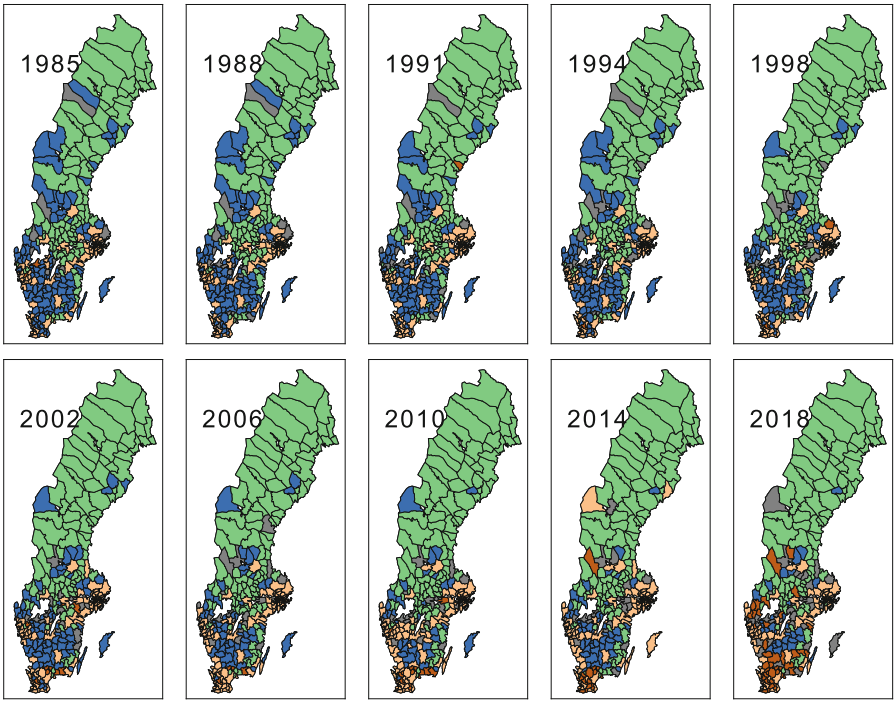

Fig. 1. Partition of Sweden into communities for the 10 parliamentary elections held between 1985 and 2018. The largest 4 communities are colored. Smaller communities are grey.

Rural South. The community displayed in blue in Fig. 1, covering rural parts of the South of Sweden as well as some municipalities in the North.

Far South. The community displayed in brown in Fig. 1 that emerges in the far South of Sweden, expanding northward. This community is only identified from 2002. Before that, it is merely a rest category.

In order to account for the characteristics of the major communities in terms of electoral behavior, standardized support scores were computed for all parties (and other possibilities) in the four main communities. The scores are displayed in Table 1.

The main features are as follows:

- In the North community, S and V are strongly overrepresented, while M, L, and KD are underrepresented. This pattern is stable over time and provides a good characterization of the North community.
- In the Urban community, M and L are strongly overrepresented, while S is underrepresented. Abstentions tend to be fewer. The underrepresentation of C decreases over time. Interestingly, the initial overrepresentation of SD in

Table 1. Standardized support score for the different parties in each of the main communities averaged over the 10 elections. Scores outside the $[-0.5, 0.5]$ interval are displayed in bold for readability.

Community	M	C	L	KD	S	V	MP	SD	Others	Invalid	N-Vot
North	**−0.83**	−0.17	**−0.61**	**−0.52**	**0.99**	**0.81**	−0.42	−0.26	−0.12	−0.26	0.33
Urban	**1.08**	**−0.64**	**0.98**	0.07	**−0.71**	−0.33	**0.60**	0.03	0.37	0.11	−0.48
Rural South	−0.10	**1.14**	−0.34	**0.78**	**−0.51**	**−0.63**	−0.19	0.09	−0.23	0.21	0.03
Far South	−0.11	−0.45	−0.27	−0.44	0.01	**−0.59**	−0.47	**1.75**	−0.18	0.30	0.46

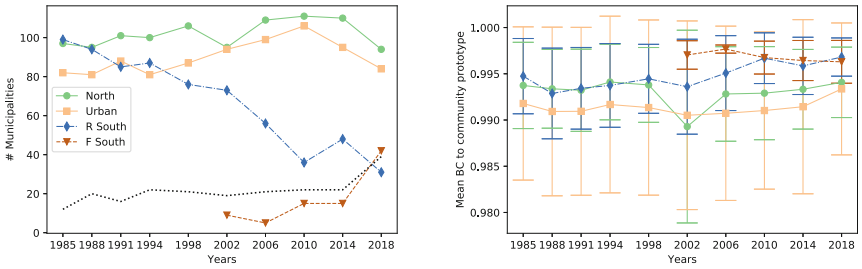

Fig. 2. Left: Evolution of the size of the main communities. The dotted line reports the cumulated size of smaller communities. **Right**: Homogeneity of the main communities. The Urban community is the least homogeneous and the most variable. Legends are the same for the two figures.

1998 and 2002 turns into underrepresentation in 2014 and 2018 while KD goes to the opposite direction since the 1980s.

- The Rural South community is characterized by an overrepresentation of both C and KD and an underrepresentation of S and V. This pattern is stable over time, however, some decline for MP can be discerned.
- The Far South community is mainly characterized by great overrepresentation of the SD party and an underrepresentation of V. It is also noticeable that the support for S has gone from being markedly overrepresented to being markedly underrepresented, and that for V becomes even more underrepresented over time.

Overall, the analysis shows that the major communities display marked differences, most of which are stable over time.

The communities have changed over time. Most visibly (see Fig. 1 and Fig. 2), the Rural South community tends to become smaller; its geographical area diminishes in favor of the other communities. In Fig. 2 (left), the evolution of the size of the main communities in terms of the number of "their" municipalities is shown.

The Rural South community's shrinking from 99 to 31 municipalities dominates the picture, while the North and Urban communities tend to grow at least until 2010. In 2014 and 2018, they are also shrinking while the emerging Far South community grows from 15 to 42 municipalities between 2014 and 2018.

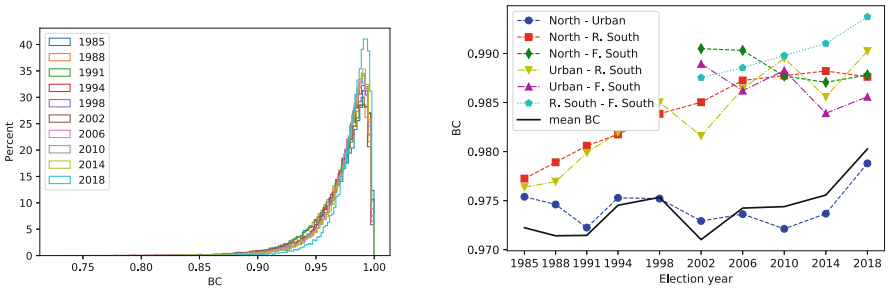

Fig. 3. Left: Distribution of similarity measure (BC) for each election year. **Right**: Evolution of the similarity between the four main communities.

The number of municipalities outside the large communities remains approximately constant until 2014, jumping then from 22 to 39.

The reduction of the Rural South community seems to be due to three different dynamics. Starting from the 1990s, the municipalities in the North that were previously similar to Rural South community switch to the North community. By 2018 only one municipality (Bjurholm) in Northern Sweden remains in "Rural South". The Urban community also gains some territory from the Rural South community. This is particularly visible in 2010, as Gothenburg and Stockholm are almost connected by Urban community, whereas in 1985, these two regions were separated by a blue region of the Rural South community. Finally, in the southernmost parts of Sweden, the Far South community has grown mainly on the territory of the Rural South community.

The communities vary also as regards their internal homogeneity. The differences in this regard are shown in Fig. 2 (right). Between 1985 and 1998, the municipalities within the North and the Rural South communities were more similar to each other than those within the Urban community. In 2002, the North community's internal variation suddenly increased, but has decreased since then. After 2002, both the Rural South and Far South communities have been internally more cohesive than the other two.

In order to compare the main communities as to their electoral behavior, prototypical vote-share distributions for each of them were computed by averaging those of "their" municipalities. Pairwise similarity scores (BC) [2] between the major communities were then calculated for each election. The results are displayed in Fig. 3 (right). Overall, Sweden is relatively homogeneous [12] at this level of measurement, and the similarity scores between communities are high. The average BC between the main communities varies between 0.971 (in 2002) and 0.980 (in 2018). The values are high because, amongst other things, all options are present in every municipality, and the low proportions of blank and invalid votes do not vary greatly across municipalities. The North and Urban communities are the most dissimilar throughout the study period. The Rural South community becomes more similar to both the Urban and the North communities over time, most in the 1980s and 1990s. The Far South community

starts out being very similar to all other major communities in 2002, becoming then less similar to North and Urban communities, but increasingly so to the Rural South community. The almost uniform increase in similarity observed between 2014 and 2018 can somewhat unexpectedly be explained by the rise of the SD party, which occurred 2018 in all parts of Sweden, making the voting profiles more similar than before, which can also be seen from the distribution of similarities displayed in Fig. 3 (left), in which the distribution for the 2018 election shows a higher degree of similarity.

The division into communities has changed from election to election. In order to measure the rate of this change, normalized mutual information (NMI) is used here. The results are displayed in Table 2.

Table 2. Evolution of the NMI measure between consecutive elections.

Elections	85–88	88–91	91–94	94–98	98–02	02–06	06–10	10–14	14–18
NMI	0.840	0.734	0.773	0.793	0.701	0.710	0.727	0.699	0.701

Over the study period, the NMI has decreased from 0.84 to 0.70, indicating an acceleration of the change in the community structure. While the partition into communities was more stable between 1985 and 1988, there occurred a larger change between the 1988 and the 1991 elections. After a temporary restabilisation, the community structure has since 2002 been changing at a markedly faster rate.

Table 3. Number of communities detected by the Louvain algorithm for each election.

Election	1985	1988	1991	1994	1998	2002	2006	2010	2014	2018
# Communities	12	14	15	17	18	19	14	14	22	24

In addition, the total number of communities (of which only the major ones have been considered here) detected by the Louvain algorithm increases over time. Table 3 shows a doubling between 1985 and 2018. This can be interpreted as a sign of fragmentation of the Swedish political landscape.

4 Concluding Remarks

In free and fair elections, voters can freely choose among the parties on offer, or choose not to vote. The individual nature of voting, along with the variation in preference always present among individuals, divides the votes within an administrative unit among the parties in different proportions and with some votes having been declared as invalid. Seen from an aggregate-level perspective, many

administrative units—often neighboring ones—are reminiscent of each other in the division of votes among parties. In previous research, numerous examples of regional propensities towards over- or underrepresentation of certain parties can be found. Such tendencies can be fairly constant despite the changing results of the parties at the national level. At the same time, entire regions can change, however slowly, and some parts of them can change more than others. This paper constitutes an attempt to identify and systematically analyze these processes in Sweden over a 33-year period.

The analysis conducted here has shown that nine out of ten Swedish municipalities could be assorted into three or four major, stable regions between 1985 and 2018. The communities are not entirely cohesive geographically (see Fig. 1). In 1985, only the North community is spatially highly concentrated, but over time the other communities seem to become more so as well. Overall, the picture is rather stable. However, the emergence of the Sweden Democrats has caused a marked change in the South of Sweden, where a belt of communities with a new common voting profile has sprung up and expanded since 2002. The rural community type dominated by Center and Christian Democrats has been on the wane during the entire study period, losing the majority of its municipalities.

In politico-scientific literature, the notion of (party system) "fragmentation" is normally used to depict an increase in the number of political parties [1]. In this study, analysing the political geography of Sweden, the meaning of "fragmentation" is tied to the number of different recognizable voting patterns in the municipalities. These two processes are not necessarily independent of each other. Similarly, "convergence" would here not necessarily point at fewer parties, or more similar political ideas across parties, but at a decrease in the number of distinct voting patterns. We have found that there are more large parties and more types of collective voting profiles at the municipal level in 2018 than there were in 1985. Both of these indicate that fragmentation in the Swedish political field, as indicated by its geography, has increased, especially after 2010. The fact that the identified dissimilarities are smaller in 2018 than 1985 indicates, in turn, that the voting patterns in Swedish municipalities as such have tended to converge, due mainly to the relatively ubiquitous nature of the fragmentation process. In this manner, it seems that the fragmentation of the field of alternatives has been accompanied by a simultaneous convergence as regards the contents of the collective voting profiles.

In order to estimate the real importance of the new entities to the national politics it is, however, essential to understand their social, and especially demographic, character that will in the last end determine their political weight in the future. As regards single parties, it is also important to take into account their possibilities of "relocating" their vote—in this regard, the slight gains in the Urban community may in the longer run be more important to the Center Party (or the Christian Democrats) than the losses in the Rural South.

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