



# Positive Relationships Across U.S. Senate Networks

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## Background

- We analyzed data that Zachary Neal collected on bill sponsorship in the U.S. Senate.<sup>4</sup>
- The dataset is an adjacency matrix output from running Neal's proposed Stochastic Degree Sequence Model (SDSM).
- A 1 in the matrix indicates a strong propensity to co-sponsor bills, a -1 indicates a strong propensity to not co-sponsor, and 0 indicates neither.
- We focused mainly on the dataset of "positives," which is the adjacency matrix with only indicators of strong tendencies to co-sponsor.

## Graph Properties of the 114th Senate Session, Positive Relationships

- Here we consider only positive relationships among members of the 114th Senate session (2015-17).
- Node degree ranges from four to 49. The mean is 28.
  - Low degree nodes tend to be political moderates. The lowest are Murkowski, Corker, Warner, Machin, Nelson, with an average rank of 54 out of 100 most politically right.
  - High degree nodes tend to be conservative. The highest are Boozman, Wicker, Isakson, Scott, Roberts, with an average rank of 16 out of 100 most politically right. (Note that Republicans had the majority.)
- Edge density is 0.29.
- Transitivity is 0.77.
- The diameter is five.
- The graph is fully connected.
- Betweenness centrality ranges from zero to 878.
  - Least central were Nelson, Reid, Murkowski, Sasse, Corker. (Note that Harry Reid was the Minority Leader for the Democrats.)
  - Most central were Ayotte, Coons, Collins, Shaheen, Stabenow.

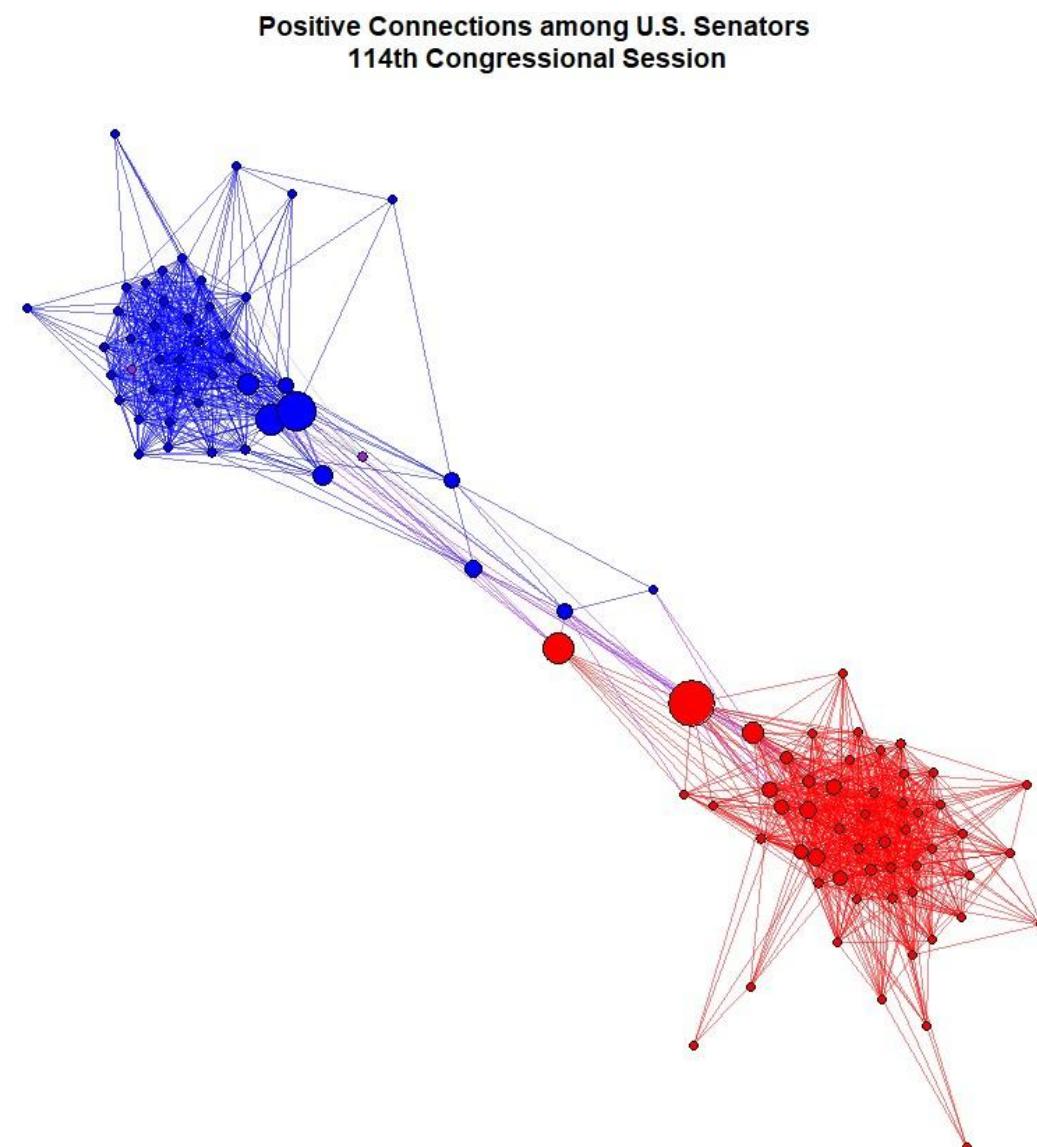


Figure 1: Positive connections among U.S. Senators in the 114th congressional session. Blue, red, and purple nodes indicate Democrats, Republicans, and independents, respectively. Blue, red, and purple edges indicate edges between two Democrats or two Republicans, respectively. Larger nodes indicate larger betweenness centrality.

## Stochastic Block Model (SBM)

- We detected two communities in the 114th Senate network of positives using R's *cluster\_edge\_betweenness*; one was mostly Democrats and one was mostly Republicans. This aligned with divisions evident in Figure 1 as well as our knowledge of how party affiliation effects bill co-sponsorship.
- We fit an SBM to capture higher connections within community.
- The matrix of edge probabilities from our fitted SBM is in Table 1 below. This estimates that the probability of a positive relationship for two senators in the same group is above 0.5, while the probability for two senators in different groups is under 0.01. This suggests polarization in Senate.

	Democrats	Republicans
Democrats	0.528	0.007
Republicans	0.007	0.640

Table 1: Estimated probabilities of forming a positive relationship in the 114th Senate network from a stochastic block model.

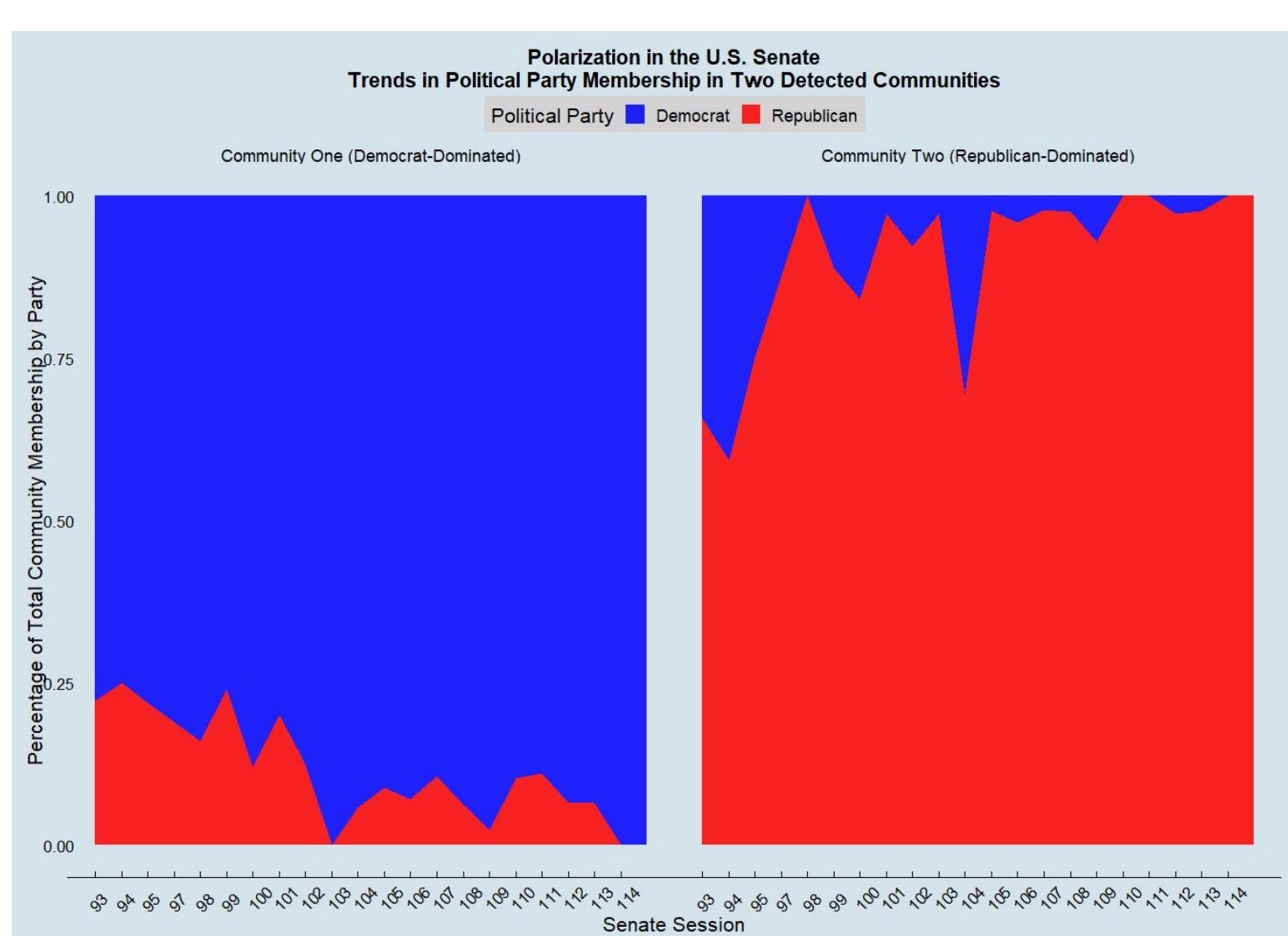


Figure 3: Percentage of party membership of the two largest communities for each session of the Senate using the network of positive relationships. These communities were found using R's *cluster\_fast\_greedy*. Note that the 96<sup>th</sup> Senate session was excluded, because the two largest communities were both dominated by the same party. Note the trend of increasing partisanship.

## References

- <sup>4</sup> Neal, Zachary (2019): A Sign of the Times: Dataset of US Congress signed network backbones from co-sponsorship data, 1973-2016. figshare. Dataset. <https://doi.org/10.6084/m9.figshare.8096429.v3>
- <sup>5</sup> Neal, Z. P. (In press). A sign of the times? Weak and strong polarization in the U.S. Congress, 1973-2016. Social Networks. Doi:10.1016/j.socnet.2018.07.007
- <sup>6</sup> Neal, Z. P. (2014). The backbone of bipartite projections: Inferring relationships from co-authorship, co-sponsorship, co-attendance and other co-behaviors. Social Networks, 39, 84-97. Doi:10.1016/j.socnet.2014.06.001
- (2017, August 24). 2016 Report Cards; All Senators. Govtrack.com. Retrieved from <https://www.govtrack.us/congress/members/report-cards/2016/senate/ideology>.

## Analysis of 114th Session of the Senate

### Latent Cluster Position Model (LPCM)

- We also fit an LPCM to model community structure while allowing greater flexibility for unmeasured variables.
- We allowed two clusters in a two-dimensional Euclidean space.
- Figure 2 below shows a plot of fitted latent positions from this model. Note the similarities to Figure 1.

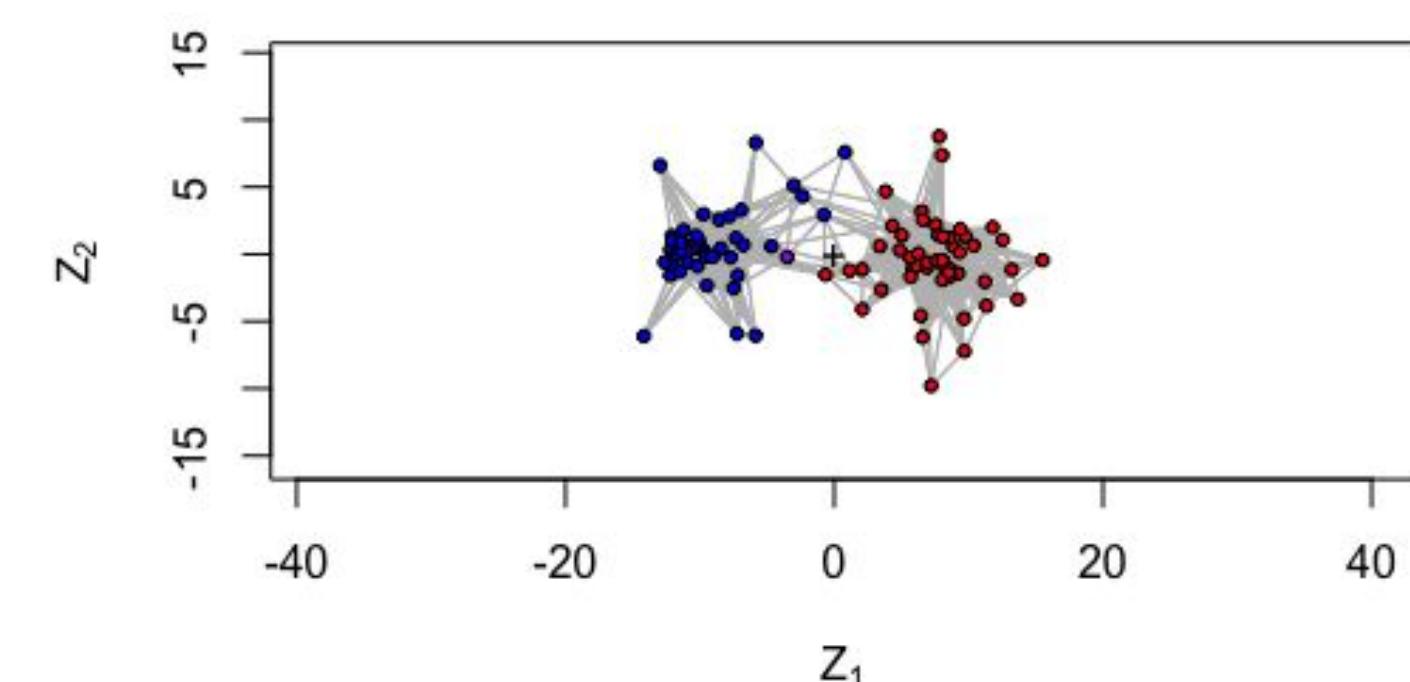


Figure 2: Latent positions estimated from an LPCM. Blue, red, and purple nodes indicate Democrats, Republicans, and independents, respectively.

## Analysis of All Senate Sessions (93rd to 114th)

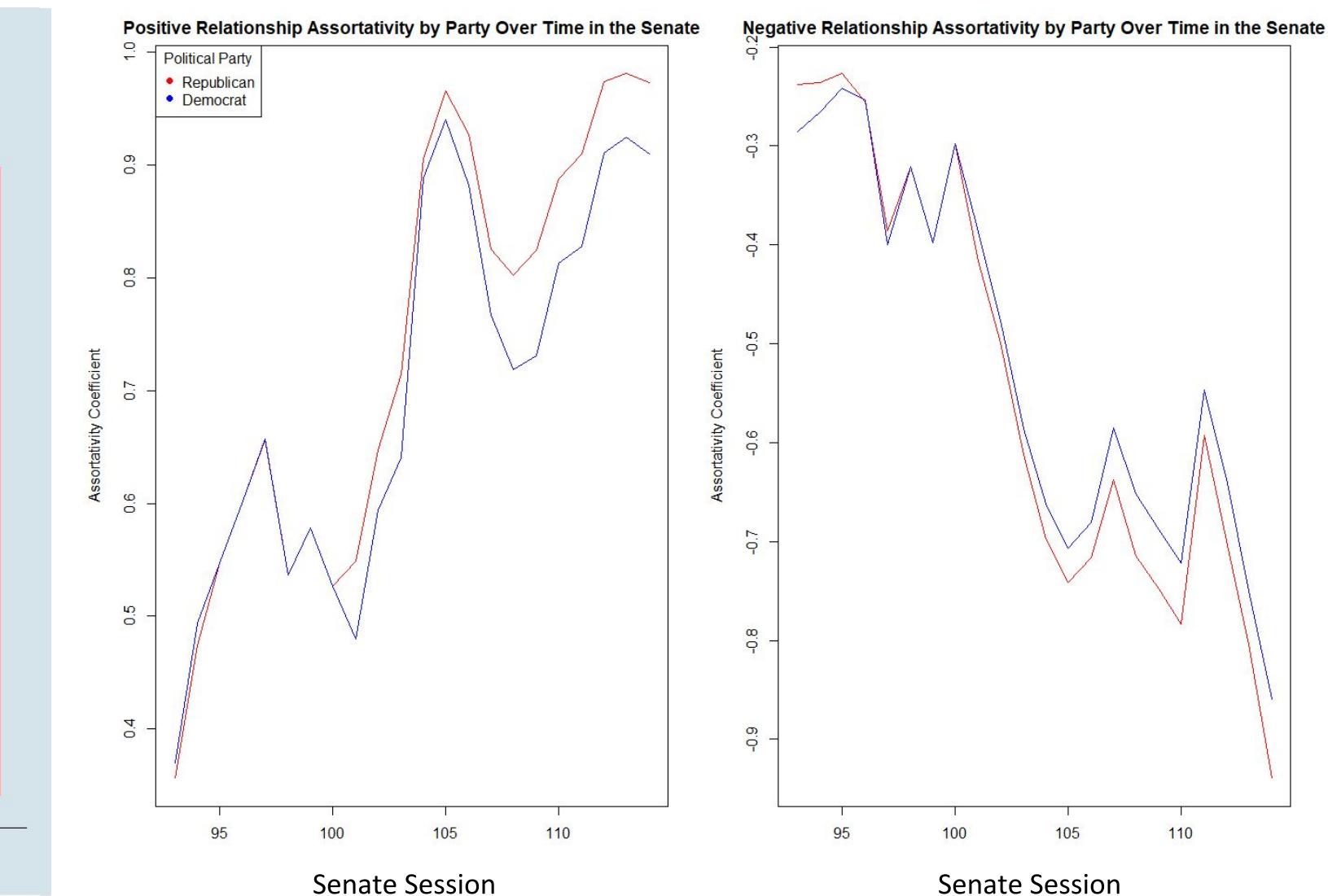


Figure 4: Assortativity by party over the 93<sup>rd</sup> to 114<sup>th</sup> Senate sessions. The left panel considers positive relationships. The right panel considers negative relationships. Since assortativity is a preference for a network's nodes to attach to others that are in the same group, these panels show another measure of increasing partisanship.

### Exponential Random Graph Models (ERGMs)

- We fit ERGMs to the 114<sup>th</sup> Senate networks of positives and negatives. We ran models with and without covariates for being in the same party and state. Results showed that party and state affiliation govern the likelihood of shared edges.

	Edges Coefficient	STD. Error	Party Coefficient	STD. Error	State Coefficient	STD. Error
Positive (Base Only)	-0.896	0.022	---	---	---	---
Positive (B+P+S)	-3.791	0.094	4.075	0.099	3.811	0.350
Negative (Base Only)	-0.173	0.020	---	---	---	---
Negative (B+P+S)	1.796	0.040	-5.322	0.096	-4.448	0.732

Table 2: Estimated coefficients from the ERGM fits to the 114th Senate session of positives and negatives, respectively. Base models include no covariates. B+P+S indicates that the model includes a covariate for being in the same party and state.

- In the second model above, we estimated the probability of connecting between parties to be 0.024 and within the same party to be 0.576 -- for all connections between states.

- We ran an ERGM that included a covariate for being in the same party for each of the Senate sessions from the 93<sup>rd</sup> to the 114<sup>th</sup> on both the positives and negatives networks.
- Results showed the ongoing strength of party affiliation plus the increasing likelihood of relationships for Senators in the same party.

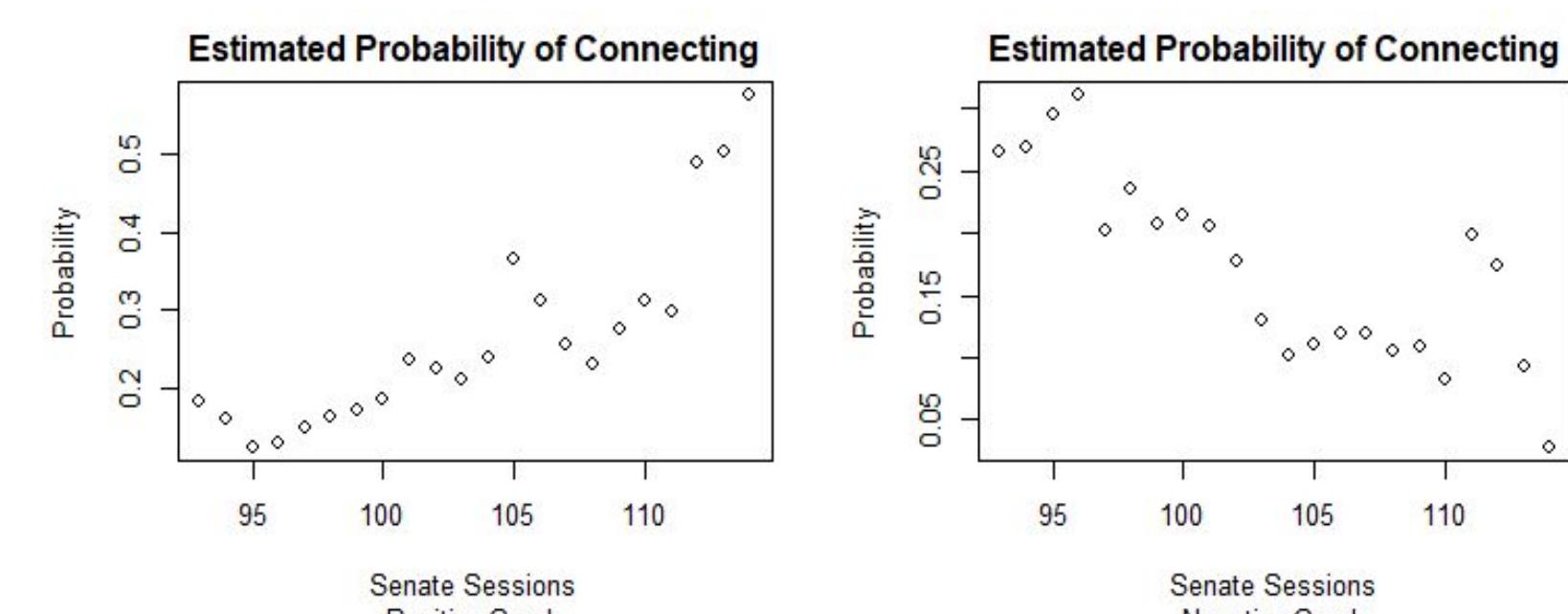


Figure 5: Estimated probabilities of connecting for Senators in the same party for each of the 93<sup>rd</sup> through 114<sup>th</sup> Senate sessions. The left panel considers positive relationships. The right panel considers negative relationships. This again suggests increasing partisanship.