DSBA 6520: Norwegian Corporate Boards:

Nathan Duma

Overview of Topic

The goal of this project is to use the tools of Network Science to explore the connections between public limited companies and directors in Norway over the span of 9 years. I will use this to look at how companies are connected by region, how the company graph metrics change over time, and how a gender representation law passed in 2003 affects director networks.

Background

- The data I used is based off a paper by Seierstad and Opsahl (2011) where they explored Norwegian gender representation law.
- In December 2003 Norway passed a law mandating 40% representation of each gender on the board of public limited liability companies.

Node and Edges

1. **Node type 1:** Company
    - There is an undirected edge between two companies if there exists an individual who has served on the boards of both companies over the nine year period.
2. **Node Type 2:** Individual Director
    - There is an undirected edge between two directors if they have ever sat on the board of the same company (it doesn’t have to be at the same time)

The Data

1. **Company data** e.g. company name, id, location. I use this to create the company vertices
2. **Director data** e.g. name, gender. I use this to create the director vertices.
3. **Director-Company data:** This data shows which director is on which company's board in any given month. I have data for the 112 months from May 2002 to August 2011. These are the edges between companies
4. **Director-Director data:** Which directors sit on the same board on any given month. I also have 112 months for this data. These are the edges between directors.

Measures and Metrics Used

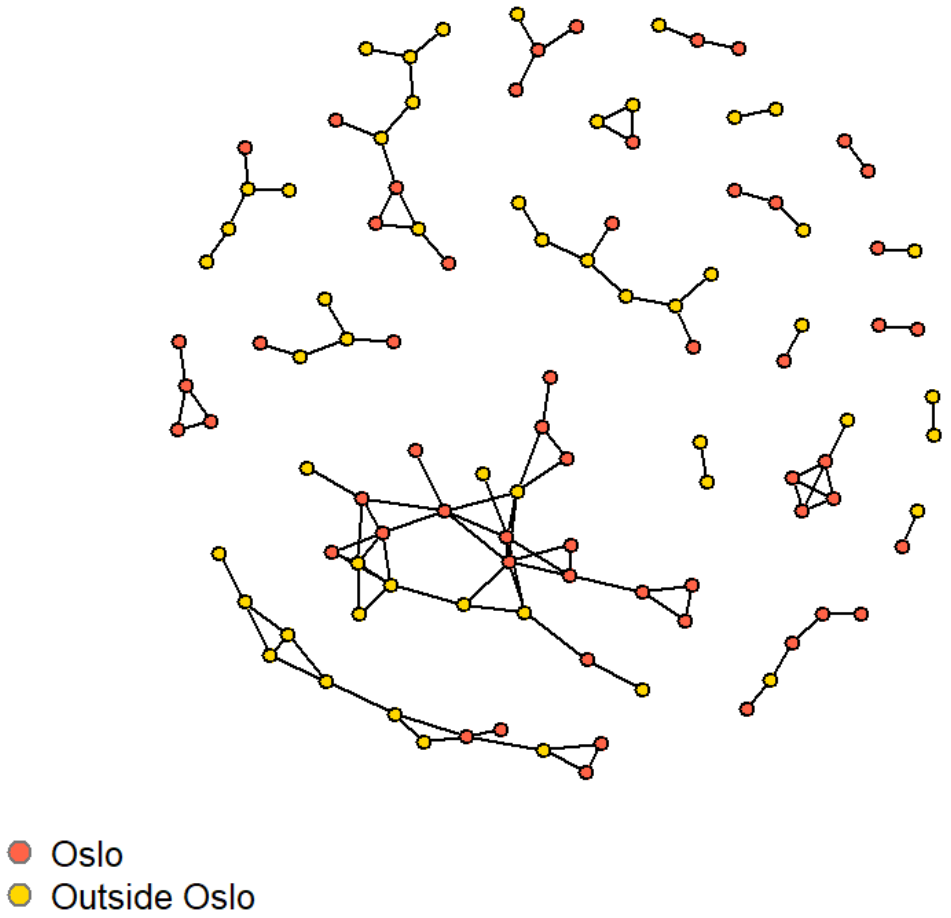
These are the measures I'll use to make sense of the graphs I create.

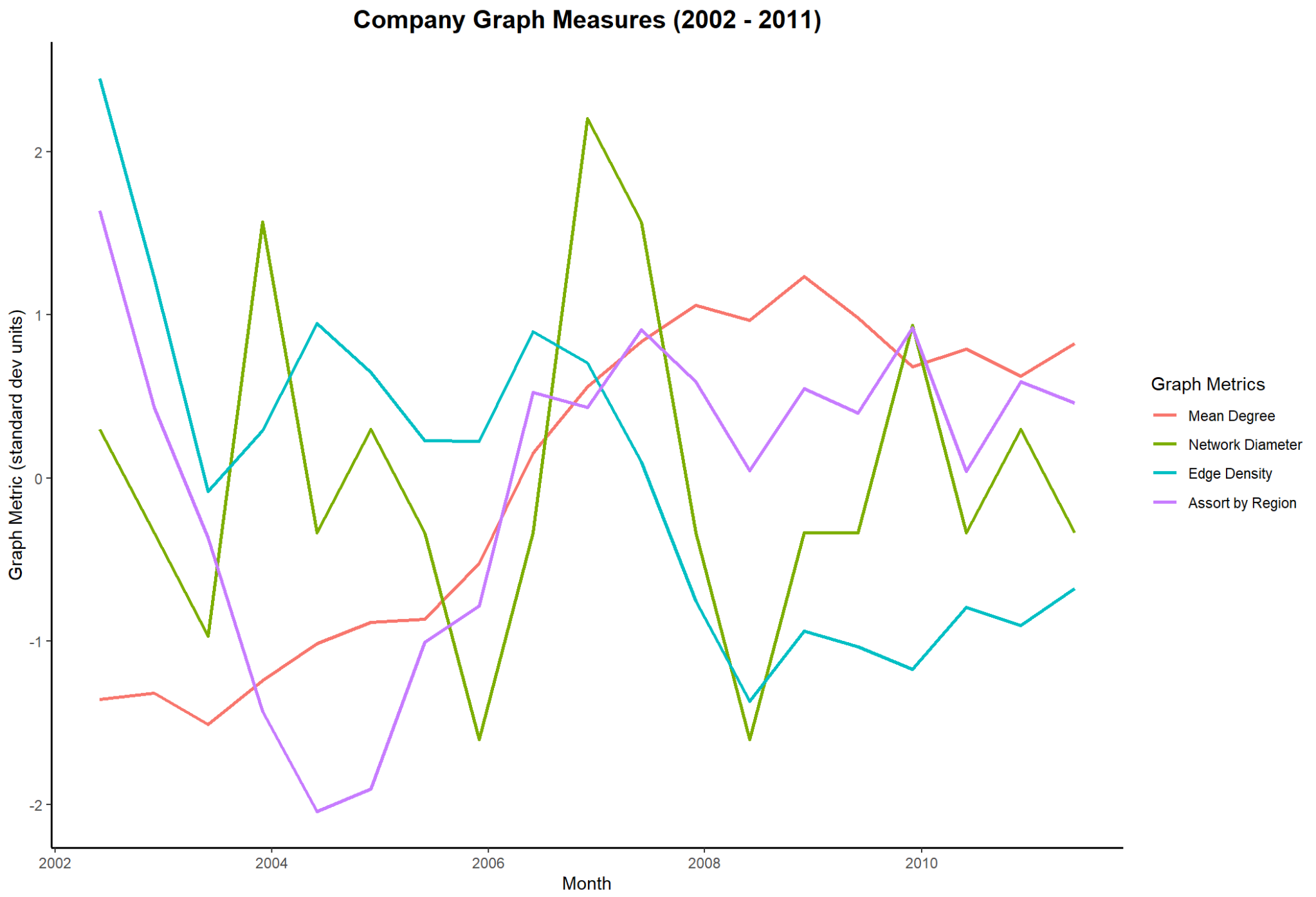
- **Mean Degree:** Shows the average number of degrees (edges) for the vertices in the network. It will give a general sense of how connected the network is.
- **Edge Density:** Is the number of edges in the network divided by the total number of possible edges. It gives a sense of how sparse our network is. Later on we'll want to see if this changes over time.
- **Graph Diameter:** The longest shortest path between any two nodes in the network.
- **Assortativity:** This is a measure of a node's preference to connect with other nodes similar to its self. In this case, we consider assortativity by company location (i.e. in Oslo vs outside Oslo) and by gender.

Section 1: Company Graphs overtime

- Last time I created an example graph of companies for just the month of May 2002 and computed its metrics.
- As expected the graph was sparse, so I extended on this by creating graphs for all 112 individual months and plotting how the metrics change across the 9 year period. In addition I computed their average metrics.
- I z-score standardized the metrics so I could fit them on one plot. This doesn’t matter for this plot as we are interested in tracking the relative change of each metric over the 9 years.

May 2002 - Shared Directors Graph (Degree > 0)




Company Graph Measures (2002 - 2011)
Graph Metric (standard dev units)
2
1
0
-1
-2
2002
2004
2006
2008
2010
Month
Graph Metrics
Mean Degree
Network Diameter
Edge Density
Assort by Region

Average Metrics Company Graph 2002 - 2011

- **Mean Degree:** On average each company shares directors with 2.86 other companies.
- **Edge Density:** On average, the total number of edges in our network is 1.47% of the number of possible edges. Another way of putting this is, if you pick two nodes from our graph at random, the probability that they are connected is 1.47%.
- **Graph Diameter:** The average longest shortest path between any two companies in the network is 13. This metric is not too useful because none of the 112 graphs is a connected graph.
- **Assortativity:** We can think of the assortativity coefficient like a correlation coefficient i.e. it takes values between -1 and 1, where 1 is perfectly assortative and -1 is perfectly disassortative. The value we obtain of 0.162 suggest companies have a small preference for to connect (share directors) with companies that are in the same location.

Section 2: Company “Super Graph”

Resolves the sparsity of the monthly graphs by combining all 112 months into 1 graph i.e. there is an undirected edge between companies if they have ever shared a director (doesn’t have to be at the same time)

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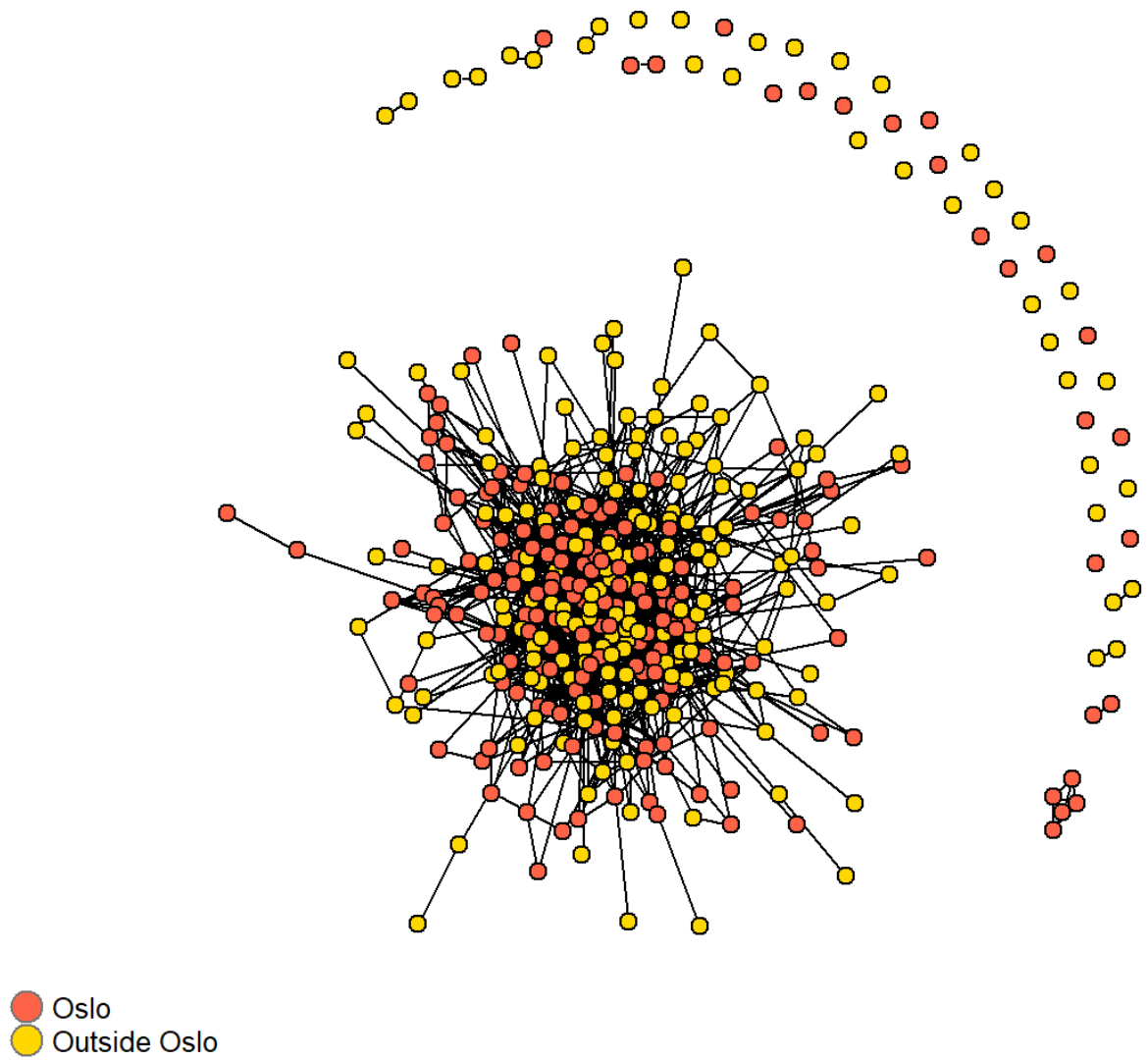
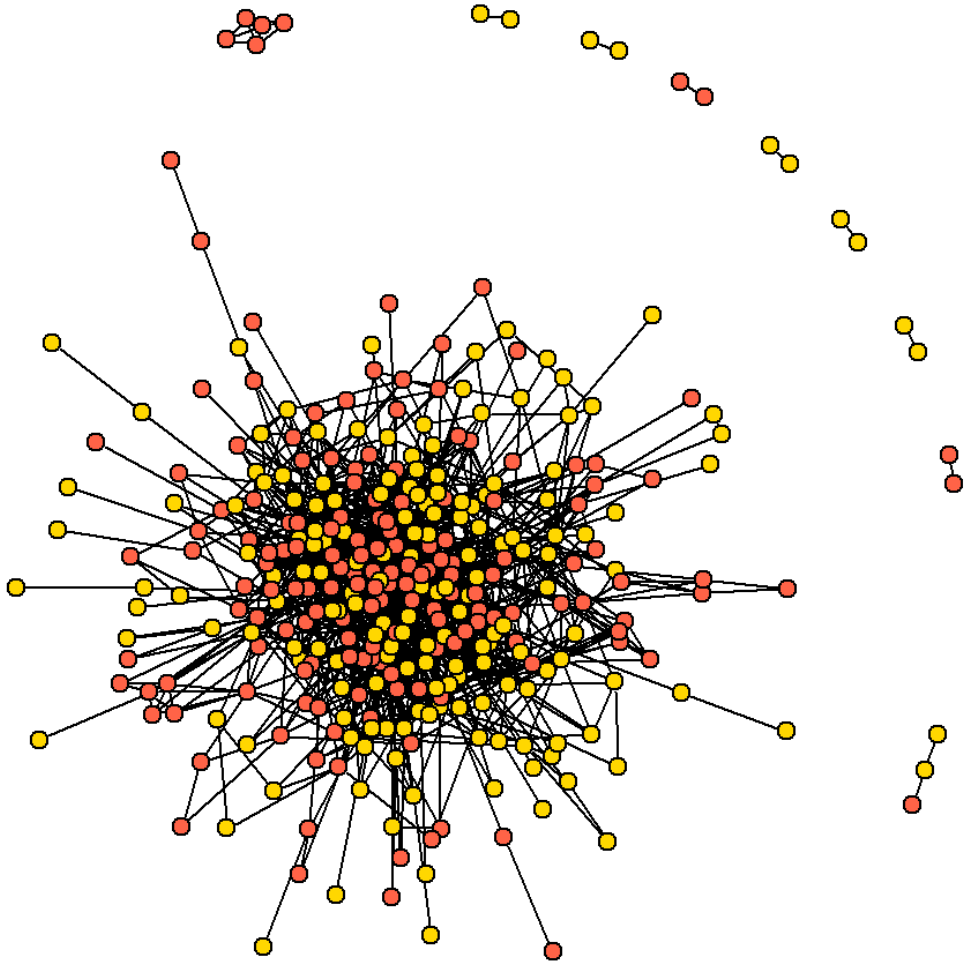
Full Company Graph (2002 - 2011)



Truncated Company Graph (2002 - 2011)



Company Aggregated Graph Metrics

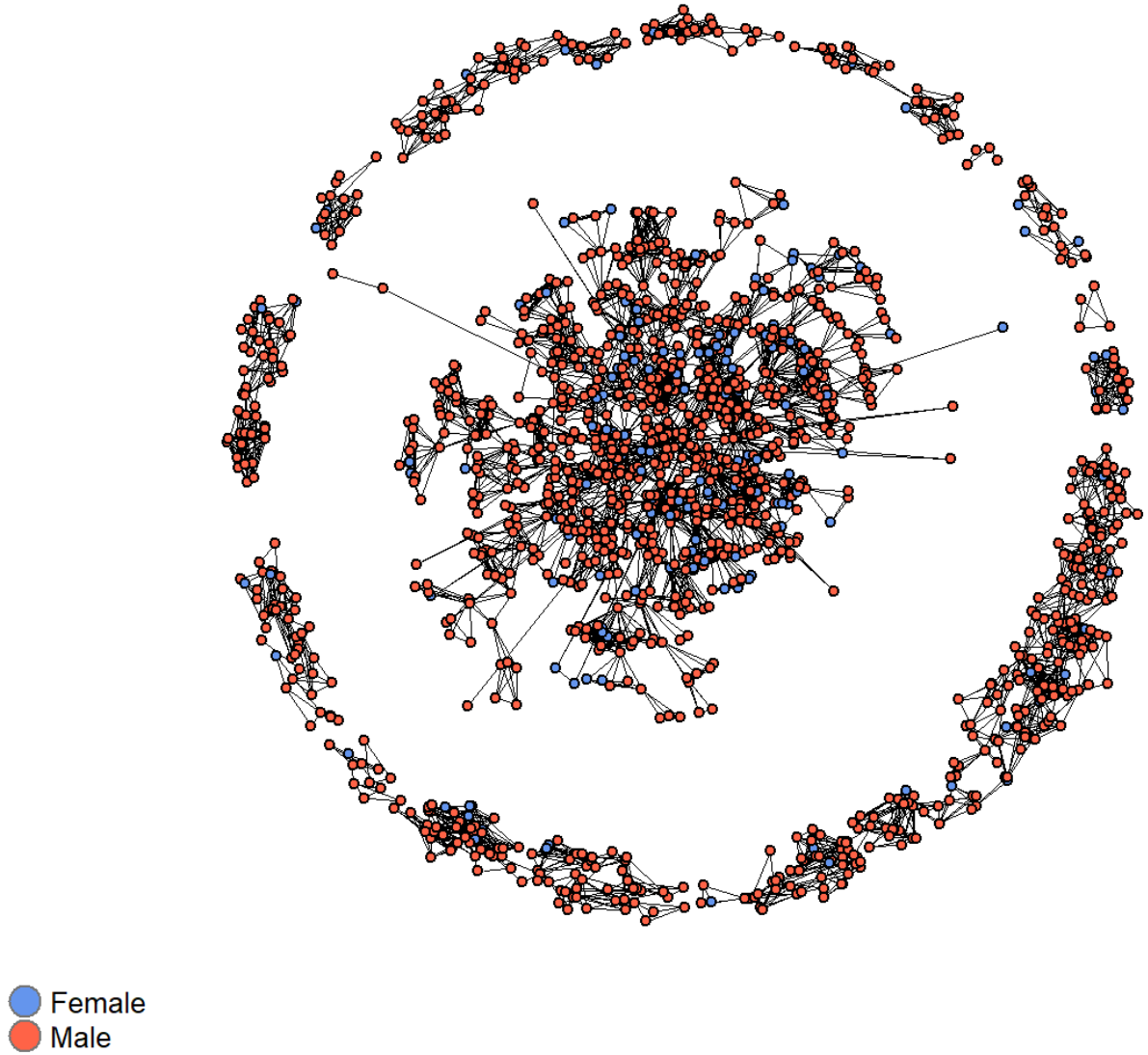
- **Mean Degree:** On average each company in the capital Oslo shares directors with 7.78 other companies. Companies outside the capital average 7.08 connections.
- **Edge Density:** On average, the total number of edges in our network is 1.94% of the number of possible edges. This shows that our **“Super graph”** is over 10 times denser than the example graph (May 2002) which has an edge density of only 0.19%. Another way of putting this is, if you pick two nodes from our graph at random, the probability that they are connected is 1.94%.
- **Graph Diameter:** The longest shortest path between any two companies in the network is 7. This is about half of the average diameters for the monthly graphs (which was 13).
- **Assortativity:**. The value we obtain of 0.11 suggests there is weak assortativity i.e. companies have a small preference for to connect (share directors) with companies that are in the same location. This value is small as Norway is a fairly small country so travel time and expense between companies in different locations would only mildly inconvenience directors.

Section 3: Gender Aggregated Graphs

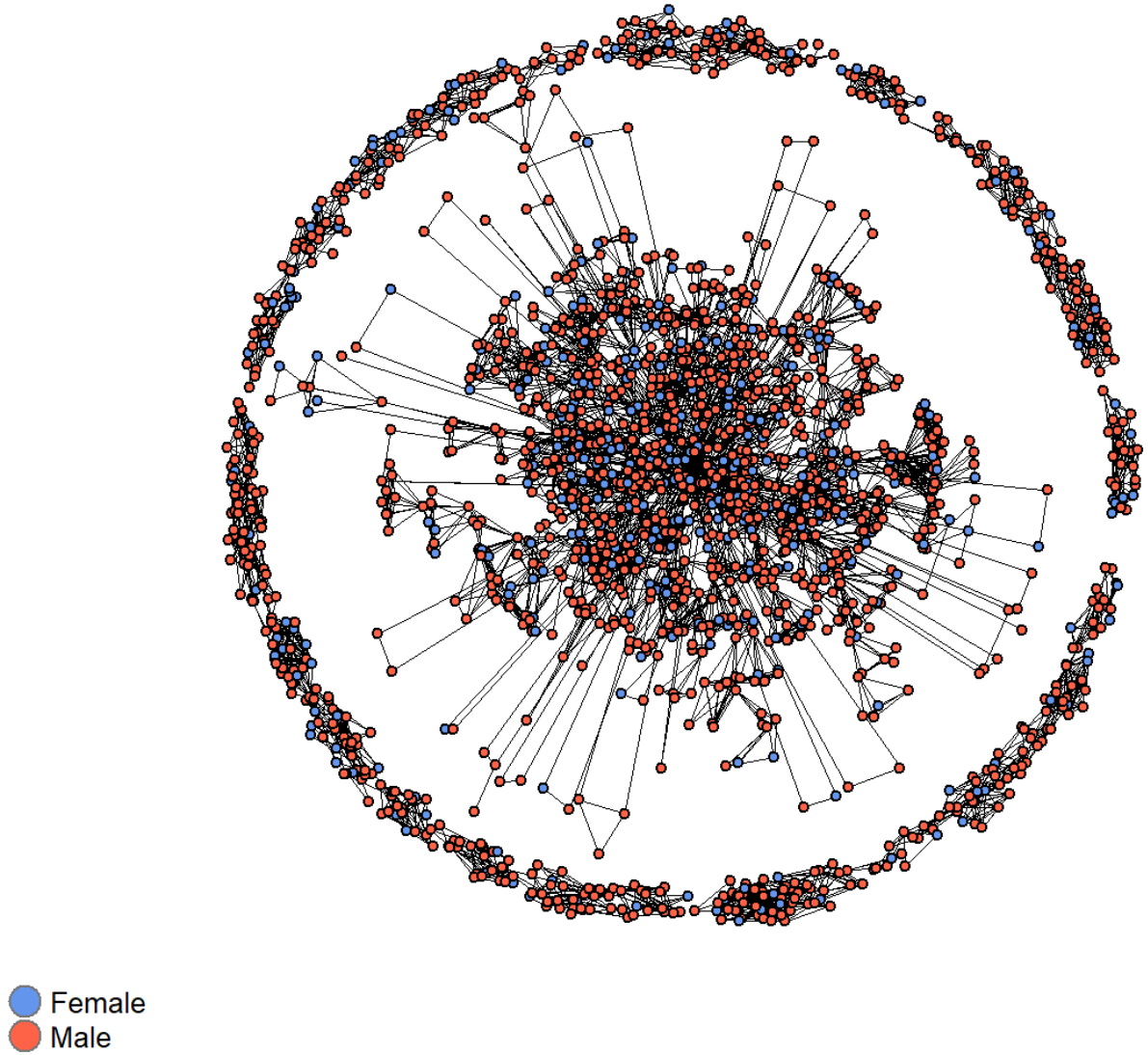
In December 2003 Norway passed a law mandating 40% representation of each gender on the board of public limited liability companies. I wanted to see if this affected the director network metrics, so I created 2 graph objects.

- The first includes the 19 months before December 2003 when the law was passed.
- The second includes the 19 months after December 2004. I give one year for the companies to start implementing the law.

Pre-Law Full Director Graph



Post-Law Full Director Graph



Pre/Post Law Metrics

- **Percentage of Women:** In the 19 months before the law was passed women made up 11.14% of the board members serving. After the law the value changes to 21.74%
- **Mean Degree:** The female mean degree is 17.82 and the male mean degree is 15.68. Again this makes sense as the paper by Seierstad and Opsahl (2011) shows that larger boards (from the biggest companies) more likely to include women. So, based on the way we defined our edges, women will have more edges on average.
- **Edge Density:** On average, the total number of edges in our network is 0.3% of the number of possible edges.

Pre/Post Law Metrics (continued)

- **Graph Diameter:** The longest shortest path between any two companies in the network is 15.
- **Assortativity:** The value we obtain of 0.0065 suggests there is no assortativity i.e. nodes have a no preference to connect with other nodes of the same type. This is dramatically different from what we saw in the graph before the law was passed where assortativity was 0.078

Conclusions – Section 1

Section 1: Company Graph Metrics Over time

- Mean degree increases over the 9 year period but in a seeming contradiction edge density declines.
- Over the 9 years, the average mean degree is 2.86. The probability that two randomly connected nodes are connected is 1.47%.
- There is small but significant assortativity between companies in Oslo (the capital) and those outside it.

Conclusions – Section 2

Section 2: Company “Super Graph” (all 9 years)

- The mean degree is higher in Oslo (7.78) than outside Oslo (7.08)
- Overall the network was less sparse than the ones for the individual months. Edge density was 0.019.
- We still see significant assortativity by Region (0.11)

Conclusions – Section 3

Section 3: Director Network (Impact of Law)

- Women have a higher mean degree both pre and post law. This is because larger boards are more likely to have female directors.
- The percentage of women on boards was 11.14% before the law was passed and 21.74% after. This suggests that the law improved the representation of women on boards.
- Assortativity by gender drops from 0.078 before the law to only 0.0065 after it. Again this suggests that directors are less assortative after the law was passed.