INFX 576: Problem Set 5 - Cohesive Groups and Graph Sets*

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Due: Thursday, February 16, 2017

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Instructions:

Before beginning this assignment, please ensure you have access to R and RStudio.

1. Download the `problemset5.Rmd` file from Canvas. You will also need the data from last week's Problem Set 4 in `problemset4_data.Rdata`.
2. Replace the "Insert Your Name Here" text in the `author:` field with your own full name. Any collaborators must be listed on the top of your assignment.
3. Be sure to include well-documented (e.g. commented) code chucks, figures and clearly written text chunk explanations as necessary. Any figures should be clearly labeled and appropriately referenced within the text.
4. Collaboration on problem sets is acceptable, and even encouraged, but each student must turn in an individual write-up in his or her own words and his or her own work. The names of all collaborators must be listed on each assignment. Do not copy-and-paste from other students' responses or code.
5. When you have completed the assignment and have **checked** that your code both runs in the Console and knits correctly when you click `Knit PDF`, rename the R Markdown file to `YourLastName_YourFirstName_ps5.Rmd`, knit a PDF and submit the PDF file on Canvas.

Setup:

In this problem set you will need, at minimum, the following R packages.

```
# Load standard libraries
library(statnet)
load("problemset4_data.Rdata")
```

Problem 1: Cohesive Subgroups

In this problem we use data collected by Krackhardt (1987), `kfr` capturing self-reported friendship ties among 21 managers in a high-tech firm. This data is directed and unvalued, it is possible for i to nominate j as a friend without reciprocation.

(a) Cliques

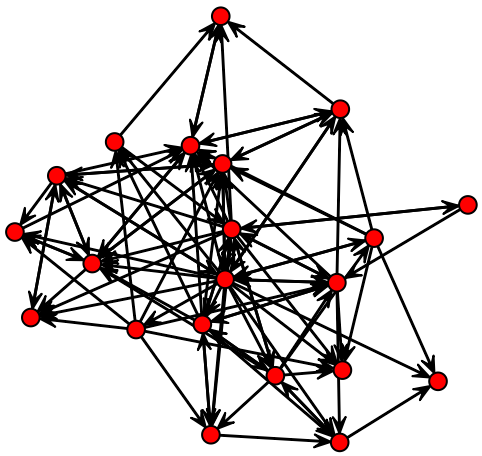
Using the `clique.census` command, perform the following analyses on `kfr`:

- Obtain a length-tabulation of clique membership by vertex.
- Obtain the combined clique co-membership matrix.

*Problems originally written by C.T. Butts (2009)

- Use the clique co-membership matrix to obtain a cohesion-based blockmodel of `kfr`. You may find the commands `hclust cutree` and `blockmodel` helpful here. Show the dendrogram (with cutoff value), block image matrix, and block image.

```
#plot thr friendship network
gplot(kfr, main="Friendship Network")
```




```
#get length-tabulation of clique membership by vertex
kfr_tabulate<-clique.census(kfr, tabulate.by.vertex = T)

#combined clique co-membership matrix by sum
kfr_comemb<-clique.census(kfr,clique.comembership = "sum")
kfr_comemb$clique.comemb
```

```
##      v1 v2 v3 v4 v5 v6 v7 v8 v9 v10 v11 v12 v13 v14 v15 v16 v17 v18 v19 v20
## v1    3  1  0  1  0  0  0  0  0   0   0   1   0   0   0   1   0   0   0   0
## v2    1  3  0  0  0  0  0  0  0   0   0   0   0   0   0   0   0   1   0   0
## v3    0  0  1  0  0  0  0  0  0   0   0   0   0   0   0   0   0   0   1   0
## v4    1  0  0  3  0  0  0  1  0   0   0   2   0   0   0   0   1   0   0   0
## v5    0  0  0  0  2  0  0  0  0   0   2   0   0   0   0   0   1   0   1   0
## v6    0  0  0  0  0  1  0  0  0   0   0   0   0   0   0   0   1   0   0   0
## v7    0  0  0  0  0  0  1  0  0   0   0   0   0   0   0   0   0   0   0   0
## v8    0  0  0  1  0  0  0  1  0   0   0   0   0   0   0   0   0   0   0   0
## v9    0  0  0  0  0  0  0  0  1   0   0   0   0   0   0   0   0   0   0   0
## v10   0  0  0  0  0  0  0  0  0   1   0   0   0   0   0   0   0   0   0   0
## v11   0  0  0  0  2  0  0  0  0   0   4   0   1   0   1   0   1   0   2   0
## v12   1  0  0  2  0  0  0  0  0   0   0   3   0   0   0   0   2   0   0   0
## v13   0  0  0  0  0  0  0  0  0   0   1   0   1   0   0   0   0   0   0   0
## v14   0  0  0  0  0  0  0  0  0   0   0   0   0   1   1   0   0   0   0   0
## v15   0  0  0  0  0  0  0  0  0   0   1   0   0   1   2   0   0   0   1   0
## v16   1  0  0  0  0  0  0  0  0   0   0   0   0   0   0   1   0   0   0   0
## v17   0  0  0  1  1  1  0  0  0   0   1   2   0   0   0   0   4   0   0   0
## v18   0  1  0  0  0  0  0  0  0   0   0   0   0   0   0   0   0   1   0   0
## v19   0  0  1  0  1  0  0  0  0   0   2   0   0   0   1   0   0   0   3   0
## v20   0  0  0  0  0  0  0  0  0   0   0   0   0   0   0   0   0   0   0   1
## v21   0  1  0  0  0  0  0  0  0   0   0   1   0   0   0   0   1   0   0   0
```

```
##     v21
## v1    0
## v2    1
## v3    0
## v4    0
## v5    0
## v6    0
## v7    0
## v8    0
## v9    0
## v10   0
## v11   0
## v12   1
## v13   0
## v14   0
## v15   0
## v16   0
## v17   1
## v18   0
## v19   0
## v20   0
## v21   2
```

```
#combined clique co-membership matrix by size
kfr_comemb<-clique.census(kfr,clique.comembership = "bysize")
kfr_comemb$clique.comemb[1,,]                              # 1-cliques
```

```
##     v1 v2 v3 v4 v5 v6 v7 v8 v9 v10 v11 v12 v13 v14 v15 v16 v17 v18 v19 v20
## v1   0  0  0  0  0  0  0  0  0   0   0   0   0   0   0   0   0   0   0   0
## v2   0  0  0  0  0  0  0  0  0   0   0   0   0   0   0   0   0   0   0   0
## v3   0  0  0  0  0  0  0  0  0   0   0   0   0   0   0   0   0   0   0   0
## v4   0  0  0  0  0  0  0  0  0   0   0   0   0   0   0   0   0   0   0   0
## v5   0  0  0  0  0  0  0  0  0   0   0   0   0   0   0   0   0   0   0   0
## v6   0  0  0  0  0  0  0  0  0   0   0   0   0   0   0   0   0   0   0   0
## v7   0  0  0  0  0  0  1  0  0   0   0   0   0   0   0   0   0   0   0   0
## v8   0  0  0  0  0  0  0  0  0   0   0   0   0   0   0   0   0   0   0   0
## v9   0  0  0  0  0  0  0  0  1   0   0   0   0   0   0   0   0   0   0   0
## v10  0  0  0  0  0  0  0  0  0   1   0   0   0   0   0   0   0   0   0   0
## v11  0  0  0  0  0  0  0  0  0   0   0   0   0   0   0   0   0   0   0   0
## v12  0  0  0  0  0  0  0  0  0   0   0   0   0   0   0   0   0   0   0   0
## v13  0  0  0  0  0  0  0  0  0   0   0   0   0   0   0   0   0   0   0   0
## v14  0  0  0  0  0  0  0  0  0   0   0   0   0   0   0   0   0   0   0   0
## v15  0  0  0  0  0  0  0  0  0   0   0   0   0   0   0   0   0   0   0   0
## v16  0  0  0  0  0  0  0  0  0   0   0   0   0   0   0   0   0   0   0   0
## v17  0  0  0  0  0  0  0  0  0   0   0   0   0   0   0   0   0   0   0   0
## v18  0  0  0  0  0  0  0  0  0   0   0   0   0   0   0   0   0   0   0   0
## v19  0  0  0  0  0  0  0  0  0   0   0   0   0   0   0   0   0   0   0   0
## v20  0  0  0  0  0  0  0  0  0   0   0   0   0   0   0   0   0   0   0   1
## v21  0  0  0  0  0  0  0  0  0   0   0   0   0   0   0   0   0   0   0   0
##     v21
## v1    0
## v2    0
## v3    0
## v4    0
## v5    0
```

```
## v6    0
## v7    0
## v8    0
## v9    0
## v10   0
## v11   0
## v12   0
## v13   0
## v14   0
## v15   0
## v16   0
## v17   0
## v18   0
## v19   0
## v20   0
## v21   0
```

```
kfr_comemb$clique.comemb[2,,]                                    # 2-cliques
```

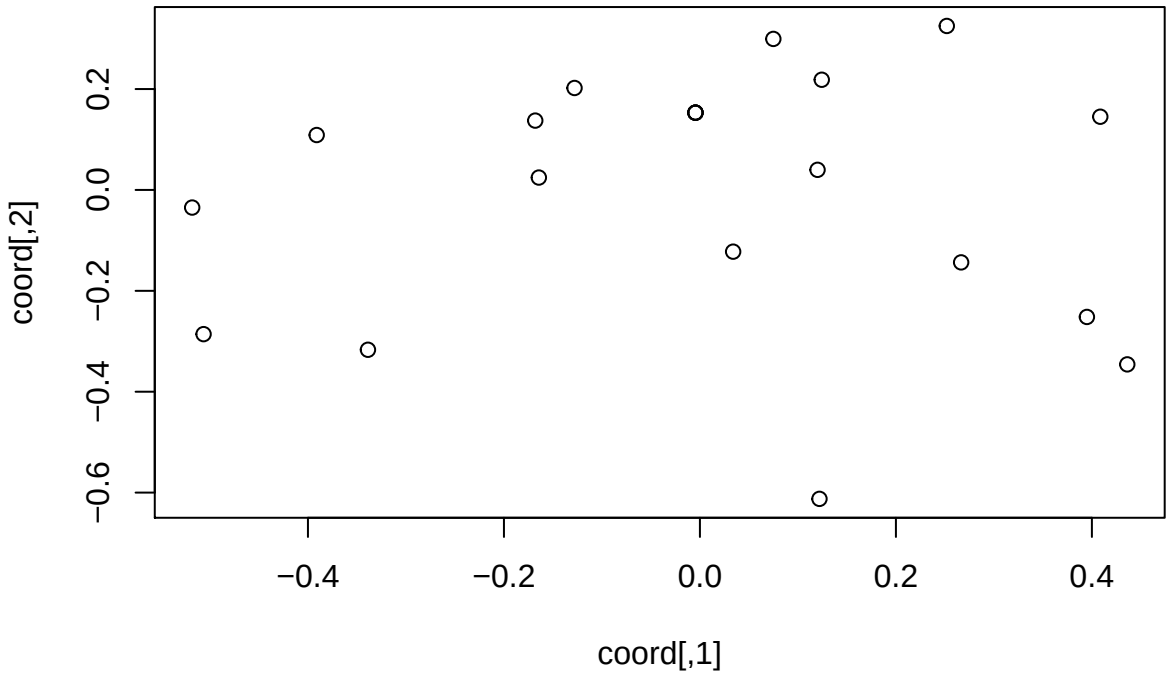
```
##     v1 v2 v3 v4 v5 v6 v7 v8 v9 v10 v11 v12 v13 v14 v15 v16 v17 v18 v19 v20
## v1   2  1  0  0  0  0  0  0  0   0   0   0   0   0   0   1   0   0   0   0
## v2   1  3  0  0  0  0  0  0  0   0   0   0   0   0   0   0   0   1   0   0
## v3   0  0  1  0  0  0  0  0  0   0   0   0   0   0   0   0   0   0   1   0
## v4   0  0  0  1  0  0  0  1  0   0   0   0   0   0   0   0   0   0   0   0
## v5   0  0  0  0  0  0  0  0  0   0   0   0   0   0   0   0   0   0   0   0
## v6   0  0  0  0  0  1  0  0  0   0   0   0   0   0   0   0   1   0   0   0
## v7   0  0  0  0  0  0  0  0  0   0   0   0   0   0   0   0   0   0   0   0
## v8   0  0  0  1  0  0  0  1  0   0   0   0   0   0   0   0   0   0   0   0
## v9   0  0  0  0  0  0  0  0  0   0   0   0   0   0   0   0   0   0   0   0
## v10  0  0  0  0  0  0  0  0  0   0   0   0   0   0   0   0   0   0   0   0
## v11  0  0  0  0  0  0  0  0  0   0   1   0   1   0   0   0   0   0   0   0
## v12  0  0  0  0  0  0  0  0  0   0   0   0   0   0   0   0   0   0   0   0
## v13  0  0  0  0  0  0  0  0  0   0   1   0   1   0   0   0   0   0   0   0
## v14  0  0  0  0  0  0  0  0  0   0   0   0   0   1   1   0   0   0   0   0
## v15  0  0  0  0  0  0  0  0  0   0   0   0   0   1   1   0   0   0   0   0
## v16  1  0  0  0  0  0  0  0  0   0   0   0   0   0   0   1   0   0   0   0
## v17  0  0  0  0  0  1  0  0  0   0   0   0   0   0   0   0   1   0   0   0
## v18  0  1  0  0  0  0  0  0  0   0   0   0   0   0   0   0   0   1   0   0
## v19  0  0  1  0  0  0  0  0  0   0   0   0   0   0   0   0   0   0   1   0
## v20  0  0  0  0  0  0  0  0  0   0   0   0   0   0   0   0   0   0   0   0
## v21  0  1  0  0  0  0  0  0  0   0   0   0   0   0   0   0   0   0   0   0
##     v21
## v1    0
## v2    1
## v3    0
## v4    0
## v5    0
## v6    0
## v7    0
## v8    0
## v9    0
## v10   0
## v11   0
## v12   0
## v13   0
```

```
## v14   0
## v15   0
## v16   0
## v17   0
## v18   0
## v19   0
## v20   0
## v21   1
```

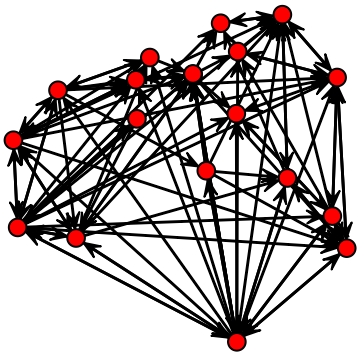
```
kfr_comemb$clique.comemb[3,,]                                    # 3-cliques
```

```
##     v1 v2 v3 v4 v5 v6 v7 v8 v9 v10 v11 v12 v13 v14 v15 v16 v17 v18 v19 v20
## v1   1  0  0  1  0  0  0  0  0   0   0   1   0   0   0   0   0   0   0   0
## v2   0  0  0  0  0  0  0  0  0   0   0   0   0   0   0   0   0   0   0   0
## v3   0  0  0  0  0  0  0  0  0   0   0   0   0   0   0   0   0   0   0   0
## v4   1  0  0  2  0  0  0  0  0   0   0   2   0   0   0   0   1   0   0   0
## v5   0  0  0  0  2  0  0  0  0   0   2   0   0   0   0   0   1   0   1   0
## v6   0  0  0  0  0  0  0  0  0   0   0   0   0   0   0   0   0   0   0   0
## v7   0  0  0  0  0  0  0  0  0   0   0   0   0   0   0   0   0   0   0   0
## v8   0  0  0  0  0  0  0  0  0   0   0   0   0   0   0   0   0   0   0   0
## v9   0  0  0  0  0  0  0  0  0   0   0   0   0   0   0   0   0   0   0   0
## v10  0  0  0  0  0  0  0  0  0   0   0   0   0   0   0   0   0   0   0   0
## v11  0  0  0  0  2  0  0  0  0   0   3   0   0   0   1   0   1   0   2   0
## v12  1  0  0  2  0  0  0  0  0   0   0   3   0   0   0   0   2   0   0   0
## v13  0  0  0  0  0  0  0  0  0   0   0   0   0   0   0   0   0   0   0   0
## v14  0  0  0  0  0  0  0  0  0   0   0   0   0   0   0   0   0   0   0   0
## v15  0  0  0  0  0  0  0  0  0   0   1   0   0   0   1   0   0   0   1   0
## v16  0  0  0  0  0  0  0  0  0   0   0   0   0   0   0   0   0   0   0   0
## v17  0  0  0  1  1  0  0  0  0   0   1   2   0   0   0   0   3   0   0   0
## v18  0  0  0  0  0  0  0  0  0   0   0   0   0   0   0   0   0   0   0   0
## v19  0  0  0  0  1  0  0  0  0   0   2   0   0   0   1   0   0   0   2   0
## v20  0  0  0  0  0  0  0  0  0   0   0   0   0   0   0   0   0   0   0   0
## v21  0  0  0  0  0  0  0  0  0   0   0   1   0   0   0   0   1   0   0   0
##     v21
## v1    0
## v2    0
## v3    0
## v4    0
## v5    0
## v6    0
## v7    0
## v8    0
## v9    0
## v10   0
## v11   0
## v12   1
## v13   0
## v14   0
## v15   0
## v16   0
## v17   1
## v18   0
## v19   0
## v20   0
## v21   1
```

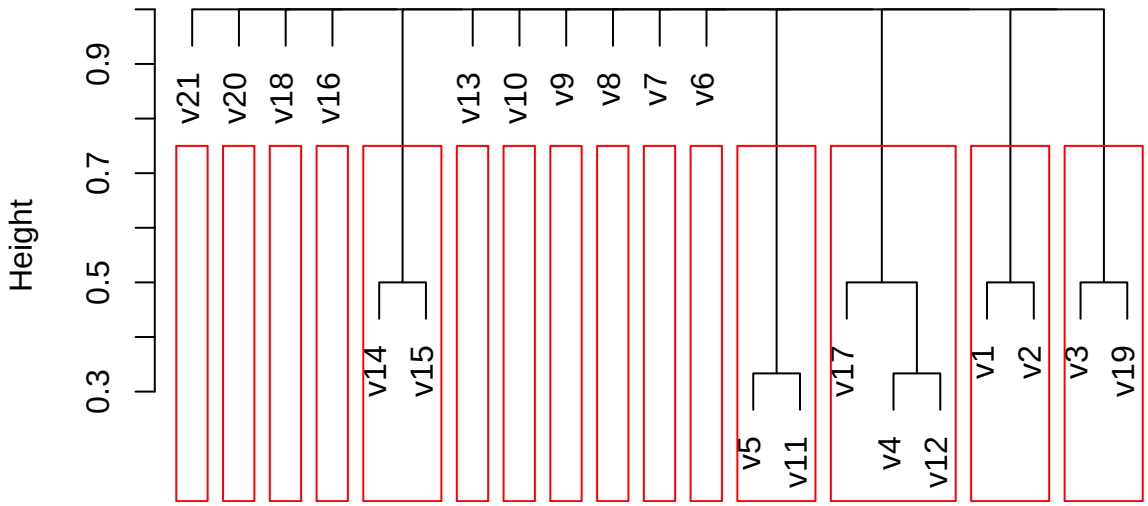
```
csco<-clique.census(kfr,clique.comembership = "sum")$clique.comemb
coord<-cmdscale(1/(1+csco))                          # Perform an MDS
plot(coord)                                          # Examine points
```



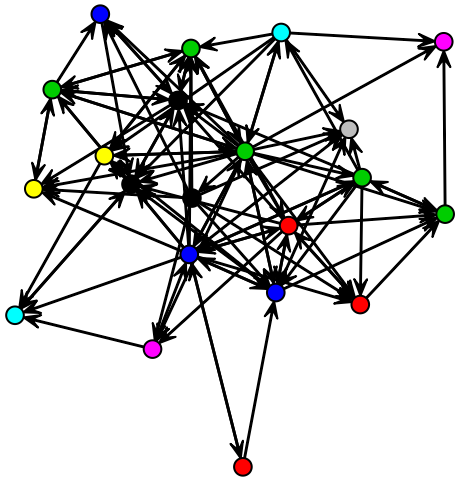

```
gplot(kfr,coord=coord)                               # Use with gplot
```



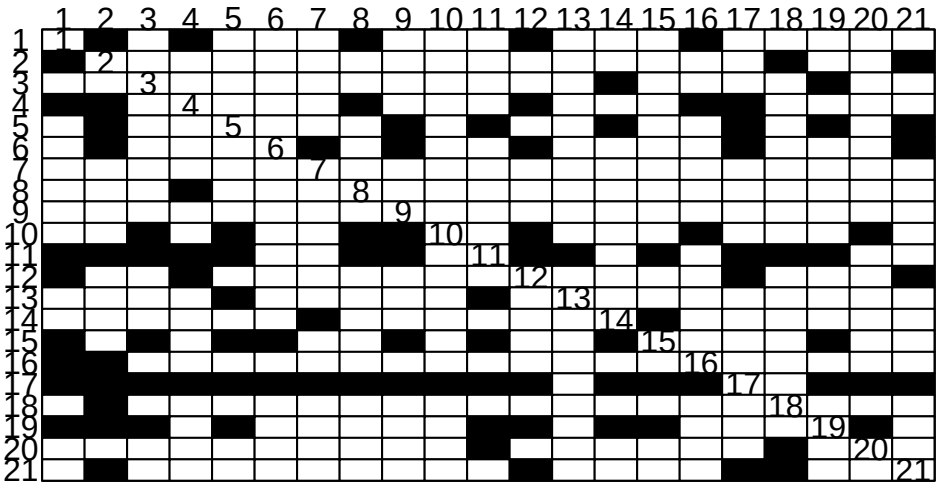
```
# For clustering, we use the hclust function
hc<-hclust(as.dist(1/(csco+1)))                      # Cluster by co-membership
plot(hc)
rect.hclust(hc,h=0.8)                                # Plot a cutoff point
```




```
ct<-cutree(hc,h=0.8)                                    # Cut the clusters
gplot(kfr,vertex.col=ct)                                # Visualize directly
```



```
#plot the sociomatrix of the friendship network
plot.sociomatrix(kfr)
```

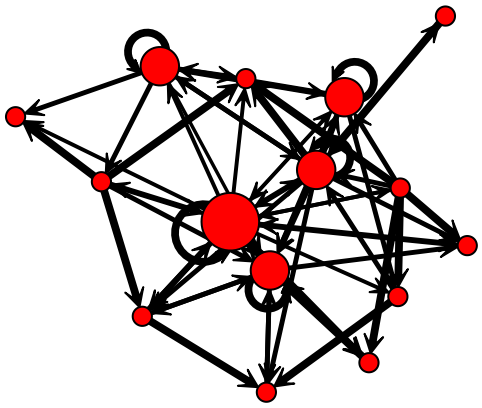


```
# generate a blockmodel and plot it
bm<-blockmodel(kfr,ct)
bm
```

```
##
## Network Blockmodel:
##
## Block membership:
##
##  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21
##  1  1  2  3  4  5  6  7  8  9  4  3 10 11 11 12  3 13  2 14 15
##
## Reduced form blockmodel:
##
##   1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21
##            Block 1   Block 2   Block 3   Block 4   Block 5   Block 6
## Block 1  1.0000000 0.0000000 0.3333333 0.0000000 0.0000000 0.0000000
## Block 2  0.5000000 1.0000000 0.1666667 0.5000000 0.0000000 0.0000000
## Block 3  0.8333333 0.3333333 1.0000000 0.3333333 0.3333333 0.3333333
## Block 4  0.7500000 0.7500000 0.6666667 1.0000000 0.0000000 0.0000000
## Block 5  0.5000000 0.0000000 0.6666667 0.0000000       NaN 1.0000000
## Block 6  0.0000000 0.0000000 0.0000000 0.0000000 0.0000000       NaN
## Block 7  0.0000000 0.0000000 0.3333333 0.0000000 0.0000000 0.0000000
## Block 8  0.0000000 0.0000000 0.0000000 0.0000000 0.0000000 0.0000000
## Block 9  0.0000000 0.5000000 0.3333333 0.5000000 0.0000000 0.0000000
## Block 10 0.0000000 0.0000000 0.0000000 1.0000000 0.0000000 0.0000000
## Block 11 0.2500000 0.5000000 0.0000000 0.5000000 0.5000000 0.5000000
## Block 12 1.0000000 0.0000000 0.0000000 0.0000000 0.0000000 0.0000000
## Block 13 0.5000000 0.0000000 0.0000000 0.0000000 0.0000000 0.0000000
## Block 14 0.0000000 0.0000000 0.0000000 0.5000000 0.0000000 0.0000000
## Block 15 0.5000000 0.0000000 0.6666667 0.0000000 0.0000000 0.0000000
##            Block 7   Block 8   Block 9 Block 10  Block 11  Block 12
## Block 1  0.5000000 0.0000000 0.0000000      0.0 0.0000000 0.5000000
## Block 2  0.0000000 0.0000000 0.0000000      0.0 0.7500000 0.0000000
## Block 3  0.6666667 0.3333333 0.3333333      0.0 0.3333333 0.6666667
## Block 4  0.5000000 1.0000000 0.0000000      0.5 0.5000000 0.0000000
## Block 5  0.0000000 1.0000000 0.0000000      0.0 0.0000000 0.0000000
## Block 6  0.0000000 0.0000000 0.0000000      0.0 0.0000000 0.0000000
## Block 7         NaN 0.0000000 0.0000000      0.0 0.0000000 0.0000000
```

```
## Block 8  0.0000000       NaN 0.0000000      0.0 0.0000000 0.0000000
## Block 9  1.0000000 1.0000000       NaN      0.0 0.0000000 1.0000000
## Block 10 0.0000000 0.0000000 0.0000000      NaN 0.0000000 0.0000000
## Block 11 0.0000000 0.5000000 0.0000000      0.0 1.0000000 0.0000000
## Block 12 0.0000000 0.0000000 0.0000000      0.0 0.0000000       NaN
## Block 13 0.0000000 0.0000000 0.0000000      0.0 0.0000000 0.0000000
## Block 14 0.0000000 0.0000000 0.0000000      0.0 0.0000000 0.0000000
## Block 15 0.0000000 0.0000000 0.0000000      0.0 0.0000000 0.0000000
##          Block 13  Block 14  Block 15
## Block 1       0.5 0.0000000 0.5000000
## Block 2       0.0 0.5000000 0.0000000
## Block 3       0.0 0.3333333 0.6666667
## Block 4       0.5 0.0000000 0.5000000
## Block 5       0.0 0.0000000 1.0000000
## Block 6       0.0 0.0000000 0.0000000
## Block 7       0.0 0.0000000 0.0000000
## Block 8       0.0 0.0000000 0.0000000
## Block 9       0.0 1.0000000 0.0000000
## Block 10      0.0 0.0000000 0.0000000
## Block 11      0.0 0.0000000 0.0000000
## Block 12      0.0 0.0000000 0.0000000
## Block 13      NaN 0.0000000 0.0000000
## Block 14      1.0       NaN 0.0000000
## Block 15      1.0 0.0000000       NaN
```

```
gplot(bm$block.model,vertex.cex=table(ct),edge.lwd=6*bm$block.model,usearrows=TRUE,diag=TRUE)
```



(b) K-Cores

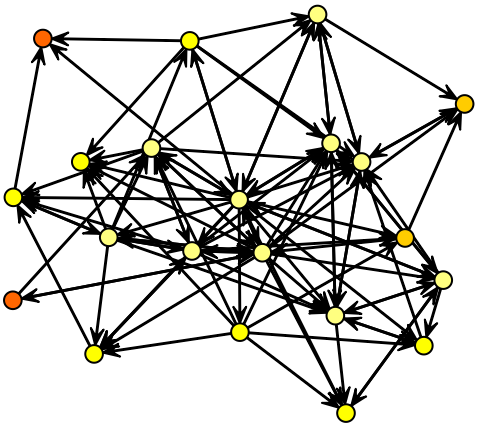
Use the `kcores` command to calculate the total degree k-cores of `kfr`. Visualize the network, indicating by size, shape, or color the core number for each vertex.

```
#get the total degree scores of the friendship network
kfr_kc<-kcores(kfr)
table(kfr_kc)
```

```
## kfr_kc
##  3  5  6  7
##  2  2  7 10
```

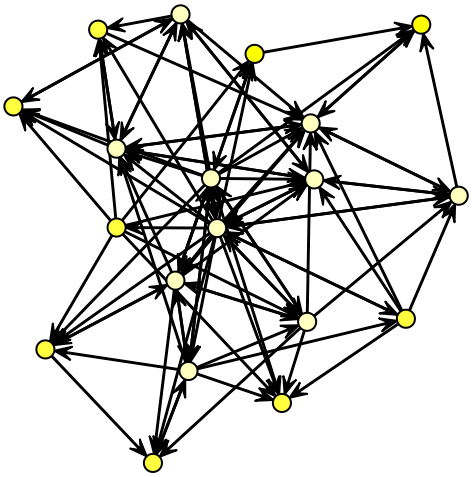
```
# plot the network for 3,4,5 and 7-core network
gplot(kfr,vertex.col=heat.colors(max(kfr_kc))[kfr_kc],main="3-cores")   #3-core plot
```

3−cores

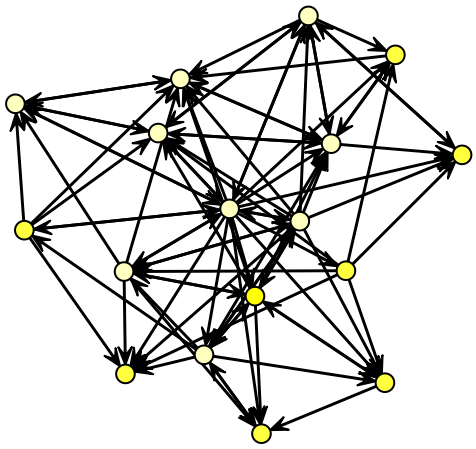


```
gplot(kfr[kfr_kc>3,kfr_kc>3],vertex.col=heat.colors(max(kfr_kc[kfr_kc>3])+1)[kfr_kc[kfr_kc>3]+1],main="5
```

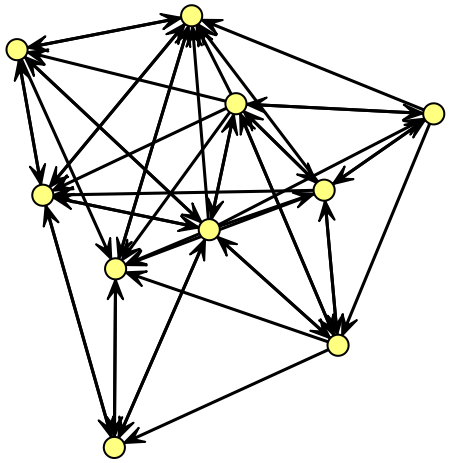
5−cores



```
gplot(kfr[kfr_kc>5,kfr_kc>5],vertex.col=heat.colors(max(kfr_kc[kfr_kc>5])+1)[kfr_kc[kfr_kc>3]+1],main="(
```




```
gplot(kfr[kfr_kc>6,kfr_kc>6],vertex.col=heat.colors(max(kfr_kc[kfr_kc>6]))[kfr_kc[kfr_kc>6]],main="7-co
```



(c) Discussion

Based on the anlaysis in parts (a) and (b), how would you summarize the structure of this network; in particular, how many distinct dense clusters do there appear to be?

• Based on the above clique structure, dendrogram, sociomatrix, blockmodel observations, we can say that there don't seem to be any grouping structure present in the network. From those observations, since we don't see any prominent clusters, we can observe only in the dendrogram that the current structure might lead to 15 clusters, which we can't label to be significant.

Problem 2: Graph Correlation

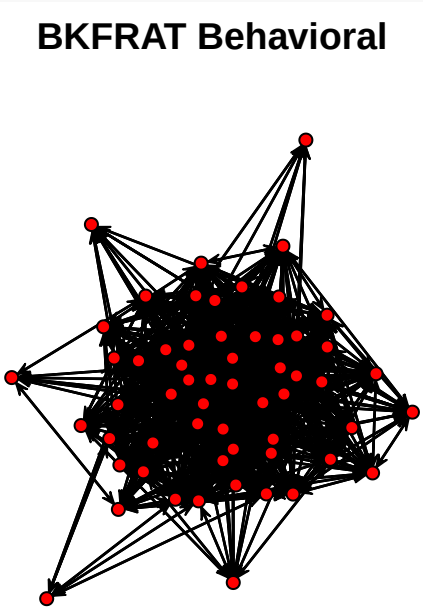
Last week, we saw network data from the famous Bernard, Killworth, and Sailer (BKS) studies. These studies examined the issue of accuracy in self-reported network data. Each study involved a group of subjects, each of whom was asked to rank-order all other group members by frequency of interaction. The self-reported

interaction frequency was referred to as the "cognitive" ntework by BKS (i.e. the network as understood by the subjects themeselves). During the study period, behavioral information on interaction within the same groups was also collected via trained observers. The network of observed pairwise interaction frequencies was referred to as the "behavioral" network. Accuracy was assessed by comparing the "cognitive" and "behavioral" networks. The BKS studies were controversial and launched a much larger literature on the accuracy of network measurement.

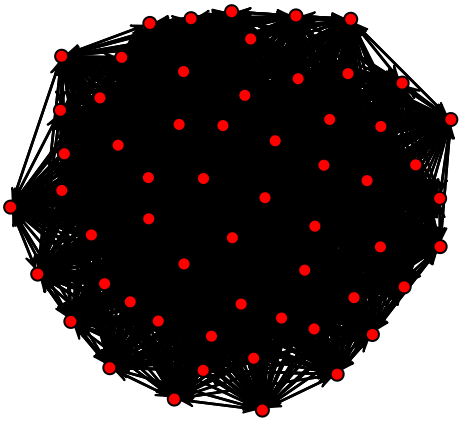
(a) Comparing Networks

For each of the data objects `bkfrat`, `bkham`, `bkoff` and `bktec` (each itself a list containing the cognitive and behavioral network from a BKS study) perform a QAP test of the correlation between the self-report and the observed structure. Show in each case the test results, including a plot of the QAP replicates.

```
#plot BKFRAT Behaviroal and Congnitive network
gplot(bkfrat$Behavioral,main="BKFRAT Behavioral")
```




```
gplot(bkfrat$Cognitive,main="BKFRAT Cognitive")
```



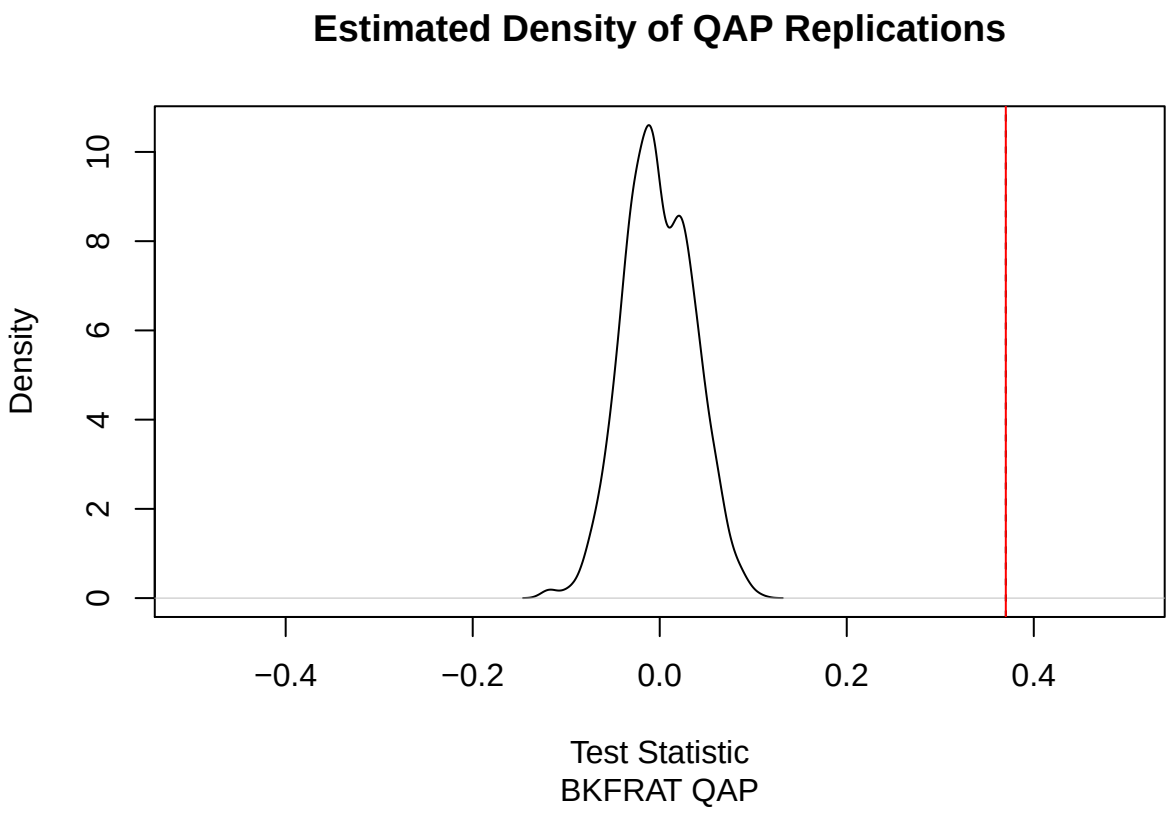
```r
#carry out the qap test for BKFRAT networkds and plot the results
gcor(bkfrat$Behavioral,bkfrat$Cognitive)
```

```
## [1] 0.3700903
```

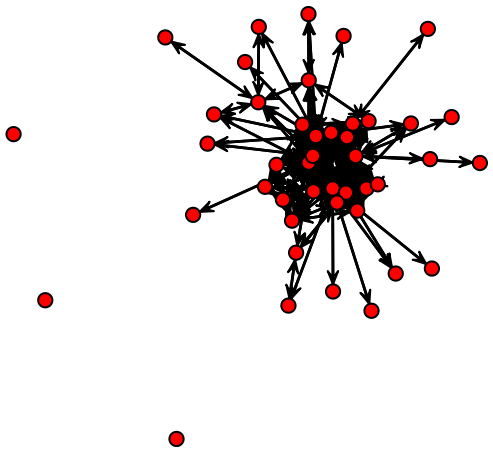
```r
bkfrat_qt<-qaptest(list(bkfrat$Behavioral,bkfrat$Cognitive),gcor,g1=1,g2=2)
summary(bkfrat_qt)                                          # Examine the results
```

```
##
## QAP Test Results
##
## Estimated p-values:
##  p(f(perm) >= f(d)): 0
##  p(f(perm) <= f(d)): 1
##
## Test Diagnostics:
##  Test Value (f(d)): 0.3700903
##  Replications: 1000
##  Distribution Summary:
##      Min:     -0.1212082
##      1stQ:    -0.02690778
##      Med:     -0.004077161
##      Mean:    -0.001205859
##      3rdQ:    0.02527114
##      Max:     0.1066111
```

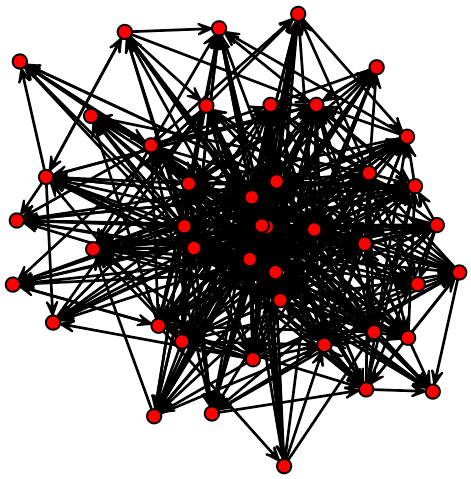
```r
plot(bkfrat_qt,sub="BKFRAT QAP",xlim=c(-0.5,0.5))
abline(v = bkfrat_qt$testval,col=2)
```



```
#plot BKHAM Behaviroal and Congnitive network
gplot(bkham$Behavioral,main="BKHAM Behavioral")
```




```
gplot(bkham$Cognitive,main="BKHAM Cognitive")
```




```
#carry out the qap test for BKFRAT networkds and plot the results
gcor(bkham$Behavioral,bkham$Cognitive)
```

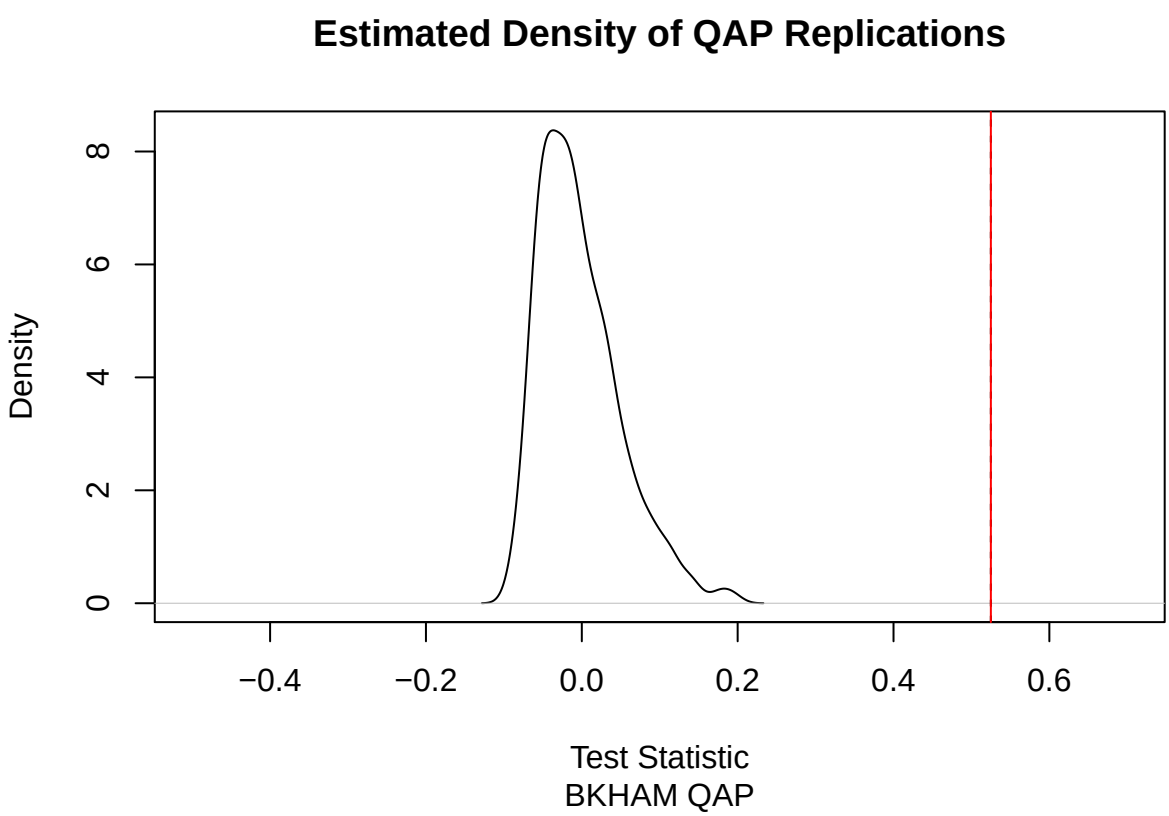
```
## [1] 0.5249309
```

```
bkham_qt<-qaptest(list(bkham$Behavioral,bkham$Cognitive),gcor,g1=1,g2=2)
summary(bkham_qt)                                    # Examine the results
```

```
##
## QAP Test Results
##
## Estimated p-values:
##  p(f(perm) >= f(d)): 0
```

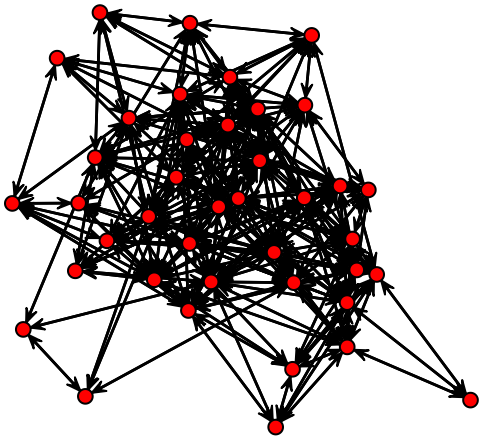
```
##  p(f(perm) <= f(d)): 1
##
## Test Diagnostics:
##  Test Value (f(d)): 0.5249309
##  Replications: 1000
##  Distribution Summary:
##      Min:     -0.09281267
##      1stQ:    -0.04215022
##      Med:     -0.01258971
##      Mean:    -0.002471194
##      3rdQ:    0.02765534
##      Max:     0.1977173
```

```
plot(bkham_qt,sub="BKHAM QAP",xlim=c(-0.5,0.7))
abline(v= bkham_qt$testval,col=2)
```



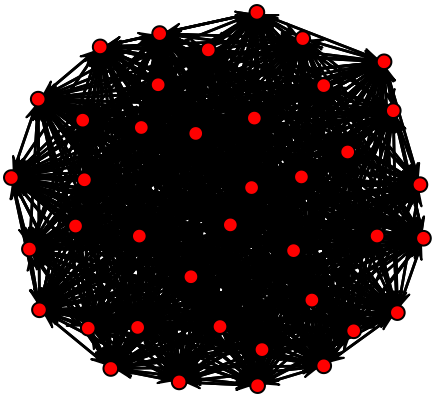

```
#plot BKOFF Behaviroal and Congnitive network
gplot(bkoff$Behavioral,main="BKOFF Behavioral")
```

BKOFF Behavioral



```
gplot(bkoff$Cognitive,main="BKOFF Cognitive")
```

BKOFF Cognitive



```
#carry out the qap test for BKFRAT networkds and plot the results
gcor(bkoff$Behavioral,bkoff$Cognitive)
```

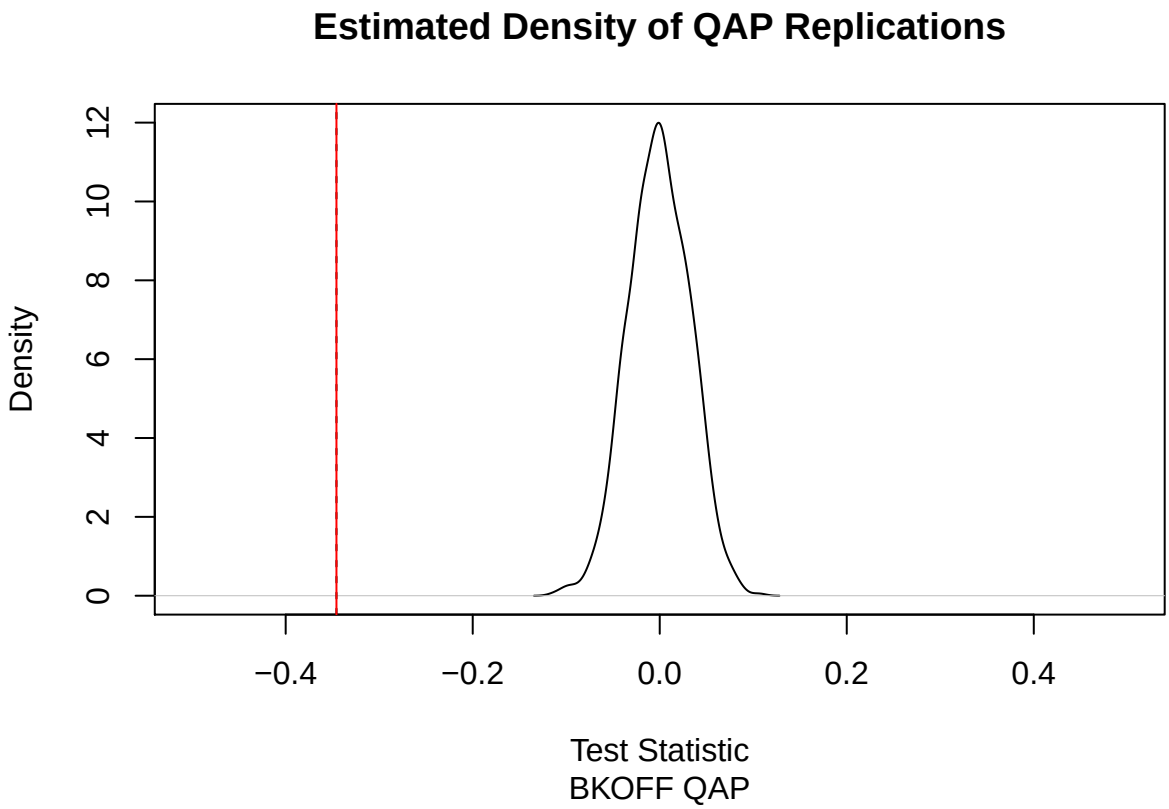
```
## [1] -0.3457147
```

```
bkoff_qt<-qaptest(list(bkoff$Behavioral,bkoff$Cognitive),gcor,g1=1,g2=2)
summary(bkoff_qt)                                          # Examine the results
```

```
##
## QAP Test Results
##
## Estimated p-values:
##  p(f(perm) >= f(d)): 1
##  p(f(perm) <= f(d)): 0
##
## Test Diagnostics:
##  Test Value (f(d)): -0.3457147
```

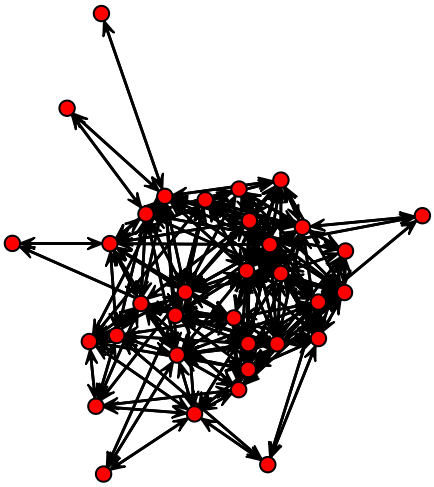
```
##  Replications: 1000
##  Distribution Summary:
##       Min:      -0.1123751
##       1stQ:     -0.02300556
##       Med:      -0.0008061903
##       Mean:     -0.000670102
##       3rdQ:     0.02266444
##       Max:      0.1059001
```

```
plot(bkoff_qt,sub="BKOFF QAP",xlim=c(-0.5,0.5))
abline(v=bkoff_qt$testval,col=2)
```



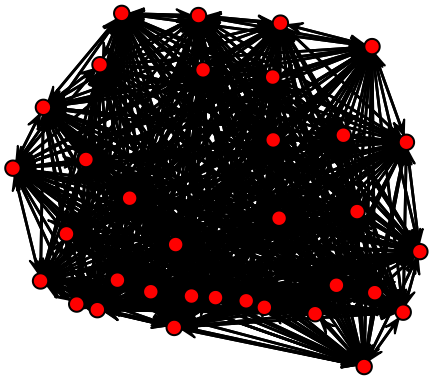

```
#plot BKTEC Behaviroal and Congnitive network
gplot(bktec$Behavioral,main="BKTEC Behavioral")
```

BKTEC Behavioral



```
gplot(bktec$Cognitive,main="BKTEC Cognitive")
```

BKTEC Cognitive



```
#carry out the qap test for BKFRAT networkds and plot the results
gcor(bktec$Behavioral,bktec$Cognitive)
```

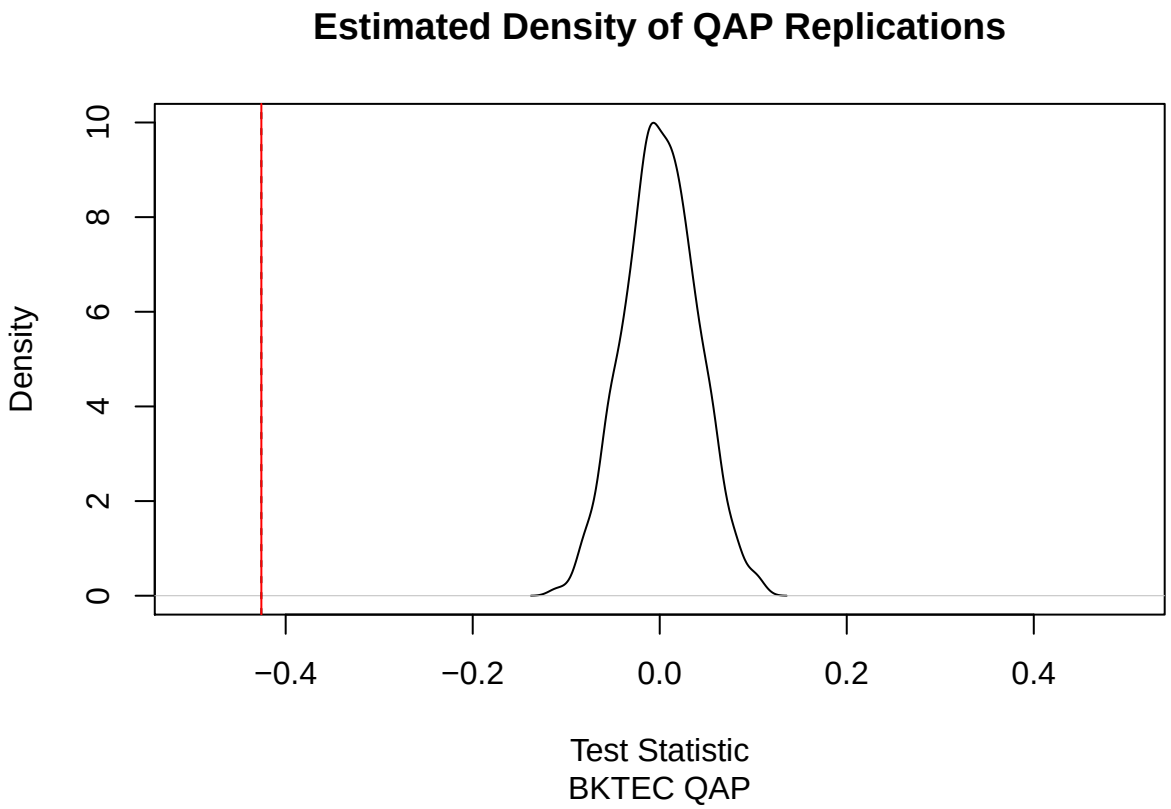
```
## [1] -0.4260065
```

```
bktec_qt<-qaptest(list(bktec$Behavioral,bktec$Cognitive),gcor,g1=1,g2=2)
summary(bktec_qt)                                          # Examine the results
```

```
##
## QAP Test Results
##
## Estimated p-values:
##  p(f(perm) >= f(d)): 1
##  p(f(perm) <= f(d)): 0
##
## Test Diagnostics:
##  Test Value (f(d)): -0.4260065
```

```
##  Replications: 1000
##  Distribution Summary:
##       Min:      -0.1115202
##       1stQ:     -0.02441753
##       Med:      0.0009635467
##       Mean:     0.001126095
##       3rdQ:     0.0273783
##       Max:      0.1095119
```

```
plot(bktec_qt,sub="BKTEC QAP",xlim=c(-0.5,0.5))
abline(v=bktec_qt$testval,col=2)
```



(b) Discussion

Use the results from part (a) to provide your own assessment of the extent to which the data does or does not show general agreement between observation and informant report. • Here we can see from the above QAP test values and the visualized plots that there is a general agreement in two of the networks, which are BKFRAT and BKHAM. Here the extent to which the two are correlated are given by the correlation values, BKFRAT:0.37 and BKHAM:0.52. • Further, the BKTEC and BKOFF networks have a negative correlation in their behavioral and cognitive networks, which tells us that there is not an agreement between the behvioral and cognitive values of interaction in the network. The extent to which the two are correlated are given by the correlation values, BKOFF:-0.35 and BKTEC:-0.42

(c) Observation and Networks

What reliability or validity issues might arise in the BKS studies if the observed report data is taken to be the true "behavioral" network? • If the true behavioral network is taken to be the observed report data, there would be reliability issues, since the protocols of the officers evaluating the interactions might be different from the actual interactions, and thus it might lead to biased results. Thus it might not account for the actual interactions and since it is subjective, it might not be validated if some other agency would measure

these interactions.

Problem 3: Multivariate Analysis of Network Sets

For this problem we will use data on international trade, called `trade` in the data for this problem set. This data captures trade in various types of products/materials among countries. You will want to explore the data before answering these questions, to ensure you understand what is present.

```
#exploration of the data
str(trade)              #structure of data
```

```
##  num [1:5, 1:24, 1:24] 0 0 0 0 0 0 1 1 1 1 ...
##  - attr(*, "dimnames")=List of 3
##   ..$ : chr [1:5] "MINERALS" "CRUDE_MATERIALS" "FOODS" "MANUFACTURED_GOODS" ...
##   ..$ : chr [1:24] "ALGERIA " "ARGENTINA " "BRAZIL " "CHINA " ...
##   ..$ : chr [1:24] "ALGERIA " "ARGENTINA " "BRAZIL " "CHINA " ...
```

```
trade
```

```
## , , ALGERIA
##
##                      ALGERIA  ARGENTINA  BRAZIL  CHINA  CZECHOSLOVAKIA
## MINERALS                   0          0       1      0               0
## CRUDE_MATERIALS            0          1       1      0               0
## FOODS                      0          1       1      1               0
## MANUFACTURED_GOODS         0          1       1      1               1
## DIPLOMATIC_EXCHANGE        0          1       1      1               1
##                      ECUADOR  EGYPT  ETHIOPIA  FINLAND  HONDURAS
## MINERALS                   0      0         0        0         0
## CRUDE_MATERIALS            0      1         1        1         0
## FOODS                      0      1         0        1         0
## MANUFACTURED_GOODS         0      0         0        1         0
## DIPLOMATIC_EXCHANGE        0      0         0        1         0
##                      INDONESIA  ISRAEL  JAPAN  LIBERIA  MADAGASCAR
## MINERALS                     0       0      1        0           0
## CRUDE_MATERIALS              0       0      1        0           0
## FOODS                        1       0      0        0           0
## MANUFACTURED_GOODS           1       0      1        0           0
## DIPLOMATIC_EXCHANGE          1       0      1        0           1
##                      NEW_ZEALAND  PAKISTAN  SPAIN  SWITZERLAND  SYRIA
## MINERALS                       0         0      1            0      0
## CRUDE_MATERIALS                1         0      1            1      1
## FOODS                          1         1      1            1      1
## MANUFACTURED_GOODS             1         0      1            1      0
## DIPLOMATIC_EXCHANGE            0         1      1            1      1
##                      THAILAND  UNITED_KINGDOM  UNITED_STATES  YUGOSLAVIA
## MINERALS                    0               1              1           1
## CRUDE_MATERIALS             0               1              1           1
## FOODS                       1               1              1           1
## MANUFACTURED_GOODS          0               1              1           1
## DIPLOMATIC_EXCHANGE         0               1              1           1
##
## , , ARGENTINA
##
##                      ALGERIA  ARGENTINA  BRAZIL  CHINA  CZECHOSLOVAKIA
## MINERALS                   0          0       1      0               0
```

```
## CRUDE_MATERIALS           0          0       1      1              0
## FOODS                     0          0       1      0              0
## MANUFACTURED_GOODS        0          0       1      1              1
## DIPLOMATIC_EXCHANGE       1          0       1      1              1
##                     ECUADOR  EGYPT  ETHIOPIA  FINLAND  HONDURAS
## MINERALS                  0      0         0        0         0
## CRUDE_MATERIALS           0      0         0        1         0
## FOODS                     1      0         0        0         0
## MANUFACTURED_GOODS        0      0         0        1         0
## DIPLOMATIC_EXCHANGE       0      1         0        1         1
##                     INDONESIA  ISRAEL  JAPAN  LIBERIA  MADAGASCAR
## MINERALS                    0       0      1        0           0
## CRUDE_MATERIALS             0       1      1        0           0
## FOODS                       0       1      0        0           0
## MANUFACTURED_GOODS          0       1      1        0           0
## DIPLOMATIC_EXCHANGE         1       1      1        0           0
##                     NEW_ZEALAND  PAKISTAN  SPAIN  SWITZERLAND  SYRIA
## MINERALS                      0         0      1            0      0
## CRUDE_MATERIALS               1         0      1            1      0
## FOODS                         0         0      1            1      0
## MANUFACTURED_GOODS            0         0      1            1      0
## DIPLOMATIC_EXCHANGE           0         1      1            1      1
##                     THAILAND  UNITED_KINGDOM  UNITED_STATES  YUGOSLAVIA
## MINERALS                   0               0              1           0
## CRUDE_MATERIALS            0               0              1           0
## FOODS                      0               0              1           0
## MANUFACTURED_GOODS         0               0              1           1
## DIPLOMATIC_EXCHANGE        1               0              1           1
##
## , , BRAZIL
##
##                     ALGERIA  ARGENTINA  BRAZIL  CHINA  CZECHOSLOVAKIA
## MINERALS                  1          1       0      1              0
## CRUDE_MATERIALS           0          1       0      0              0
## FOODS                     0          1       0      0              1
## MANUFACTURED_GOODS        0          1       0      1              1
## DIPLOMATIC_EXCHANGE       1          1       0      1              1
##                     ECUADOR  EGYPT  ETHIOPIA  FINLAND  HONDURAS
## MINERALS                  0      0         0        0         0
## CRUDE_MATERIALS           0      0         0        0         0
## FOODS                     1      0         0        0         0
## MANUFACTURED_GOODS        1      0         0        1         0
## DIPLOMATIC_EXCHANGE       1      1         0        1         1
##                     INDONESIA  ISRAEL  JAPAN  LIBERIA  MADAGASCAR
## MINERALS                    0       0      1        0           0
## CRUDE_MATERIALS             0       0      1        0           0
## FOODS                       0       1      0        0           0
## MANUFACTURED_GOODS          0       0      1        0           0
## DIPLOMATIC_EXCHANGE         1       1      1        0           0
##                     NEW_ZEALAND  PAKISTAN  SPAIN  SWITZERLAND  SYRIA
## MINERALS                      0         0      0            0      0
## CRUDE_MATERIALS               0         0      1            1      0
## FOODS                         0         0      1            1      0
## MANUFACTURED_GOODS            0         0      1            1      0
```

```
## DIPLOMATIC_EXCHANGE           0         1      1            1      1
##                     THAILAND  UNITED_KINGDOM  UNITED_STATES  YUGOSLAVIA
## MINERALS                   0               1              1           0
## CRUDE_MATERIALS            0               1              1           0
## FOODS                      0               1              1           1
## MANUFACTURED_GOODS         1               1              1           0
## DIPLOMATIC_EXCHANGE        1               1              1           1
##
## , , CHINA
##
##                     ALGERIA  ARGENTINA  BRAZIL  CHINA  CZECHOSLOVAKIA
## MINERALS                  0          0       0      0               0
## CRUDE_MATERIALS           1          1       1      0               0
## FOODS                     0          0       1      0               0
## MANUFACTURED_GOODS        1          1       1      0               1
## DIPLOMATIC_EXCHANGE       1          1       1      0               1
##                     ECUADOR  EGYPT  ETHIOPIA  FINLAND  HONDURAS
## MINERALS                  0      0         0        0         0
## CRUDE_MATERIALS           0      1         0        1         0
## FOODS                     0      0         0        0         0
## MANUFACTURED_GOODS        0      0         0        1         0
## DIPLOMATIC_EXCHANGE       1      1         1        1         0
##                     INDONESIA  ISRAEL  JAPAN  LIBERIA  MADAGASCAR
## MINERALS                    0       0      1        0           0
## CRUDE_MATERIALS             1       0      1        0           0
## FOODS                       1       0      1        0           0
## MANUFACTURED_GOODS          1       0      1        0           0
## DIPLOMATIC_EXCHANGE         0       0      1        1           1
##                     NEW_ZEALAND  PAKISTAN  SPAIN  SWITZERLAND  SYRIA
## MINERALS                      0         0      0            0      0
## CRUDE_MATERIALS               1         1      1            1      0
## FOODS                         1         0      1            1      0
## MANUFACTURED_GOODS            1         1      1            1      0
## DIPLOMATIC_EXCHANGE           1         1      1            1      1
##                     THAILAND  UNITED_KINGDOM  UNITED_STATES  YUGOSLAVIA
## MINERALS                   0               1              1           0
## CRUDE_MATERIALS            1               1              1           1
## FOODS                      1               1              1           1
## MANUFACTURED_GOODS         1               1              1           1
## DIPLOMATIC_EXCHANGE        1               1              1           1
##
## , , CZECHOSLOVAKIA
##
##                     ALGERIA  ARGENTINA  BRAZIL  CHINA  CZECHOSLOVAKIA
## MINERALS                  0          0       0      0               0
## CRUDE_MATERIALS           1          1       1      1               0
## FOODS                     0          1       1      1               0
## MANUFACTURED_GOODS        1          0       1      1               0
## DIPLOMATIC_EXCHANGE       1          1       1      1               0
##                     ECUADOR  EGYPT  ETHIOPIA  FINLAND  HONDURAS
## MINERALS                  0      0         0        0         0
## CRUDE_MATERIALS           0      1         1        1         1
## FOODS                     1      1         1        1         1
## MANUFACTURED_GOODS        0      1         0        1         0
```

```
## DIPLOMATIC_EXCHANGE        1      1         0        1         0
##                      INDONESIA  ISRAEL  JAPAN  LIBERIA  MADAGASCAR
## MINERALS                     0       0      0        0           0
## CRUDE_MATERIALS              1       0      1        0           0
## FOODS                        1       0      1        0           0
## MANUFACTURED_GOODS           1       0      1        0           0
## DIPLOMATIC_EXCHANGE          1       0      1        0           0
##                      NEW_ZEALAND  PAKISTAN  SPAIN  SWITZERLAND  SYRIA
## MINERALS                       0         0      0            1      0
## CRUDE_MATERIALS                1         1      0            1      1
## FOODS                          0         1      1            1      0
## MANUFACTURED_GOODS             0         1      1            1      0
## DIPLOMATIC_EXCHANGE            0         0      1            1      1
##                      THAILAND  UNITED_KINGDOM  UNITED_STATES  YUGOSLAVIA
## MINERALS                    0               1              0           1
## CRUDE_MATERIALS             1               1              1           1
## FOODS                       1               1              1           1
## MANUFACTURED_GOODS          0               1              1           1
## DIPLOMATIC_EXCHANGE         0               1              1           1
##
## , , ECUADOR
##
##                      ALGERIA  ARGENTINA  BRAZIL  CHINA  CZECHOSLOVAKIA
## MINERALS                   0          0       1      0               0
## CRUDE_MATERIALS            0          1       1      0               0
## FOODS                      0          1       0      0               0
## MANUFACTURED_GOODS         0          1       1      0               1
## DIPLOMATIC_EXCHANGE        0          1       1      1               1
##                      ECUADOR  EGYPT  ETHIOPIA  FINLAND  HONDURAS
## MINERALS                   0      0         0        0         0
## CRUDE_MATERIALS            0      0         0        1         0
## FOODS                      0      0         0        0         0
## MANUFACTURED_GOODS         0      0         0        1         0
## DIPLOMATIC_EXCHANGE        0      1         0        0         1
##                      INDONESIA  ISRAEL  JAPAN  LIBERIA  MADAGASCAR
## MINERALS                     0       0      1        0           0
## CRUDE_MATERIALS              0       1      1        0           0
## FOODS                        0       0      0        0           0
## MANUFACTURED_GOODS           0       0      1        0           0
## DIPLOMATIC_EXCHANGE          0       1      1        0           0
##                      NEW_ZEALAND  PAKISTAN  SPAIN  SWITZERLAND  SYRIA
## MINERALS                       0         0      0            0      0
## CRUDE_MATERIALS                0         0      1            1      0
## FOODS                          1         0      1            0      0
## MANUFACTURED_GOODS             0         0      1            1      0
## DIPLOMATIC_EXCHANGE            0         0      1            1      0
##                      THAILAND  UNITED_KINGDOM  UNITED_STATES  YUGOSLAVIA
## MINERALS                    0               1              1           0
## CRUDE_MATERIALS             0               1              1           0
## FOODS                       1               0              1           0
## MANUFACTURED_GOODS          0               1              1           0
## DIPLOMATIC_EXCHANGE         0               1              1           1
##
## , , EGYPT
```

```
##
##                     ALGERIA  ARGENTINA  BRAZIL  CHINA  CZECHOSLOVAKIA
## MINERALS                  1          0       0      1               0
## CRUDE_MATERIALS           0          0       1      1               1
## FOODS                     0          1       1      1               1
## MANUFACTURED_GOODS        0          0       1      1               1
## DIPLOMATIC_EXCHANGE       0          1       1      1               1
##                     ECUADOR  EGYPT  ETHIOPIA  FINLAND  HONDURAS
## MINERALS                  0      0         0        0         0
## CRUDE_MATERIALS           0      0         1        1         0
## FOODS                     0      0         0        1         1
## MANUFACTURED_GOODS        0      0         0        1         0
## DIPLOMATIC_EXCHANGE       1      0         1        1         0
##                     INDONESIA  ISRAEL  JAPAN  LIBERIA  MADAGASCAR
## MINERALS                    0       1      1        1           0
## CRUDE_MATERIALS             0       0      1        1           0
## FOODS                       1       1      1        0           0
## MANUFACTURED_GOODS          1       0      1        0           0
## DIPLOMATIC_EXCHANGE         1       1      1        1           0
##                     NEW_ZEALAND  PAKISTAN  SPAIN  SWITZERLAND  SYRIA
## MINERALS                      0         0      1            0      0
## CRUDE_MATERIALS               1         0      1            1      0
## FOODS                         1         0      1            1      1
## MANUFACTURED_GOODS            1         0      1            1      0
## DIPLOMATIC_EXCHANGE           0         1      1            1      0
##                     THAILAND  UNITED_KINGDOM  UNITED_STATES  YUGOSLAVIA
## MINERALS                   0               1              1           0
## CRUDE_MATERIALS            1               1              1           1
## FOODS                      1               1              1           1
## MANUFACTURED_GOODS         0               1              1           1
## DIPLOMATIC_EXCHANGE        1               1              1           1
##
## , , ETHIOPIA
##
##                     ALGERIA  ARGENTINA  BRAZIL  CHINA  CZECHOSLOVAKIA
## MINERALS                  0          0       0      0               0
## CRUDE_MATERIALS           0          0       0      1               0
## FOODS                     0          0       0      0               0
## MANUFACTURED_GOODS        0          0       0      1               1
## DIPLOMATIC_EXCHANGE       1          1       0      1               1
##                     ECUADOR  EGYPT  ETHIOPIA  FINLAND  HONDURAS
## MINERALS                  0      0         0        0         0
## CRUDE_MATERIALS           0      0         0        0         0
## FOODS                     0      0         0        0         0
## MANUFACTURED_GOODS        0      1         0        1         0
## DIPLOMATIC_EXCHANGE       0      1         0        1         0
##                     INDONESIA  ISRAEL  JAPAN  LIBERIA  MADAGASCAR
## MINERALS                    0       0      0        0           0
## CRUDE_MATERIALS             0       0      1        0           0
## FOODS                       0       0      0        0           0
## MANUFACTURED_GOODS          0       1      1        0           0
## DIPLOMATIC_EXCHANGE         1       0      1        1           0
##                     NEW_ZEALAND  PAKISTAN  SPAIN  SWITZERLAND  SYRIA
## MINERALS                      0         0      0            0      0
```

```
## CRUDE_MATERIALS               0         0      0            0      0
## FOODS                         0         0      0            1      0
## MANUFACTURED_GOODS            0         0      0            1      0
## DIPLOMATIC_EXCHANGE           0         0      1            1      0
##                     THAILAND  UNITED_KINGDOM  UNITED_STATES  YUGOSLAVIA
## MINERALS                   0               1              1           0
## CRUDE_MATERIALS            0               1              1           1
## FOODS                      0               1              1           0
## MANUFACTURED_GOODS         0               1              1           1
## DIPLOMATIC_EXCHANGE        0               1              1           1
##
## , , FINLAND
##
##                     ALGERIA  ARGENTINA  BRAZIL  CHINA  CZECHOSLOVAKIA
## MINERALS                  0          0       0      1               0
## CRUDE_MATERIALS           1          1       1      1               1
## FOODS                     0          1       1      1               1
## MANUFACTURED_GOODS        0          1       1      1               1
## DIPLOMATIC_EXCHANGE       0          1       1      1               1
##                     ECUADOR  EGYPT  ETHIOPIA  FINLAND  HONDURAS
## MINERALS                  0      0         0        0         0
## CRUDE_MATERIALS           1      1         0        0         0
## FOODS                     1      1         1        0         1
## MANUFACTURED_GOODS        0      1         0        0         0
## DIPLOMATIC_EXCHANGE       0      1         0        0         0
##                     INDONESIA  ISRAEL  JAPAN  LIBERIA  MADAGASCAR
## MINERALS                    0       0      0        0           0
## CRUDE_MATERIALS             1       1      1        0           0
## FOODS                       1       1      1        0           1
## MANUFACTURED_GOODS          1       1      1        0           0
## DIPLOMATIC_EXCHANGE         1       1      1        0           0
##                     NEW_ZEALAND  PAKISTAN  SPAIN  SWITZERLAND  SYRIA
## MINERALS                      0         0      1            0      0
## CRUDE_MATERIALS               1         0      1            1      0
## FOODS                         1         1      1            1      0
## MANUFACTURED_GOODS            0         1      1            1      0
## DIPLOMATIC_EXCHANGE           0         0      1            1      0
##                     THAILAND  UNITED_KINGDOM  UNITED_STATES  YUGOSLAVIA
## MINERALS                   0               1              1           0
## CRUDE_MATERIALS            1               1              1           0
## FOODS                      1               1              1           1
## MANUFACTURED_GOODS         1               1              1           1
## DIPLOMATIC_EXCHANGE        0               1              1           1
##
## , , HONDURAS
##
##                     ALGERIA  ARGENTINA  BRAZIL  CHINA  CZECHOSLOVAKIA
## MINERALS                  0          0       0      0               0
## CRUDE_MATERIALS           0          0       0      0               0
## FOODS                     0          0       0      0               0
## MANUFACTURED_GOODS        0          0       1      1               1
## DIPLOMATIC_EXCHANGE       0          1       1      1               0
##                     ECUADOR  EGYPT  ETHIOPIA  FINLAND  HONDURAS
## MINERALS                  0      0         0        0         0
```

```
## CRUDE_MATERIALS           0      0         0        0         0
## FOODS                     0      0         0        0         0
## MANUFACTURED_GOODS        0      0         0        1         0
## DIPLOMATIC_EXCHANGE       1      0         0        0         0
##                     INDONESIA  ISRAEL  JAPAN  LIBERIA  MADAGASCAR
## MINERALS                    0       0      1        0           0
## CRUDE_MATERIALS             0       0      0        0           0
## FOODS                       0       0      1        0           0
## MANUFACTURED_GOODS          0       0      1        0           0
## DIPLOMATIC_EXCHANGE         0       1      1        0           0
##                     NEW_ZEALAND  PAKISTAN  SPAIN  SWITZERLAND  SYRIA
## MINERALS                      0         0      0            0      0
## CRUDE_MATERIALS               0         0      1            0      0
## FOODS                         1         0      1            0      0
## MANUFACTURED_GOODS            0         0      1            1      0
## DIPLOMATIC_EXCHANGE           0         0      1            0      0
##                     THAILAND  UNITED_KINGDOM  UNITED_STATES  YUGOSLAVIA
## MINERALS                   0               0              1           0
## CRUDE_MATERIALS            0               0              1           0
## FOODS                      0               1              1           0
## MANUFACTURED_GOODS         0               1              1           0
## DIPLOMATIC_EXCHANGE        0               1              1           0
##
## , , INDONESIA
##
##                     ALGERIA  ARGENTINA  BRAZIL  CHINA  CZECHOSLOVAKIA
## MINERALS                  0          0       0      1               0
## CRUDE_MATERIALS           1          1       1      1               0
## FOODS                     0          1       1      1               0
## MANUFACTURED_GOODS        0          1       1      1               1
## DIPLOMATIC_EXCHANGE       1          1       1      0               1
##                     ECUADOR  EGYPT  ETHIOPIA  FINLAND  HONDURAS
## MINERALS                  0      0         0        0         0
## CRUDE_MATERIALS           0      1         0        1         0
## FOODS                     0      1         0        1         0
## MANUFACTURED_GOODS        0      0         0        1         0
## DIPLOMATIC_EXCHANGE       0      1         0        1         0
##                     INDONESIA  ISRAEL  JAPAN  LIBERIA  MADAGASCAR
## MINERALS                    0       0      1        0           0
## CRUDE_MATERIALS             0       0      1        0           0
## FOODS                       0       0      1        0           0
## MANUFACTURED_GOODS          0       0      1        0           0
## DIPLOMATIC_EXCHANGE         0       0      1        0           0
##                     NEW_ZEALAND  PAKISTAN  SPAIN  SWITZERLAND  SYRIA
## MINERALS                      0         0      0            1      0
## CRUDE_MATERIALS               1         1      1            1      0
## FOODS                         1         1      1            1      0
## MANUFACTURED_GOODS            1         1      1            1      0
## DIPLOMATIC_EXCHANGE           1         1      1            1      1
##                     THAILAND  UNITED_KINGDOM  UNITED_STATES  YUGOSLAVIA
## MINERALS                   0               1              1           0
## CRUDE_MATERIALS            1               1              1           0
## FOODS                      1               1              1           0
## MANUFACTURED_GOODS         1               1              1           1
```

```
## DIPLOMATIC_EXCHANGE         1               1              1          1
##
## , , ISRAEL
##
##                     ALGERIA  ARGENTINA  BRAZIL  CHINA  CZECHOSLOVAKIA
## MINERALS                  0          0       0      0               0
## CRUDE_MATERIALS           0          1       1      0               0
## FOODS                     0          1       1      0               0
## MANUFACTURED_GOODS        0          1       1      0               0
## DIPLOMATIC_EXCHANGE       0          1       1      0               0
##                     ECUADOR  EGYPT  ETHIOPIA  FINLAND  HONDURAS
## MINERALS                  0      0         0        1         0
## CRUDE_MATERIALS           0      1         1        1         0
## FOODS                     0      1         1        1         1
## MANUFACTURED_GOODS        0      0         0        1         0
## DIPLOMATIC_EXCHANGE       1      0         0        1         0
##                     INDONESIA  ISRAEL  JAPAN  LIBERIA  MADAGASCAR
## MINERALS                    0       0      0        0           0
## CRUDE_MATERIALS             0       0      1        1           0
## FOODS                       0       0      1        0           0
## MANUFACTURED_GOODS          0       0      1        0           0
## DIPLOMATIC_EXCHANGE         0       0      1        0           0
##                     NEW_ZEALAND  PAKISTAN  SPAIN  SWITZERLAND  SYRIA
## MINERALS                      0         0      0            1      0
## CRUDE_MATERIALS               1         0      1            1      0
## FOODS                         0         0      1            1      0
## MANUFACTURED_GOODS            0         0      1            1      0
## DIPLOMATIC_EXCHANGE           0         0      0            1      0
##                     THAILAND  UNITED_KINGDOM  UNITED_STATES  YUGOSLAVIA
## MINERALS                   0               1              1           1
## CRUDE_MATERIALS            1               1              1           1
## FOODS                      1               1              1           1
## MANUFACTURED_GOODS         1               1              1           1
## DIPLOMATIC_EXCHANGE        0               1              1           0
##
## , , JAPAN
##
##                     ALGERIA  ARGENTINA  BRAZIL  CHINA  CZECHOSLOVAKIA
## MINERALS                  1          0       0      1               0
## CRUDE_MATERIALS           0          1       1      1               0
## FOODS                     0          1       1      1               1
## MANUFACTURED_GOODS        1          1       1      1               1
## DIPLOMATIC_EXCHANGE       1          1       1      1               1
##                     ECUADOR  EGYPT  ETHIOPIA  FINLAND  HONDURAS
## MINERALS                  0      1         0        0         0
## CRUDE_MATERIALS           0      1         1        1         1
## FOODS                     1      0         1        1         1
## MANUFACTURED_GOODS        0      1         0        1         0
## DIPLOMATIC_EXCHANGE       1      1         1        1         1
##                     INDONESIA  ISRAEL  JAPAN  LIBERIA  MADAGASCAR
## MINERALS                    1       0      0        0           0
## CRUDE_MATERIALS             1       0      0        1           1
## FOODS                       1       1      0        0           1
## MANUFACTURED_GOODS          1       1      0        0           0
```

```
## DIPLOMATIC_EXCHANGE          1       1      0       1           1
##                     NEW_ZEALAND  PAKISTAN  SPAIN  SWITZERLAND  SYRIA
## MINERALS                      1         0      0            0      0
## CRUDE_MATERIALS               1         1      1            1      1
## FOODS                         1         1      1            1      0
## MANUFACTURED_GOODS            1         1      1            1      0
## DIPLOMATIC_EXCHANGE           1         1      1            1      1
##                     THAILAND  UNITED_KINGDOM  UNITED_STATES  YUGOSLAVIA
## MINERALS                   0               0              1           0
## CRUDE_MATERIALS            1               1              1           1
## FOODS                      1               1              1           1
## MANUFACTURED_GOODS         1               1              1           1
## DIPLOMATIC_EXCHANGE        1               1              1           1
##
## , , LIBERIA
##
##                     ALGERIA  ARGENTINA  BRAZIL  CHINA  CZECHOSLOVAKIA
## MINERALS                  0          0       1      0               0
## CRUDE_MATERIALS           0          0       0      0               0
## FOODS                     0          0       1      1               0
## MANUFACTURED_GOODS        0          0       1      1               1
## DIPLOMATIC_EXCHANGE       1          0       0      1               0
##                     ECUADOR  EGYPT  ETHIOPIA  FINLAND  HONDURAS
## MINERALS                  0      0         0        0         0
## CRUDE_MATERIALS           0      0         0        0         0
## FOODS                     0      0         0        0         0
## MANUFACTURED_GOODS        0      0         0        0         0
## DIPLOMATIC_EXCHANGE       0      1         1        0         0
##                     INDONESIA  ISRAEL  JAPAN  LIBERIA  MADAGASCAR
## MINERALS                    0       0      0        0           0
## CRUDE_MATERIALS             0       0      0        0           0
## FOODS                       0       0      1        0           0
## MANUFACTURED_GOODS          0       0      1        0           0
## DIPLOMATIC_EXCHANGE         0       1      1        0           0
##                     NEW_ZEALAND  PAKISTAN  SPAIN  SWITZERLAND  SYRIA
## MINERALS                      0         0      1            1      0
## CRUDE_MATERIALS               0         0      0            0      0
## FOODS                         0         0      1            1      0
## MANUFACTURED_GOODS            0         1      1            1      0
## DIPLOMATIC_EXCHANGE           0         0      1            1      0
##                     THAILAND  UNITED_KINGDOM  UNITED_STATES  YUGOSLAVIA
## MINERALS                   0               1              1           0
## CRUDE_MATERIALS            0               1              1           0
## FOODS                      0               1              1           0
## MANUFACTURED_GOODS         0               1              1           0
## DIPLOMATIC_EXCHANGE        0               1              1           0
##
## , , MADAGASCAR
##
##                     ALGERIA  ARGENTINA  BRAZIL  CHINA  CZECHOSLOVAKIA
## MINERALS                  0          0       0      1               0
## CRUDE_MATERIALS           0          0       1      0               0
## FOODS                     0          0       0      0               0
## MANUFACTURED_GOODS        0          0       0      1               0
```

```
## DIPLOMATIC_EXCHANGE        1          0       0      1              0
##                      ECUADOR  EGYPT  ETHIOPIA  FINLAND  HONDURAS
## MINERALS                   0      0         0        0         0
## CRUDE_MATERIALS            0      0         0        0         0
## FOODS                      0      0         0        0         0
## MANUFACTURED_GOODS         0      0         0        0         0
## DIPLOMATIC_EXCHANGE        0      1         0        0         0
##                      INDONESIA  ISRAEL  JAPAN  LIBERIA  MADAGASCAR
## MINERALS                     0       0      0        0           0
## CRUDE_MATERIALS              0       0      0        0           0
## FOODS                        0       0      1        0           0
## MANUFACTURED_GOODS           0       0      1        0           0
## DIPLOMATIC_EXCHANGE          1       0      1        0           0
##                      NEW_ZEALAND  PAKISTAN  SPAIN  SWITZERLAND  SYRIA
## MINERALS                       0         0      1            0      0
## CRUDE_MATERIALS                0         0      0            0      0
## FOODS                          0         0      0            1      0
## MANUFACTURED_GOODS             0         0      1            1      0
## DIPLOMATIC_EXCHANGE            0         0      0            1      0
##                      THAILAND  UNITED_KINGDOM  UNITED_STATES  YUGOSLAVIA
## MINERALS                    1               0              1           0
## CRUDE_MATERIALS             0               0              1           0
## FOODS                       1               1              1           0
## MANUFACTURED_GOODS          0               1              1           0
## DIPLOMATIC_EXCHANGE         0               1              1           0
##
## , , NEW_ZEALAND
##
##                      ALGERIA  ARGENTINA  BRAZIL  CHINA  CZECHOSLOVAKIA
## MINERALS                   0          0       0      1               0
## CRUDE_MATERIALS            0          0       1      1               0
## FOODS                      0          1       1      1               0
## MANUFACTURED_GOODS         0          0       1      1               1
## DIPLOMATIC_EXCHANGE        0          0       0      1               1
##                      ECUADOR  EGYPT  ETHIOPIA  FINLAND  HONDURAS
## MINERALS                   0      0         0        0         0
## CRUDE_MATERIALS            0      0         0        1         0
## FOODS                      1      0         0        0         0
## MANUFACTURED_GOODS         0      0         0        1         0
## DIPLOMATIC_EXCHANGE        0      1         0        0         0
##                      INDONESIA  ISRAEL  JAPAN  LIBERIA  MADAGASCAR
## MINERALS                     1       0      1        0           0
## CRUDE_MATERIALS              1       0      1        0           0
## FOODS                        1       1      1        0           0
## MANUFACTURED_GOODS           1       1      1        0           0
## DIPLOMATIC_EXCHANGE          1       1      1        0           0
##                      NEW_ZEALAND  PAKISTAN  SPAIN  SWITZERLAND  SYRIA
## MINERALS                       0         0      0            0      0
## CRUDE_MATERIALS                0         0      1            1      0
## FOODS                          0         1      1            1      0
## MANUFACTURED_GOODS             0         1      1            1      0
## DIPLOMATIC_EXCHANGE            0         0      0            1      0
##                      THAILAND  UNITED_KINGDOM  UNITED_STATES  YUGOSLAVIA
## MINERALS                    0               1              1           0
```

```
## CRUDE_MATERIALS             1               1              1          0
## FOODS                       1               1              1          0
## MANUFACTURED_GOODS          1               1              1          1
## DIPLOMATIC_EXCHANGE         1               1              1          1
##
## , , PAKISTAN
##
##                     ALGERIA  ARGENTINA  BRAZIL  CHINA  CZECHOSLOVAKIA
## MINERALS                  0          0       0      1               0
## CRUDE_MATERIALS           0          0       1      1               0
## FOODS                     0          1       1      1               0
## MANUFACTURED_GOODS        0          1       1      1               1
## DIPLOMATIC_EXCHANGE       1          1       1      1               1
##                     ECUADOR  EGYPT  ETHIOPIA  FINLAND  HONDURAS
## MINERALS                  0      0         0        0         0
## CRUDE_MATERIALS           0      1         0        1         0
## FOODS                     0      0         0        0         0
## MANUFACTURED_GOODS        0      0         0        1         0
## DIPLOMATIC_EXCHANGE       0      1         0        0         0
##                     INDONESIA  ISRAEL  JAPAN  LIBERIA  MADAGASCAR
## MINERALS                    0       0      1        0           0
## CRUDE_MATERIALS             1       0      1        1           0
## FOODS                       1       0      1        1           0
## MANUFACTURED_GOODS          1       0      1        0           0
## DIPLOMATIC_EXCHANGE         1       0      1        0           0
##                     NEW_ZEALAND  PAKISTAN  SPAIN  SWITZERLAND  SYRIA
## MINERALS                      0         0      1            0      0
## CRUDE_MATERIALS               1         0      1            1      0
## FOODS                         1         0      0            1      1
## MANUFACTURED_GOODS            1         0      1            1      0
## DIPLOMATIC_EXCHANGE           0         0      1            1      1
##                     THAILAND  UNITED_KINGDOM  UNITED_STATES  YUGOSLAVIA
## MINERALS                   0               1              1          0
## CRUDE_MATERIALS            1               1              1          1
## FOODS                      1               1              1          0
## MANUFACTURED_GOODS         1               1              1          1
## DIPLOMATIC_EXCHANGE        1               1              1          1
##
## , , SPAIN
##
##                     ALGERIA  ARGENTINA  BRAZIL  CHINA  CZECHOSLOVAKIA
## MINERALS                  1          1       0      1               0
## CRUDE_MATERIALS           1          1       1      1               1
## FOODS                     1          1       1      1               1
## MANUFACTURED_GOODS        0          1       1      1               1
## DIPLOMATIC_EXCHANGE       1          1       1      1               1
##                     ECUADOR  EGYPT  ETHIOPIA  FINLAND  HONDURAS
## MINERALS                  0      1         0        1         0
## CRUDE_MATERIALS           0      1         1        1         1
## FOODS                     1      0         1        1         1
## MANUFACTURED_GOODS        0      1         1        1         0
## DIPLOMATIC_EXCHANGE       1      1         0        1         1
##                     INDONESIA  ISRAEL  JAPAN  LIBERIA  MADAGASCAR
## MINERALS                    1       0      1        0           0
```

```
## CRUDE_MATERIALS             1       1      1        1           1
## FOODS                       1       1      1        1           1
## MANUFACTURED_GOODS          1       1      1        0           0
## DIPLOMATIC_EXCHANGE         1       0      1        0           0
##                     NEW_ZEALAND  PAKISTAN  SPAIN  SWITZERLAND  SYRIA
## MINERALS                      0         0      0            0      1
## CRUDE_MATERIALS               1         1      0            1      1
## FOODS                         1         0      0            1      0
## MANUFACTURED_GOODS            1         1      0            1      0
## DIPLOMATIC_EXCHANGE           0         1      0            1      1
##                     THAILAND  UNITED_KINGDOM  UNITED_STATES  YUGOSLAVIA
## MINERALS                   0               1              1           1
## CRUDE_MATERIALS            1               1              1           1
## FOODS                      1               1              1           1
## MANUFACTURED_GOODS         1               1              1           1
## DIPLOMATIC_EXCHANGE        1               1              1           1
##
## , , SWITZERLAND
##
##                     ALGERIA  ARGENTINA  BRAZIL  CHINA  CZECHOSLOVAKIA
## MINERALS                  1          0       0      0               1
## CRUDE_MATERIALS           0          1       1      1               1
## FOODS                     0          1       1      1               1
## MANUFACTURED_GOODS        0          1       1      1               1
## DIPLOMATIC_EXCHANGE       1          1       1      1               1
##                     ECUADOR  EGYPT  ETHIOPIA  FINLAND  HONDURAS
## MINERALS                  0      0         0        0         0
## CRUDE_MATERIALS           0      1         1        1         1
## FOODS                     1      1         1        1         1
## MANUFACTURED_GOODS        0      1         0        1         0
## DIPLOMATIC_EXCHANGE       1      1         0        1         0
##                     INDONESIA  ISRAEL  JAPAN  LIBERIA  MADAGASCAR
## MINERALS                    0       0      0        0           0
## CRUDE_MATERIALS             1       1      1        1           0
## FOODS                       1       1      1        0           1
## MANUFACTURED_GOODS          1       1      1        0           0
## DIPLOMATIC_EXCHANGE         1       1      1        0           0
##                     NEW_ZEALAND  PAKISTAN  SPAIN  SWITZERLAND  SYRIA
## MINERALS                      0         0      0            0      0
## CRUDE_MATERIALS               1         1      1            0      0
## FOODS                         1         1      1            0      0
## MANUFACTURED_GOODS            0         1      1            0      0
## DIPLOMATIC_EXCHANGE           0         1      1            0      0
##                     THAILAND  UNITED_KINGDOM  UNITED_STATES  YUGOSLAVIA
## MINERALS                   0               1              1           1
## CRUDE_MATERIALS            1               1              1           1
## FOODS                      1               1              1           1
## MANUFACTURED_GOODS         1               1              1           1
## DIPLOMATIC_EXCHANGE        1               1              1           1
##
## , , SYRIA
##
##                     ALGERIA  ARGENTINA  BRAZIL  CHINA  CZECHOSLOVAKIA
## MINERALS                  1          0       0      0               0
```

```
## CRUDE_MATERIALS           0          0       0      0              1
## FOODS                     0          1       1      1              1
## MANUFACTURED_GOODS        0          0       1      1              1
## DIPLOMATIC_EXCHANGE       1          1       1      1              1
##                     ECUADOR  EGYPT  ETHIOPIA  FINLAND  HONDURAS
## MINERALS                  0      0         0        0         0
## CRUDE_MATERIALS           0      0         1        0         0
## FOODS                     0      0         0        1         1
## MANUFACTURED_GOODS        0      0         0        1         0
## DIPLOMATIC_EXCHANGE       0      0         0        0         0
##                     INDONESIA  ISRAEL  JAPAN  LIBERIA  MADAGASCAR
## MINERALS                    0       0      0        0           0
## CRUDE_MATERIALS             0       0      1        1           0
## FOODS                       0       0      1        0           0
## MANUFACTURED_GOODS          0       0      1        0           0
## DIPLOMATIC_EXCHANGE         1       0      1        0           0
##                     NEW_ZEALAND  PAKISTAN  SPAIN  SWITZERLAND  SYRIA
## MINERALS                      0         0      1            0      0
## CRUDE_MATERIALS               1         0      1            1      0
## FOODS                         1         0      1            1      0
## MANUFACTURED_GOODS            0         1      1            1      0
## DIPLOMATIC_EXCHANGE           0         1      1            1      0
##                     THAILAND  UNITED_KINGDOM  UNITED_STATES  YUGOSLAVIA
## MINERALS                   0               1              1           1
## CRUDE_MATERIALS            0               1              1           1
## FOODS                      1               1              1           1
## MANUFACTURED_GOODS         1               1              1           1
## DIPLOMATIC_EXCHANGE        0               1              1           1
##
## , , THAILAND
##
##                     ALGERIA  ARGENTINA  BRAZIL  CHINA  CZECHOSLOVAKIA
## MINERALS                  0          0       0      1              0
## CRUDE_MATERIALS           0          1       1      1              0
## FOODS                     0          1       1      1              1
## MANUFACTURED_GOODS        0          1       1      1              1
## DIPLOMATIC_EXCHANGE       0          1       1      1              0
##                     ECUADOR  EGYPT  ETHIOPIA  FINLAND  HONDURAS
## MINERALS                  0      0         0        0         0
## CRUDE_MATERIALS           0      1         0        1         0
## FOODS                     0      0         0        1         0
## MANUFACTURED_GOODS        0      0         0        1         0
## DIPLOMATIC_EXCHANGE       0      1         0        1         0
##                     INDONESIA  ISRAEL  JAPAN  LIBERIA  MADAGASCAR
## MINERALS                    1       0      1        0           0
## CRUDE_MATERIALS             1       0      1        0           0
## FOODS                       1       1      1        0           0
## MANUFACTURED_GOODS          1       1      1        0           0
## DIPLOMATIC_EXCHANGE         1       1      1        0           0
##                     NEW_ZEALAND  PAKISTAN  SPAIN  SWITZERLAND  SYRIA
## MINERALS                      0         1      0            0      0
## CRUDE_MATERIALS               1         1      1            1      0
## FOODS                         1         0      1            1      0
## MANUFACTURED_GOODS            1         1      1            1      0
```

```
## DIPLOMATIC_EXCHANGE           1         1      1            1      0
##                     THAILAND  UNITED_KINGDOM  UNITED_STATES  YUGOSLAVIA
## MINERALS                   0               1              1           0
## CRUDE_MATERIALS            0               1              1           1
## FOODS                      0               1              1           0
## MANUFACTURED_GOODS         0               1              1           1
## DIPLOMATIC_EXCHANGE        0               1              1           1
##
## , , UNITED_KINGDOM
##
##                     ALGERIA  ARGENTINA  BRAZIL  CHINA  CZECHOSLOVAKIA
## MINERALS                  1          0       1      0               0
## CRUDE_MATERIALS           0          0       1      1               1
## FOODS                     0          0       1      1               1
## MANUFACTURED_GOODS        0          0       1      1               1
## DIPLOMATIC_EXCHANGE       1          0       1      1               1
##                     ECUADOR  EGYPT  ETHIOPIA  FINLAND  HONDURAS
## MINERALS                  0      1         0        1         0
## CRUDE_MATERIALS           1      1         1        1         1
## FOODS                     1      1         1        1         1
## MANUFACTURED_GOODS        0      1         1        1         0
## DIPLOMATIC_EXCHANGE       1      1         1        1         1
##                     INDONESIA  ISRAEL  JAPAN  LIBERIA  MADAGASCAR
## MINERALS                    1       0      1        0           0
## CRUDE_MATERIALS             1       1      1        1           1
## FOODS                       1       1      1        0           0
## MANUFACTURED_GOODS          1       1      1        0           1
## DIPLOMATIC_EXCHANGE         1       1      1        1           0
##                     NEW_ZEALAND  PAKISTAN  SPAIN  SWITZERLAND  SYRIA
## MINERALS                      0         0      1            1      1
## CRUDE_MATERIALS               1         1      1            1      1
## FOODS                         1         1      1            1      0
## MANUFACTURED_GOODS            1         1      1            1      0
## DIPLOMATIC_EXCHANGE           1         1      1            1      1
##                     THAILAND  UNITED_KINGDOM  UNITED_STATES  YUGOSLAVIA
## MINERALS                   0               0              1           0
## CRUDE_MATERIALS            1               0              1           1
## FOODS                      1               0              1           1
## MANUFACTURED_GOODS         1               0              1           1
## DIPLOMATIC_EXCHANGE        1               0              1           1
##
## , , UNITED_STATES
##
##                     ALGERIA  ARGENTINA  BRAZIL  CHINA  CZECHOSLOVAKIA
## MINERALS                  1          1       1      1               0
## CRUDE_MATERIALS           0          1       1      1               0
## FOODS                     0          1       1      1               1
## MANUFACTURED_GOODS        0          1       1      1               1
## DIPLOMATIC_EXCHANGE       1          1       1      1               1
##                     ECUADOR  EGYPT  ETHIOPIA  FINLAND  HONDURAS
## MINERALS                  1      1         0        1         0
## CRUDE_MATERIALS           1      1         1        1         1
## FOODS                     1      1         1        1         1
## MANUFACTURED_GOODS        1      1         0        1         1
```

```
## DIPLOMATIC_EXCHANGE        1      1         1        1         1
##                      INDONESIA  ISRAEL  JAPAN  LIBERIA  MADAGASCAR
## MINERALS                     1       0      1        0           0
## CRUDE_MATERIALS              1       1      1        1           1
## FOODS                        1       1      1        1           1
## MANUFACTURED_GOODS           1       1      1        0           0
## DIPLOMATIC_EXCHANGE          1       1      1        1           1
##                      NEW_ZEALAND  PAKISTAN  SPAIN  SWITZERLAND  SYRIA
## MINERALS                       0         0      1            0      0
## CRUDE_MATERIALS                1         1      1            1      0
## FOODS                          1         1      1            1      0
## MANUFACTURED_GOODS             1         1      1            1      0
## DIPLOMATIC_EXCHANGE            1         1      1            1      1
##                      THAILAND  UNITED_KINGDOM  UNITED_STATES  YUGOSLAVIA
## MINERALS                    1               1              0           1
## CRUDE_MATERIALS             1               1              0           1
## FOODS                       1               1              0           1
## MANUFACTURED_GOODS          1               1              0           1
## DIPLOMATIC_EXCHANGE         1               1              0           1
##
## , , YUGOSLAVIA
##
##                      ALGERIA  ARGENTINA  BRAZIL  CHINA  CZECHOSLOVAKIA
## MINERALS                   1          0       0      0               1
## CRUDE_MATERIALS            1          1       1      1               1
## FOODS                      0          1       1      0               1
## MANUFACTURED_GOODS         1          0       1      1               1
## DIPLOMATIC_EXCHANGE        1          1       1      1               1
##                      ECUADOR  EGYPT  ETHIOPIA  FINLAND  HONDURAS
## MINERALS                   0      1         0        0         0
## CRUDE_MATERIALS            0      1         0        1         1
## FOODS                      1      0         0        1         1
## MANUFACTURED_GOODS         0      1         0        1         0
## DIPLOMATIC_EXCHANGE        1      1         1        1         0
##                      INDONESIA  ISRAEL  JAPAN  LIBERIA  MADAGASCAR
## MINERALS                     0       0      0        1           0
## CRUDE_MATERIALS              1       1      1        1           0
## FOODS                        1       1      0        0           0
## MANUFACTURED_GOODS           1       1      1        0           0
## DIPLOMATIC_EXCHANGE          1       0      1        0           0
##                      NEW_ZEALAND  PAKISTAN  SPAIN  SWITZERLAND  SYRIA
## MINERALS                       0         0      1            1      0
## CRUDE_MATERIALS                1         0      1            1      1
## FOODS                          0         0      1            1      0
## MANUFACTURED_GOODS             1         0      1            1      0
## DIPLOMATIC_EXCHANGE            0         1      1            1      1
##                      THAILAND  UNITED_KINGDOM  UNITED_STATES  YUGOSLAVIA
## MINERALS                    0               1              1           0
## CRUDE_MATERIALS             1               1              1           0
## FOODS                       0               1              1           0
## MANUFACTURED_GOODS          1               1              1           0
## DIPLOMATIC_EXCHANGE         1               1              1           0
```

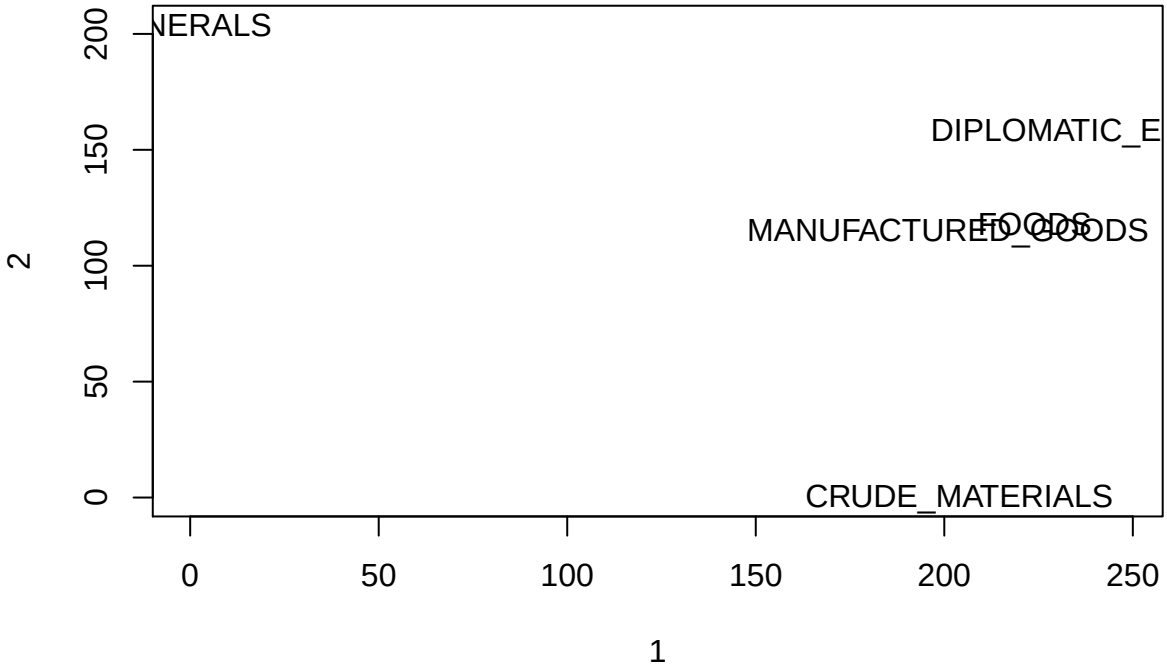
(a) Clustering

Show a hierarchical clustering of the trade networks, based on the Hamming distance. Compare this with a two-dimensional MDS solution on the same data.

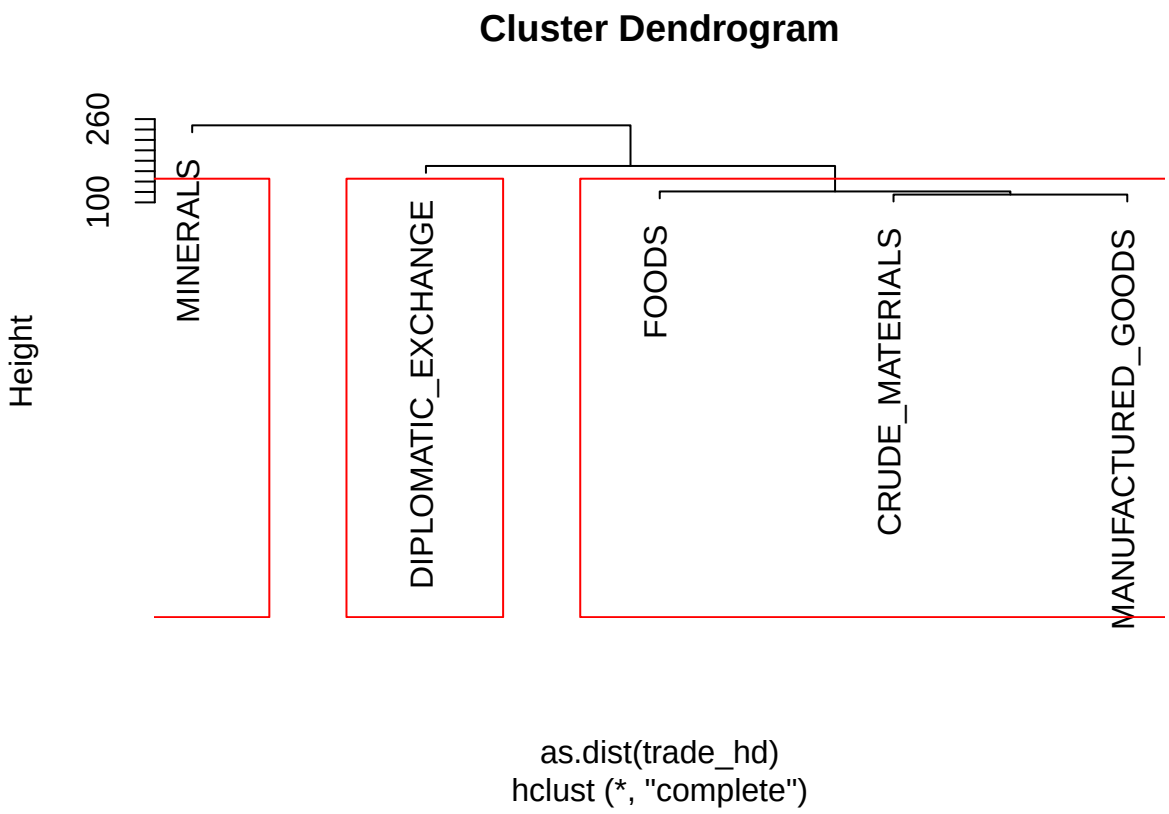
```
#calculate the hamming distance of trade data
trade_hd<-hdist(trade)
trade_hd
```

```
##     1   2   3   4   5
## 1   0 204 224 201 248
## 2 204   0 118 115 158
## 3 224 118   0 121 170
## 4 201 115 121   0 127
## 5 248 158 170 127   0
```

```
#calculate the mds solution and plot it
trade_mds<-trade_hd
plot(trade_mds,type="n")                                    # Plot the results
text(trade_mds,label=rownames(trade))
```




```
#cluster the trade data based on the values and plot a dendrogram
trade_hc<-hclust(as.dist(trade_hd))
plot(trade_hc,labels=rownames(trade))
rect.hclust(trade_hc, k=3)
```



(b) PCA

Conduct a PCA on the trade networks. How many dimensions are needed to account for the bulk of the variation in these networks? Try using a scree plot to help with this question. Plot the loadings on the first two components; what does this suggest about the undering relationships among the trade networks?

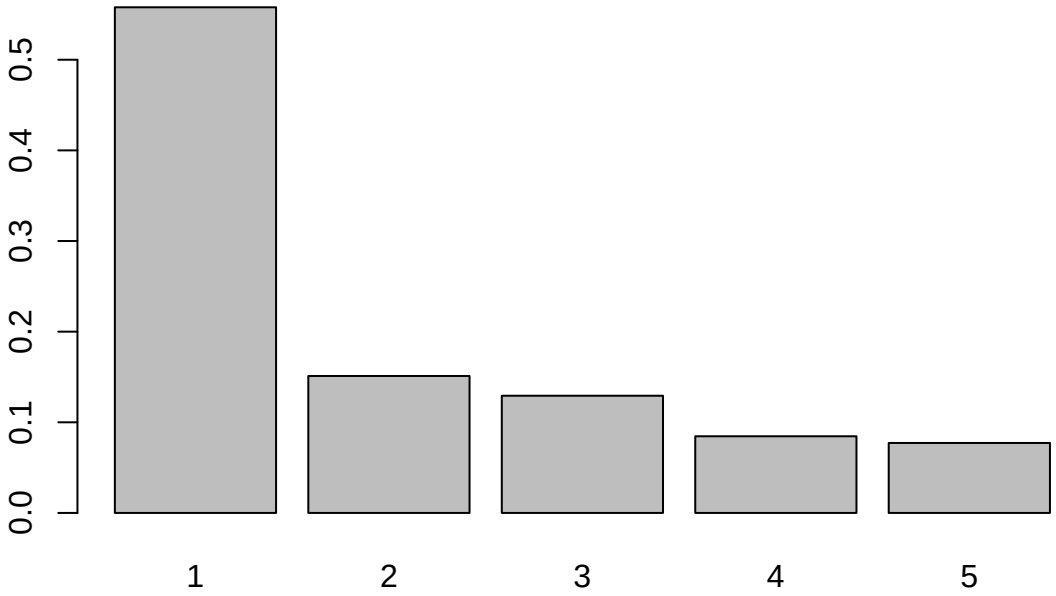
```
# calculate the correlation of the trade network
trade_cor<-gcor(trade)
trade_cor
```

```
##           1         2         3         4         5
## 1 1.0000000 0.3725626 0.2877321 0.3922966 0.3380220
## 2 0.3725626 1.0000000 0.5670013 0.5775224 0.4165298
## 3 0.2877321 0.5670013 1.0000000 0.5554769 0.3700570
## 4 0.3922966 0.5775224 0.5554769 1.0000000 0.5333617
## 5 0.3380220 0.4165298 0.3700570 0.5333617 1.0000000
```

```
# calculate the eigenvector values of the trade network
trade_eig<-eigen(trade_cor)
evals<-trade_eig$value                                    # Extract eigenvalues
evals/sum(evals)                                         # Variance explained
```

```
## [1] 0.55785530 0.15109490 0.12929625 0.08457135 0.07718221
```

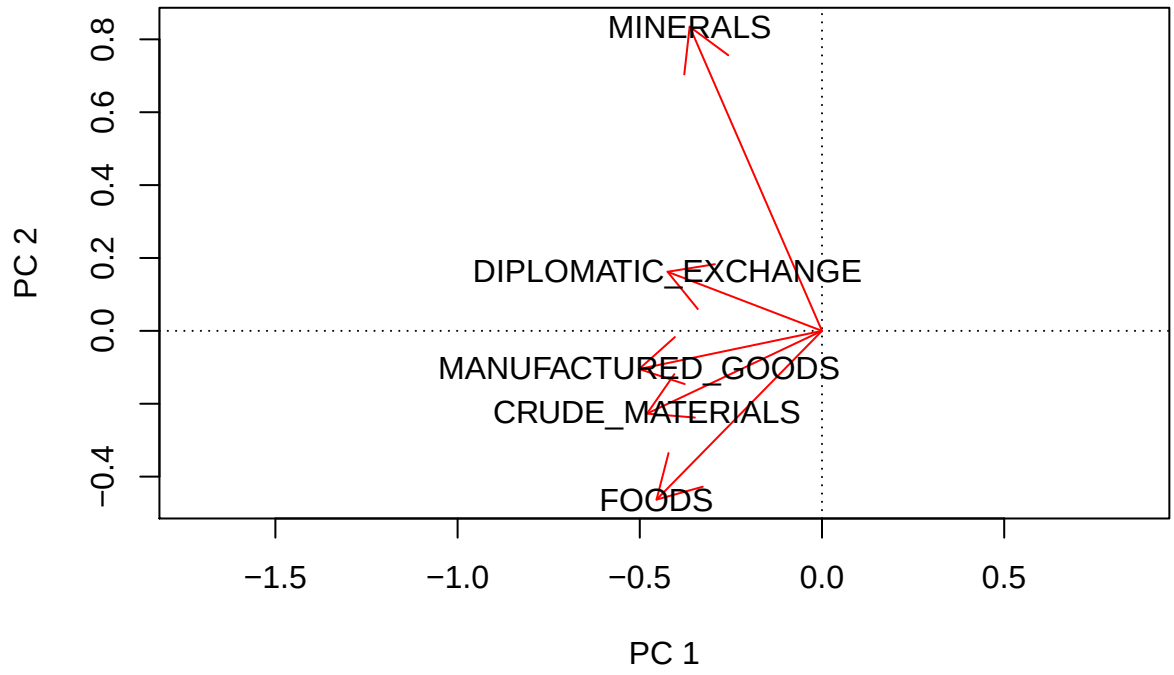
```r
barplot(evals/sum(evals),names.arg=1:length(evals))       #screenplot
```




```r
load<-trade_eig$vector[,1:2]
rownames(load)<-rownames(trade)
load
```

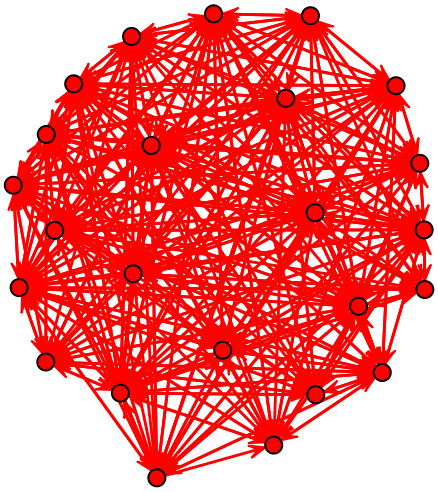
```
##                            [,1]       [,2]
## MINERALS             -0.3630871  0.8347337
## CRUDE_MATERIALS      -0.4801280 -0.2271629
## FOODS                -0.4540009 -0.4629607
## MANUFACTURED_GOODS   -0.5018676 -0.1047656
## DIPLOMATIC_EXCHANGE -0.4238597  0.1621982
```

```r
plot(load[,1:2],type="n",asp=1,xlab="PC 1",ylab="PC 2")
abline(h=0,v=0,lty=3)
arrows(0,0,load[,1],load[,2],col=2)          # Should be read angularly!
text(load[,1:2],label=rownames(trade))
```




```
S1<-apply(sweep(as.sociomatrix.sna(trade),1,load[,1],"*"),c(2,3),sum)
S2<-apply(sweep(as.sociomatrix.sna(trade),1,load[,2],"*"),c(2,3),sum)

coord<-gplot.layout.fruchtermanreingold(as.edgelist.sna(S1>0),NULL)
gplot(S1!=0,edge.col=sign(S1)+3,coord=coord)
```



- The variance of the network can be explained by only a single dimension of the nework,which is the trade in minerals value

(c) Discussion

Compare your PCA results to those obtained using MDS. In what ways are they similar? Different?

- The results obtained in MDS shows that the Minerals dimension is pretty far away from all the other dimensions and thus it is unique. This can possibly be reinforced by the values that are obtained from the PCA results, which shows that maximum variance of the trade network can be explained by the Minerals dimension.