Statistical Data Analysis of US Economic Data

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libraries

```
library(psych)
```

```
## Warning: package 'psych' was built under R version 4.2.3
```

```
library(CCA)
```

```
## Warning: package 'CCA' was built under R version 4.2.3
```

```
## Loading required package: fda
```

```
## Warning: package 'fda' was built under R version 4.2.3
```

```
## Loading required package: splines
```

```
## Loading required package: fds
```

```
## Warning: package 'fds' was built under R version 4.2.3
```

```
## Loading required package: rainbow
```

```
## Warning: package 'rainbow' was built under R version 4.2.3
```

```
## Loading required package: MASS
```

```
## Loading required package: pcaPP
```

```
## Warning: package 'pcaPP' was built under R version 4.2.3
```

```
## Loading required package: RCurl
```

```
## Warning: package 'RCurl' was built under R version 4.2.3
```

```
## Loading required package: deSolve
```

```
## Warning: package 'deSolve' was built under R version 4.2.3
```

```
##
## Attaching package: 'fda'
```

```
## The following object is masked from 'package:graphics':
##
##     matplot
```

```
## Loading required package: fields
```

```
## Warning: package 'fields' was built under R version 4.2.3
```

```
## Loading required package: spam
```

```
## Warning: package 'spam' was built under R version 4.2.3
```

```
## Spam version 2.9-1 (2022-08-07) is loaded.
## Type 'help( Spam)' or 'demo( spam)' for a short introduction
## and overview of this package.
## Help for individual functions is also obtained by adding the
## suffix '.spam' to the function name, e.g. 'help( chol.spam)'.
```

```
##
## Attaching package: 'spam'
```

```
## The following objects are masked from 'package:base':
##
##     backsolve, forwardsolve
```

```
## Loading required package: viridis
```

```
## Warning: package 'viridis' was built under R version 4.2.3
```

```
## Loading required package: viridisLite
```

```
##
## Try help(fields) to get started.
```

```
##
## Attaching package: 'fields'
```

```
## The following object is masked from 'package:psych':
##
##     describe
```

```
library(scatterplot3d)
```

```
## Warning: package 'scatterplot3d' was built under R version 4.2.3
```

```r
library(dplyr)
```

```
##
## Attaching package: 'dplyr'
```

```
## The following object is masked from 'package:MASS':
##
##     select
```

```
## The following objects are masked from 'package:stats':
##
##     filter, lag
```

```
## The following objects are masked from 'package:base':
##
##     intersect, setdiff, setequal, union
```

loading the data

```r
places = read.csv(file.choose(), header = T)
#places
```

Summary statistics

```r
summary(places)
```

```
##    Climate           HousingCost      HlthCare         Crime
##  Length:329         Min.   :105.0   Min.   : 5159   Min.   :  43
##  Class :character   1st Qu.:480.0   1st Qu.: 6760   1st Qu.: 583
##  Mode  :character   Median :542.0   Median : 7877   Median : 833
##                     Mean   :538.7   Mean   : 8347   Mean   :1186
##                     3rd Qu.:592.0   3rd Qu.: 9015   3rd Qu.:1445
##                     Max.   :910.0   Max.   :23640   Max.   :7850
##      Transp            Educ           Arts          Recreat           Econ
##  Min.   : 308.0   Min.   :1145   Min.   :1701   Min.   :   52   Min.   : 300
##  1st Qu.: 707.0   1st Qu.:3141   1st Qu.:2619   1st Qu.:  778   1st Qu.:1316
##  Median : 947.0   Median :4080   Median :2794   Median : 1871   Median :1670
##  Mean   : 961.1   Mean   :4210   Mean   :2815   Mean   : 3151   Mean   :1846
##  3rd Qu.:1156.0   3rd Qu.:5205   3rd Qu.:3012   3rd Qu.: 3844   3rd Qu.:2176
##  Max.   :2498.0   Max.   :8625   Max.   :3781   Max.   :56745   Max.   :4800
##     CaseNum          Long          Lat                 Pop
##  Min.   :3045   Min.   :  1   Min.   :-127.20   Min.   :25.65
##  1st Qu.:4842   1st Qu.: 83   1st Qu.: -96.69   1st Qu.:34.22
##  Median :5384   Median :165   Median : -86.81   Median :39.65
##  Mean   :5525   Mean   :165   Mean   : -90.18   Mean   :38.18
##  3rd Qu.:6113   3rd Qu.:247   3rd Qu.: -80.01   3rd Qu.:41.82
##  Max.   :9980   Max.   :329   Max.   : -68.77   Max.   :48.88
##      StNum              X
##  Min.   :  62820   Min.   : 1.00
##  1st Qu.: 132866   1st Qu.:11.00
##  Median : 241617   Median :25.00
##  Mean   : 522118   Mean   :25.64
##  3rd Qu.: 515259   3rd Qu.:39.00
##  Max.   :8274961   Max.   :51.00
```

```
city_names = places[,1]
```

Data Transformation

```
data_log = places
data_log[,c(2,3,4,5,7,8,9)] = log(data_log[,c(2,3,4,5,7,8,9)])
```

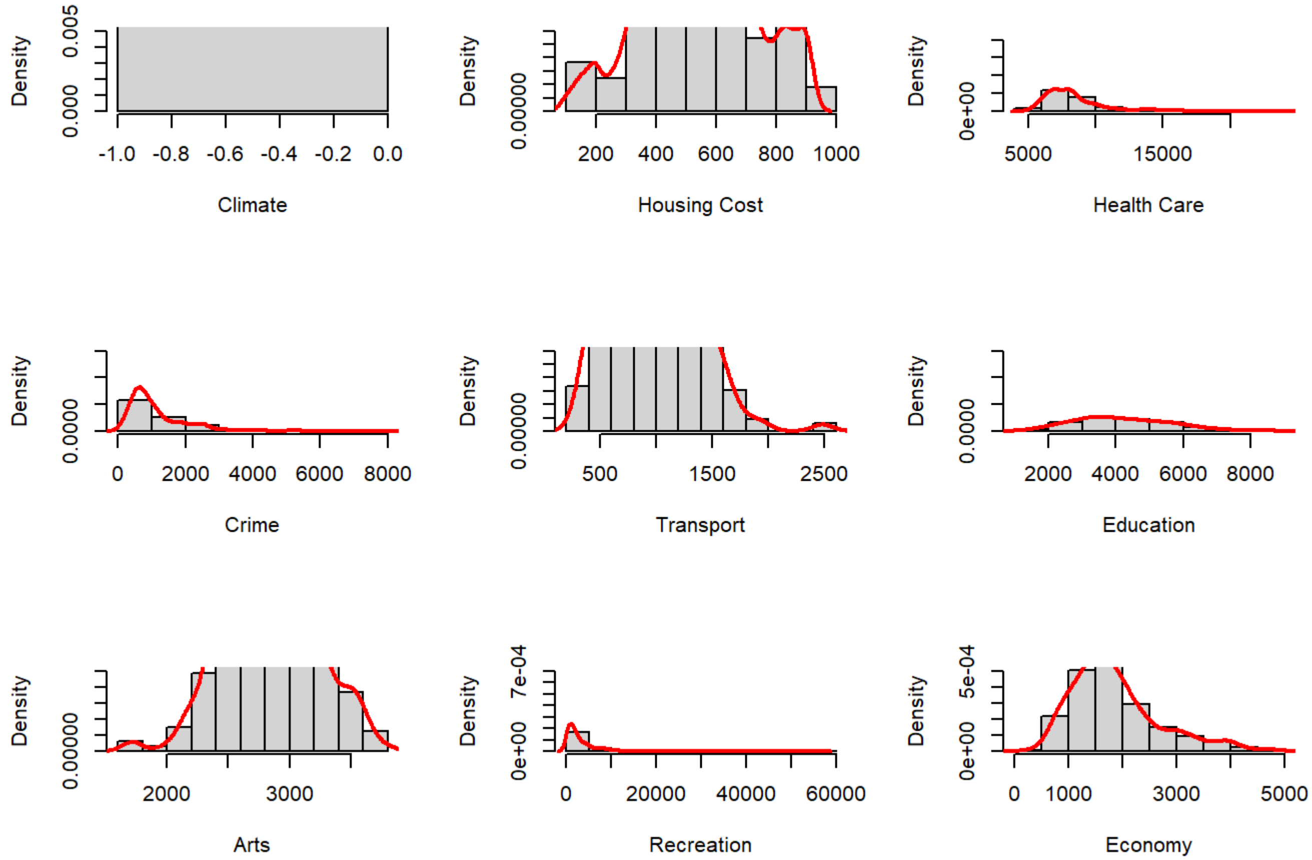
Visualisation

1. Untransformed Data

```
par(mfrow=c(3,3))
places$Climate <- as.numeric(places$Climate)
```

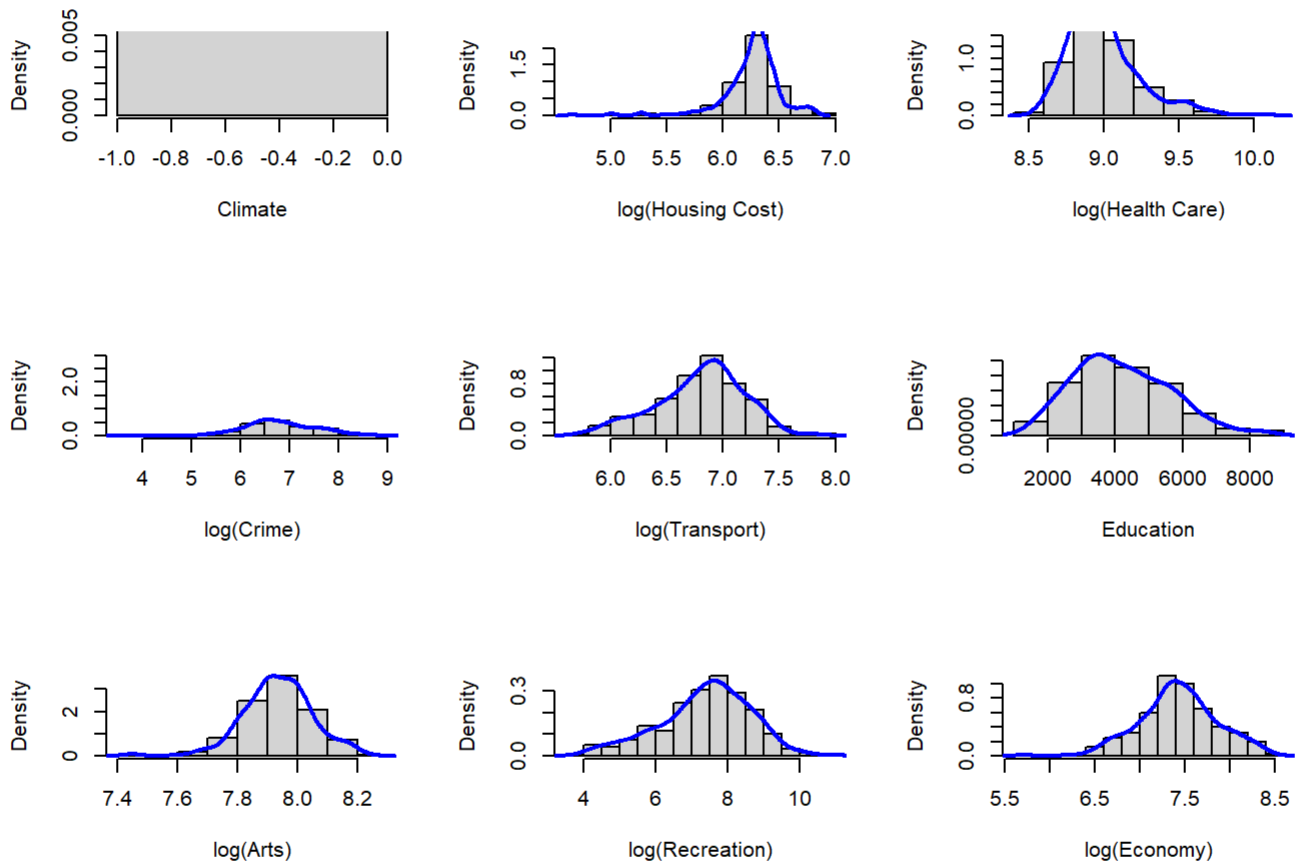
```
## Warning: NAs introduced by coercion
```

```
places$Climate[is.na(places$Climate)] <- 0

hist(places$Climate, prob = TRUE, ylim = c(0, 0.005), main = NA, xlab = "Climate")
lines(density(places[,1]),col="red",lwd=2)

hist(places[,2],prob=TRUE,ylim = c(0,0.0003),main = NA,xlab = "Housing Cost")
lines(density(places[,2]),col="red",lwd=2)

hist(places[,3],prob=TRUE,ylim = c(0,0.0009),main = NA,xlab = "Health Care")
lines(density(places[,3]),col="red",lwd=2)

hist(places[,4],prob=TRUE,ylim = c(0,0.0015),main = NA,xlab = "Crime")
lines(density(places[,4]),col="red",lwd=2)

hist(places[,5],prob=TRUE,ylim = c(0,0.0003),main = NA,xlab = "Transport")
lines(density(places[,5]),col="red",lwd=2)

hist(places[,6],prob=TRUE,ylim = c(0,0.0015),main = NA,xlab = "Education")
lines(density(places[,6]),col="red",lwd=2)

hist(places[,7],prob=TRUE,ylim = c(0,0.00025),main = NA,xlab = "Arts")
lines(density(places[,7]),col="red",lwd=2)

hist(places[,8],prob=TRUE,ylim = c(0,0.0007),main = NA,xlab = "Recreation")
lines(density(places[,8]),col="red",lwd=2)

hist(places[,9],prob=TRUE,ylim = c(0,0.0005),main = NA,xlab = "Economy")
lines(density(places[,9]),col="red",lwd=2)
```



2. Transformed data

```
par(mfrow=c(3,3))
places$Climate <- as.numeric(places$Climate)
hist(places$Climate, prob = TRUE, ylim = c(0, 0.005), main = NA, xlab = "Climate")
lines(density(places$Climate), col = "blue", lwd = 2)

hist(data_log[,2],prob=TRUE,main = NA,xlab = "log(Housing Cost)")
lines(density(data_log[,2]),col="blue",lwd=2)

hist(data_log[,3],prob=TRUE,main = NA,ylim = c(0,1.4),xlab = "log(Health Care)")
lines(density(data_log[,3]),col="blue",lwd=2)

hist(data_log[,4],prob=TRUE,main = NA,ylim= c(0,3),xlab = "log(Crime)")
lines(density(data_log[,4]),col="blue",lwd=2)

hist(data_log[,5],prob=TRUE,main = NA,xlab = "log(Transport)")
lines(density(data_log[,5]),col="blue",lwd=2)

hist(data_log[,6],prob=TRUE,main = NA,xlab = "Education")
lines(density(data_log[,6]),col="blue",lwd=2)

hist(data_log[,7],prob=TRUE,main = NA,xlab = "log(Arts)")
lines(density(data_log[,7]),col="blue",lwd=2)

hist(data_log[,8],prob=TRUE,main = NA,xlab = "log(Recreation)")
lines(density(data_log[,8]),col="blue",lwd=2)

hist(data_log[,9],prob=TRUE,main = NA,xlab = "log(Economy)")
lines(density(data_log[,9]),col="blue",lwd=2)
```



colnames and rownames for the log transformed data

```
colnames(data_log) = c("Climate", "HousingCost", "HlthCare","Crime","Transp","Educ","Arts", "Recreat","Econ")
rownames(data_log) = city_names
```

Correlation matrix

```
data_log$Climate <- as.numeric(data_log$Climate)
```

```
## Warning: NAs introduced by coercion
```

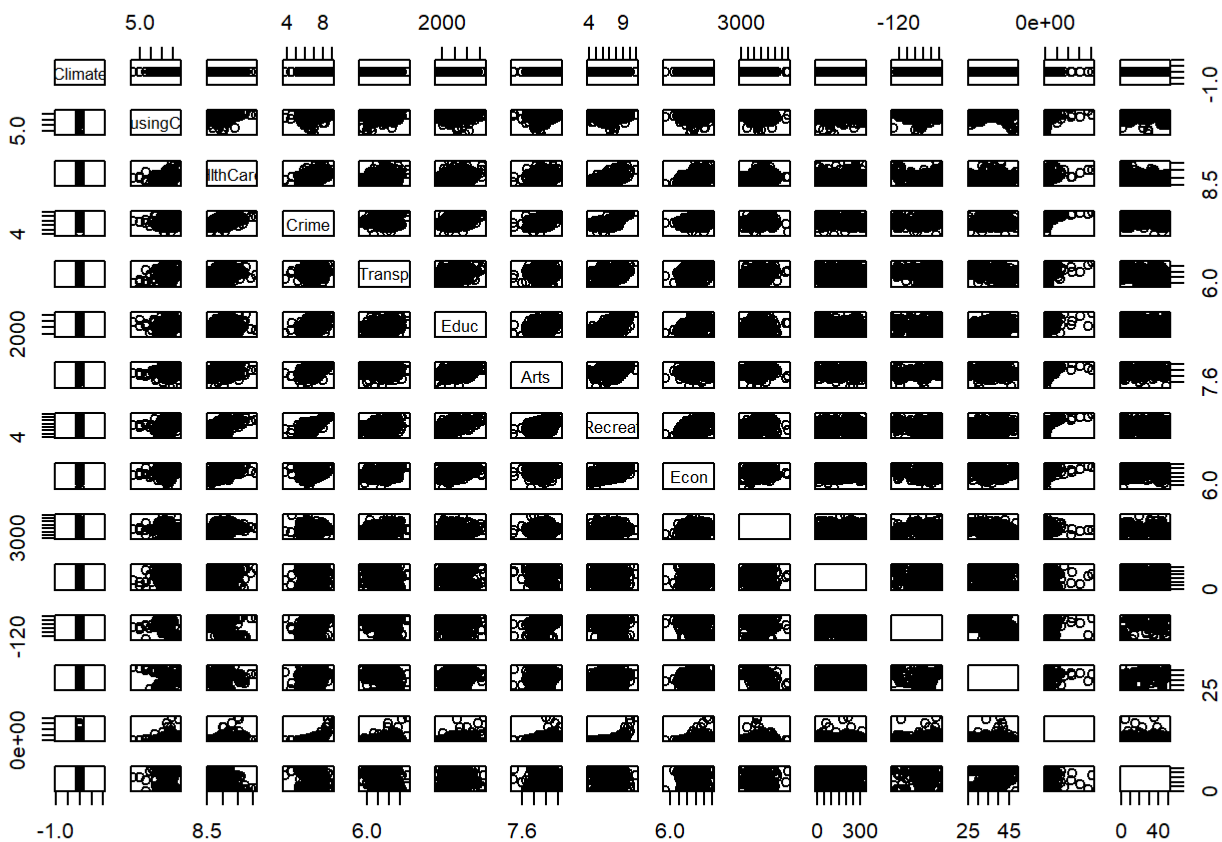
```
data_log$Educ <- as.numeric(data_log$Educ)

data_log[is.na(data_log)] <- 0

cor(data_log)
```

```
## Warning in cor(data_log): the standard deviation is zero
```

```
##              Climate HousingCost    HlthCare        Crime      Transp
## Climate            1          NA          NA           NA          NA
## HousingCost       NA  1.00000000  0.27296448  0.150560853  0.22775093
## HlthCare          NA  0.27296448  1.00000000  0.431935493  0.13923425
## Crime             NA  0.15056085  0.43193549  1.000000000  0.18362455
## Transp            NA  0.22775093  0.13923425  0.183624550  1.00000000
## Educ              NA  0.03424105  0.32428769  0.447394137  0.27559314
## Arts              NA  0.07745819  0.20208781  0.464763552  0.05550755
## Recreat           NA  0.17268298  0.50850131  0.678128621  0.34646165
## Econ              NA  0.12060965  0.46069631  0.254036198  0.29212402
## <NA>              NA -0.10429920  0.29032351  0.022621537  0.26817467
## <NA>              NA  0.09501600  0.09298513  0.003321376  0.03831948
## <NA>              NA -0.11705350 -0.14638998  0.255328567 -0.24881019
## <NA>              NA -0.05381434  0.20935822  0.149400615 -0.40815361
## <NA>              NA  0.20809655  0.34544939  0.594585830  0.34113491
## <NA>              NA -0.06505669 -0.22173325 -0.080638875 -0.22292407
##                    Educ       Arts     Recreat         Econ          <NA>
## Climate              NA         NA          NA           NA            NA
## HousingCost  0.03424105 0.07745819  0.17268298  0.12060965 -0.1042991959
## HlthCare     0.32428769 0.20208781  0.50850131  0.46069631  0.2903235124
## Crime        0.44739414 0.46476355  0.67812862  0.25403620  0.0226215370
## Transp       0.27559314 0.05550755  0.34646165  0.29212402  0.2681746726
## Educ         1.00000000 0.32230122  0.55233967  0.39390231  0.0592467535
## Arts         0.32230122 1.00000000  0.34789851  0.09300112  0.1154994504
## Recreat      0.55233967 0.34789851  1.00000000  0.49651912  0.1068522007
## Econ         0.39390231 0.09300112  0.49651912  1.00000000  0.1722302876
## <NA>         0.05924675 0.11549945  0.10685220  0.17223029  1.0000000000
## <NA>        -0.01130171 0.01554301  0.02753837  0.05853543  0.0096770315
## <NA>        -0.06147827 0.35253448 -0.03294129 -0.20169841  0.0005405777
## <NA>         0.22012207 0.08817433  0.11673024  0.02915801 -0.3974000570
## <NA>         0.40221425 0.33969890  0.56653959  0.34528737  0.0597583731
## <NA>        -0.01292504 0.12302572 -0.05281775 -0.08809709 -0.0766658507
##                     <NA>          <NA>        <NA>         <NA>        <NA>
## Climate               NA            NA          NA           NA          NA
## HousingCost  0.095015998 -0.1170534964 -0.05381434  0.208096552 -0.06505669
## HlthCare     0.092985132 -0.1463899813  0.20935822  0.345449386 -0.22173325
## Crime        0.003321376  0.2553285672  0.14940062  0.594585830 -0.08063887
## Transp       0.038319477 -0.2488101862 -0.40815361  0.341134909 -0.22292407
## Educ        -0.011301715 -0.0614782729  0.22012207  0.402214251 -0.01292504
```

```
## Arts         0.015543006  0.3525344776  0.08817433  0.339698897  0.12302572
## Recreat      0.027538373 -0.0329412907  0.11673024  0.566539594 -0.05281775
## Econ         0.058535433 -0.2016984139  0.02915801  0.345287369 -0.08809709
## <NA>         0.009677032  0.0005405777 -0.39740006  0.059758373 -0.07666585
## <NA>         1.000000000 -0.1074371900  0.03843321  0.014569723  0.01094864
## <NA>        -0.107437190  1.0000000000  0.02150614  0.000803367  0.07537326
## <NA>         0.038433206  0.0215061428  1.00000000 -0.012937948  0.18525107
## <NA>         0.014569723  0.0008033670 -0.01293795  1.000000000 -0.03839843
## <NA>         0.010948639  0.0753732601  0.18525107 -0.038398426  1.00000000
```

```
pairs(data_log)
```



```r
round(cor(data_log),digits = 4)
```

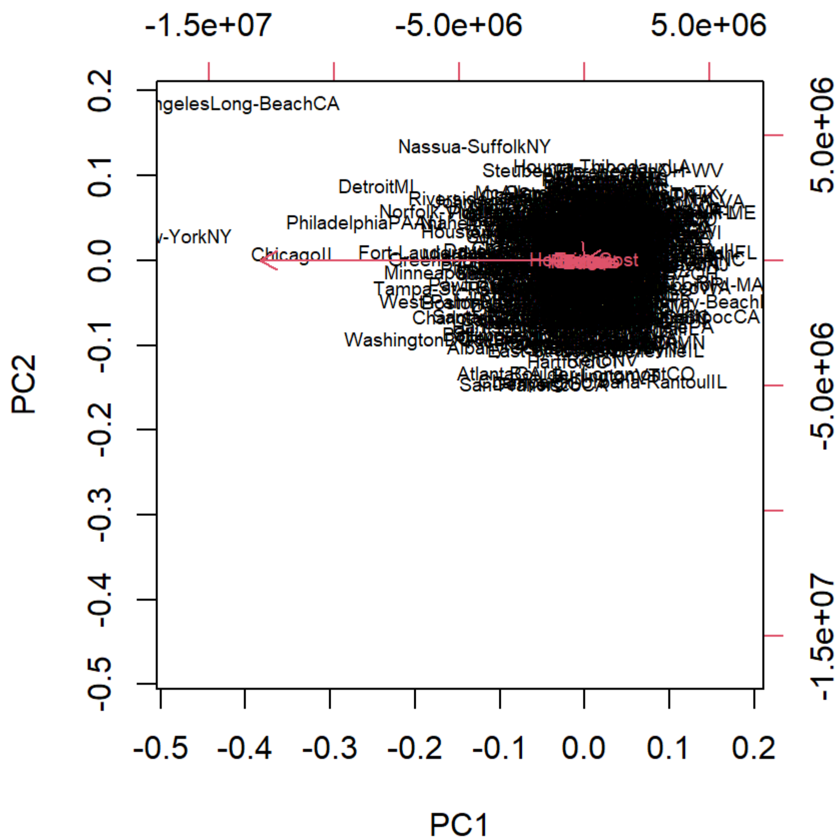
```
## Warning in cor(data_log): the standard deviation is zero
```

```
##             Climate HousingCost HlthCare   Crime  Transp    Educ   Arts Recreat
## Climate           1          NA       NA      NA      NA      NA     NA      NA
## HousingCost      NA      1.0000   0.2730  0.1506  0.2278  0.0342 0.0775  0.1727
## HlthCare         NA      0.2730   1.0000  0.4319  0.1392  0.3243 0.2021  0.5085
## Crime            NA      0.1506   0.4319  1.0000  0.1836  0.4474 0.4648  0.6781
## Transp           NA      0.2278   0.1392  0.1836  1.0000  0.2756 0.0555  0.3465
## Educ             NA      0.0342   0.3243  0.4474  0.2756  1.0000 0.3223  0.5523
## Arts             NA      0.0775   0.2021  0.4648  0.0555  0.3223 1.0000  0.3479
## Recreat          NA      0.1727   0.5085  0.6781  0.3465  0.5523 0.3479  1.0000
## Econ             NA      0.1206   0.4607  0.2540  0.2921  0.3939 0.0930  0.4965
## <NA>             NA     -0.1043   0.2903  0.0226  0.2682  0.0592 0.1155  0.1069
## <NA>             NA      0.0950   0.0930  0.0033  0.0383 -0.0113 0.0155  0.0275
## <NA>             NA     -0.1171  -0.1464  0.2553 -0.2488 -0.0615 0.3525 -0.0329
## <NA>             NA     -0.0538   0.2094  0.1494 -0.4082  0.2201 0.0882  0.1167
## <NA>             NA      0.2081   0.3454  0.5946  0.3411  0.4022 0.3397  0.5665
## <NA>             NA     -0.0651  -0.2217 -0.0806 -0.2229 -0.0129 0.1230 -0.0528
##                Econ    <NA>    <NA>    <NA>    <NA>    <NA>    <NA>
## Climate          NA      NA      NA      NA      NA      NA      NA
## HousingCost  0.1206 -0.1043  0.0950 -0.1171 -0.0538  0.2081 -0.0651
## HlthCare     0.4607  0.2903  0.0930 -0.1464  0.2094  0.3454 -0.2217
## Crime        0.2540  0.0226  0.0033  0.2553  0.1494  0.5946 -0.0806
## Transp       0.2921  0.2682  0.0383 -0.2488 -0.4082  0.3411 -0.2229
## Educ         0.3939  0.0592 -0.0113 -0.0615  0.2201  0.4022 -0.0129
## Arts         0.0930  0.1155  0.0155  0.3525  0.0882  0.3397  0.1230
## Recreat      0.4965  0.1069  0.0275 -0.0329  0.1167  0.5665 -0.0528
## Econ         1.0000  0.1722  0.0585 -0.2017  0.0292  0.3453 -0.0881
## <NA>         0.1722  1.0000  0.0097  0.0005 -0.3974  0.0598 -0.0767
## <NA>         0.0585  0.0097  1.0000 -0.1074  0.0384  0.0146  0.0109
## <NA>        -0.2017  0.0005 -0.1074  1.0000  0.0215  0.0008  0.0754
## <NA>         0.0292 -0.3974  0.0384  0.0215  1.0000 -0.0129  0.1853
## <NA>         0.3453  0.0598  0.0146  0.0008 -0.0129  1.0000 -0.0384
## <NA>        -0.0881 -0.0767  0.0109  0.0754  0.1853 -0.0384  1.0000
```

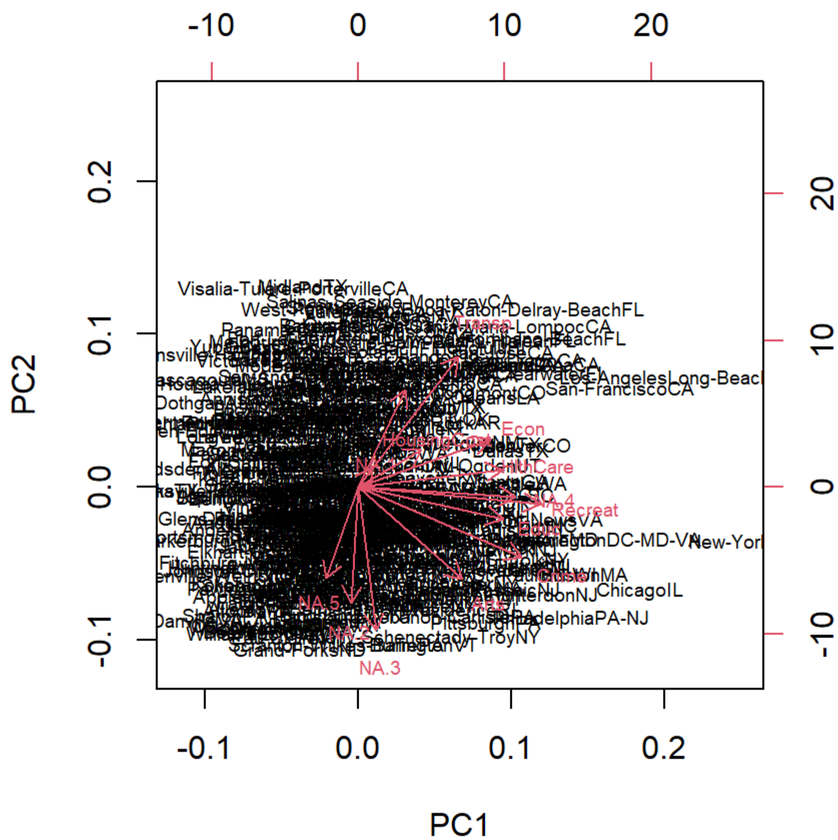
Principal Component Analysis

```
non_constant_columns <- apply(data_log, 2, var) != 0
data_log_filtered <- data_log[, non_constant_columns]

pca.data = prcomp(data_log,scale = F)
pca.dataScale <- prcomp(data_log_filtered, scale = TRUE) #with scaling

#biplots
biplot(pca.data, cex = 0.6)
```

```
## Warning in arrows(0, 0, y[, 1L] * 0.8, y[, 2L] * 0.8, col = col[2L], length =
## arrow.len): zero-length arrow is of indeterminate angle and so skipped

## Warning in arrows(0, 0, y[, 1L] * 0.8, y[, 2L] * 0.8, col = col[2L], length =
## arrow.len): zero-length arrow is of indeterminate angle and so skipped

## Warning in arrows(0, 0, y[, 1L] * 0.8, y[, 2L] * 0.8, col = col[2L], length =
## arrow.len): zero-length arrow is of indeterminate angle and so skipped

## Warning in arrows(0, 0, y[, 1L] * 0.8, y[, 2L] * 0.8, col = col[2L], length =
## arrow.len): zero-length arrow is of indeterminate angle and so skipped

## Warning in arrows(0, 0, y[, 1L] * 0.8, y[, 2L] * 0.8, col = col[2L], length =
## arrow.len): zero-length arrow is of indeterminate angle and so skipped

## Warning in arrows(0, 0, y[, 1L] * 0.8, y[, 2L] * 0.8, col = col[2L], length =
## arrow.len): zero-length arrow is of indeterminate angle and so skipped

## Warning in arrows(0, 0, y[, 1L] * 0.8, y[, 2L] * 0.8, col = col[2L], length =
## arrow.len): zero-length arrow is of indeterminate angle and so skipped

## Warning in arrows(0, 0, y[, 1L] * 0.8, y[, 2L] * 0.8, col = col[2L], length =
## arrow.len): zero-length arrow is of indeterminate angle and so skipped

## Warning in arrows(0, 0, y[, 1L] * 0.8, y[, 2L] * 0.8, col = col[2L], length =
## arrow.len): zero-length arrow is of indeterminate angle and so skipped

## Warning in arrows(0, 0, y[, 1L] * 0.8, y[, 2L] * 0.8, col = col[2L], length =
## arrow.len): zero-length arrow is of indeterminate angle and so skipped

## Warning in arrows(0, 0, y[, 1L] * 0.8, y[, 2L] * 0.8, col = col[2L], length =
## arrow.len): zero-length arrow is of indeterminate angle and so skipped

## Warning in arrows(0, 0, y[, 1L] * 0.8, y[, 2L] * 0.8, col = col[2L], length =
## arrow.len): zero-length arrow is of indeterminate angle and so skipped

## Warning in arrows(0, 0, y[, 1L] * 0.8, y[, 2L] * 0.8, col = col[2L], length =
## arrow.len): zero-length arrow is of indeterminate angle and so skipped
```

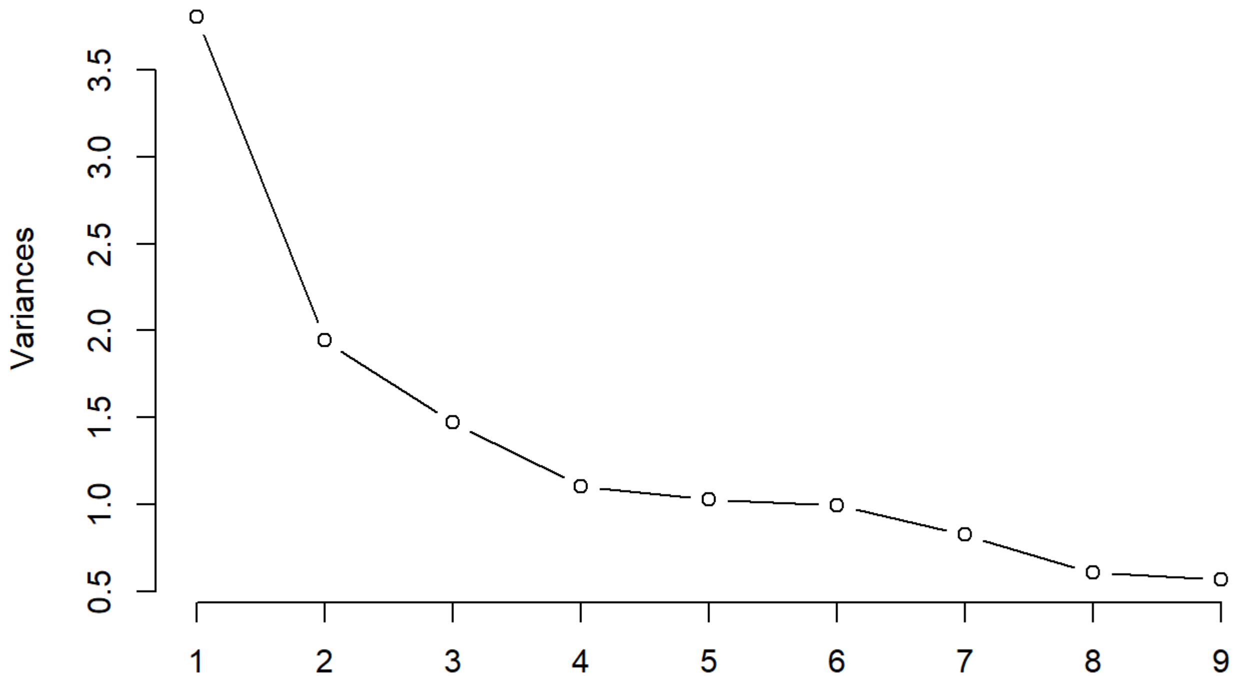



```
biplot(pca.dataScale, cex = 0.6)
```



Number of PC’s 1:“Elbow Rule”

```
clean_data <- data_log[complete.cases(data_log), ]
non_zero_sd_columns <- apply(clean_data, 2, sd) != 0
clean_data_filtered <- clean_data[, non_zero_sd_columns]

correlation_matrix <- cor(clean_data_filtered)
eig <- eigen(correlation_matrix)

screeplot(pca.dataScale, type="l", npcs = 9, main = NULL)
```




```
pve = rep(NA, dim(data_log)[2]) # proportion of variance explained
for(i in 1:9)
{
  pve[i] = print(sum(eig$values[1:i])/9)
}
```

```
## [1] 0.4226638
## [1] 0.6386353
## [1] 0.8020706
## [1] 0.9248888
## [1] 1.038863
## [1] 1.14956
## [1] 1.241133
## [1] 1.308513
## [1] 1.371401
```

```
eig$values
```

```
##  [1] 3.8039745 1.9437429 1.4709181 1.1053639 1.0257636 0.9962754 0.8241574
##  [8] 0.6064208 0.5659893 0.4610233 0.3918910 0.3442996 0.2389301 0.2212501
```

```
pve
```

```
##  [1] 0.4226638 0.6386353 0.8020706 0.9248888 1.0388625 1.1495598 1.2411329
##  [8] 1.3085130 1.3714007        NA        NA        NA        NA        NA
## [15]        NA
```

2: “Including PC’s to explain 80% of total variation”

```
pca.variance <- eig$values
round(sum(pca.variance[1:5])/sum(pca.variance),digits=2) #82%
```

```
## [1] 0.67
```

```
round(sum(pca.variance[1:6])/sum(pca.variance),digits=2)
```

```
## [1] 0.74
```

3: “Kaiser rule”

```
round(pca.variance,digits=2)
```

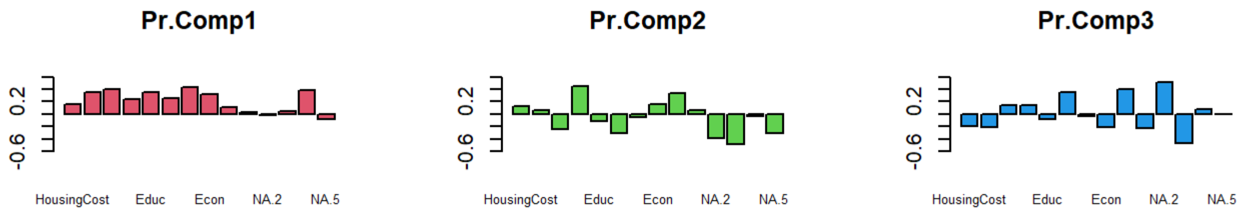
```
##  [1] 3.80 1.94 1.47 1.11 1.03 1.00 0.82 0.61 0.57 0.46 0.39 0.34 0.24 0.22
```

```
mean(pca.variance)
```

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

interpretation of PC's

```
par(mfrow=c(3,3))

barplot(pca.dataScale$rotation[,1],col=2,main='Pr.Comp1',
        ylim = c(-0.7,0.7),cex.names=0.6)
barplot(pca.dataScale$rotation[,2],col=3,main='Pr.Comp2',
        ylim = c(-0.7,0.7),cex.names=0.6)
barplot(pca.dataScale$rotation[,3],col=4,main='Pr.Comp3',
        ylim = c(-0.7,0.7),cex.names=0.6)
```



Correlation matrix of varaibles and PC's

```
cor_matrix <- pca.dataScale$rotation %*% diag(pca.dataScale$sdev)[, 1:9]
round(cor_matrix,digits=3)
```

```
##                [,1]   [,2]   [,3]   [,4]   [,5]   [,6]   [,7]   [,8]   [,9]
## HousingCost  0.298  0.176 -0.239  0.729 -0.048  0.053 -0.459  0.148 -0.121
## HlthCare     0.677  0.082 -0.252 -0.157 -0.201  0.443 -0.293  0.003  0.144
## Crime        0.768 -0.330  0.174  0.143  0.074  0.125  0.123 -0.165  0.158
## Transp       0.469  0.615  0.165  0.167  0.139 -0.302  0.161  0.168 -0.016
## Educ         0.681 -0.151 -0.105 -0.255  0.148 -0.225  0.191  0.414 -0.088
## Arts         0.489 -0.433  0.424  0.103 -0.223 -0.050 -0.064  0.347 -0.060
## Recreat      0.854 -0.079 -0.044 -0.051  0.069 -0.068  0.050 -0.121  0.034
## Econ         0.620  0.224 -0.254 -0.307 -0.025 -0.061 -0.100 -0.249 -0.542
## <NA>         0.223  0.458  0.479 -0.430 -0.382  0.110 -0.251  0.066  0.160
## NA.1         0.068  0.089 -0.278  0.224 -0.797 -0.028  0.467 -0.038 -0.033
## NA.2        -0.033 -0.543  0.625  0.130 -0.062  0.253  0.040 -0.116 -0.322
## NA.3         0.084 -0.674 -0.573 -0.174  0.007  0.132 -0.013  0.131  0.078
## NA.4         0.738 -0.046  0.095  0.194  0.117 -0.173  0.077 -0.324  0.242
## NA.5        -0.148 -0.429 -0.007 -0.094 -0.288 -0.710 -0.381 -0.137  0.058
```

PC scores

```
PC1PC2.scores <- round(pca.dataScale$x[,1:2],digits = 3)
row.names(PC1PC2.scores) <- NULL

PC1PC2.scores <- cbind.data.frame(city_names, PC1PC2.scores)
PC1.rank <- PC1PC2.scores[order(PC1PC2.scores[,2],decreasing = TRUE),c(1,2)]
PC1.rank
```

```
##                          city_names   PC1
## 213                        New-YorkNY 8.861
## 179          Los-AngelesLong-BeachCA 7.410
## 65                          ChicagoIL 6.527
## 270                   San-FranciscoCA 6.055
## 314                 WashingtonDC-MD-VA 5.693
## 43                           BostonMA 5.241
## 234                  PhiladelphiaPA-NJ 4.935
## 26                        BaltimoreMD 4.312
## 86                          DetroitMI 4.057
## 269                       San-DiegoCA 3.901
## 84                           DenverCO 3.898
## 278                         SeattleWA 3.788
## 218                         OaklandCA 3.682
## 214                          NewarkNJ 3.631
## 69                        ClevelandOH 3.601
## 77                           DallasTX 3.547
## 20                          AtlantaGA 3.450
## 192                    Miami-HialeahFL 3.430
## 262                     St.-LouisMO-IL 3.404
## 11                Anaheim-Santa-AnaCA 3.367
## 271                        San-JoseCA 3.286
## 135                         HoustonTX 3.148
## 131                        HartfordCT 3.133
## 207                   Nassua-SuffolkNY 3.117
## 237                      PittsburghPA 2.975
## 197          Minneapolis-St.-PaulMN-WI 2.865
## 34                   Bergen-PassaicNJ 2.858
## 240                        PortlandOR 2.858
## 133                        HonoluluHI 2.821
## 290                        StamfordCT 2.742
## 212                     New-OrleansLA 2.693
## 217                         NorwalkCT 2.564
## 210                New-Haven-MeridenCT 2.525
## 196                       MilwaukeeWI 2.451
## 247                   Raleigh-DurhamNC 2.450
## 256                       RochesterNY 2.419
## 243                      ProvidenceRI 2.345
## 193      Middlesex-SomersetHunterdonNJ 2.272
```

```
## 297         Tampa-St.-Petersburg-ClearwaterFL  2.246
## 48                       Bridgeport-MilfordCT  2.236
## 67                         CincinnatiOH-KY-IN  2.213
## 44                         Boulder-LongmontCO  2.204
## 235                                 PhoenixAZ  2.186
## 5                               AlbuquerqueNM  2.177
## 53                                  BuffaloNY  2.108
## 272        Santa-Barbara-Santa-Maria-LompocCA  2.073
## 252                    Richmond-PetersburgVA  2.050
## 200                          Monmouth-OceanNJ  2.003
## 318 West-Palm-Beach-Boca-Raton-Delray-BeachFL  1.972
## 258                              SacramentoCA  1.869
## 15                                Ann-ArborMI  1.866
## 266                     Salt-Lake-City-OgdenUT  1.846
## 253                 Riverside-San-BernardinoCA  1.753
## 153                              Kansas-CityMO  1.748
## 302                                 TrentonNJ  1.738
## 216     Norfolk-Virginia-Beach-Newport-NewsVA  1.717
## 225                                 OrlandoFL  1.635
## 303                                  TusconAZ  1.608
## 108 Fort-Lauderdale-Hollywood-Pompano-BeachFL  1.606
## 273                              Santa-CruzCA  1.572
## 191                            MemphisTN-AR-MS  1.537
## 55                               BurlingtonVT  1.532
## 294                                SyracuseNY  1.532
## 138                            IndianapolisIN  1.531
## 180                            LouisvilleKY-IN  1.502
## 74                                 ColumbusOH  1.496
## 78                                  DanburyCT  1.466
## 185                                 MadisonWI  1.464
## 223                                OmahaNE-IA  1.444
## 323                          WilmingtonDE-NJ-MD  1.414
## 4                    Albany-Schenectady-TroyNY  1.412
## 221                            Oklahoma-CityOK  1.326
## 274                     Santa-Rosa-PetalumaCA  1.278
## 250                                   RenoNV  1.238
## 287                             SpringfieldIL  1.191
## 288                             SpringfieldMA  1.187
## 114                          Forth-ArlingtonTX  1.156
```

```
## 206                            NashvilleTN  1.146
## 142                         JacksonvilleFL  1.134
## 162                          Lake-CountyIL  1.093
## 62         Charlotte-Gastonia-Rock-HillNC-SC  1.088
## 130            Harrisburg-Lebanon-CarlislePA  1.081
## 300                               ToledoOH  1.076
## 63                        CharlottesvilleVA  1.057
## 59             Champaign-Urbana-RantoulIL  1.048
## 60                            CharlestonSC  1.038
## 295                               TacomaWA  0.949
## 97                    Eugene-SpringfieldOR  0.943
## 126     Greensboro-Winston-Salem-High-PointNC  0.941
## 168                            Las-VegasNV  0.933
## 145                          Jersey-CityNJ  0.920
## 268                          San-AntonioTX  0.911
## 81                    Dayton-SpringfieldOH  0.910
## 239                             PortlandME  0.870
## 21                         Atlantic-CityNJ  0.854
## 2                                  AkronOH  0.845
## 173                    Lexington-FayetteKY  0.834
## 308              Vallejo-Fairfield-NapaCA  0.824
## 38                            BirminghamAL  0.795
## 224                        Orange-CountyNY  0.783
## 72                              ColumbiaSC  0.781
## 165                 Lansing-East-LansingMI  0.758
## 304                                TulsaOK  0.754
## 265            Salinas-Seaside-MontereyCA  0.752
## 209                         New-BritainCT  0.716
## 12                            AnchorageAK  0.715
## 264                       Salem-GlousterMA  0.708
## 119                        Gary-HammondIN  0.696
## 150                           KalamazooMI  0.659
## 276                            SavannahGA  0.654
## 115                              FresnoCA  0.621
## 227                       Oxnard-VenturaCA  0.584
## 118                 Galveston-Texas-CityTX  0.582
## 141                             JacksonMS  0.563
## 211               New-London-NorwichCT-RI  0.554
## 152                          Kansas-CityKS  0.548
```

```
## 154                          KenoshaWI  0.513
## 148                           JolietIL  0.481
## 194                      MiddletownCT  0.463
## 85                        Des-MoinesIA  0.417
## 170           Lawrence-HaverhillMA-NH  0.393
## 117                      GainesvilleFL  0.385
## 70                 Colorado-SpringsCO  0.355
## 175                          LincolnNE  0.330
## 282                      ShreveportLA  0.323
## 176     Little-RockNorth-Little-RockAR  0.317
## 127         Greenville-SpartanburgSC  0.259
## 263                            SalemOR  0.241
## 122                     Grand-RapidsMI  0.235
## 285           South-Bend-MishawakaIN  0.215
## 24                            AustinTX  0.196
## 82                    Daytona-BeachFL  0.194
## 320                          WichitaKS  0.194
## 139                        Iowa-CityIA  0.181
## 325                        WorcesterMA  0.155
## 198                           MobileAL  0.145
## 156                        KnoxvilleTN  0.119
## 41              Bloomington-NormalIL  0.099
## 182                          LubbockTX  0.088
## 107          Fort-Collins-Lover=landCO  0.080
## 23                     Aurora-ElginIL  0.077
## 50                        BrocktonMA  0.030
## 296                     TallahasseeFL  0.013
## 35                         BillingsMT -0.001
## 113                      Fort-WayneIN -0.016
## 275                        SarasotaFL -0.033
## 27                           BangorME -0.040
## 324                      WilmingtonNC -0.047
## 158                       La-CrosseWI -0.052
## 160                       LafayetteLA -0.053
## 231  Pawtucket-Woonsocket-AttleboroRI-MA -0.057
## 42                       Boise-CityID -0.072
## 301                          TopekaKS -0.075
## 181                        LowellMA-NH -0.076
## 80       Davenport-Rock-Island-MolineIA-IL -0.152
```

```
## 71                                   ColumbiaMO -0.169
## 286                                   SpokaneWA -0.182
## 104                                     FlintMI -0.195
## 259                  Saginaw-Bay-City-MidlandMI -0.211
## 190             Melbourne-Titusville-Palm-BayFL -0.220
## 232                                  PensacolaFL -0.224
## 311              Vineland-Millville-BridgetonNJ -0.231
## 109                                 Fort-MyersFL -0.235
## 37                                 BinghamptonNY -0.254
## 328                          Youngstown-WarrenOH -0.254
## 129                        Hamilton-MiddletownOH -0.260
## 18                                  AshevilleNC -0.271
## 246                                    RacineWI -0.273
## 205                                    NashuaNH -0.277
## 99                               Fall-RiverMA-RI -0.299
## 254                                   RoanokeVA -0.319
## 110                                Fort-PierceFL -0.334
## 316                     Waterloo-Cedar-FallsIA -0.356
## 90                   East-St.-Louis-BellevilleIL -0.359
## 249                                   ReddingCA -0.364
## 233                                    PeoriaIL -0.400
## 66                                      ChicoCA -0.408
## 25                                BakersfieldCA -0.410
## 8                           AltonGranite-CityIL -0.419
## 28                                Baton-RougeLA -0.432
## 159                                 LafayetteIN -0.436
## 61                                 CharlestonWV -0.477
## 293                                  StocktonCA -0.487
## 277                    Scranton-Wilkes-BarrePA -0.502
## 32                                 BellinghamWA -0.554
## 167                                 Las-CrucesNM -0.556
## 178                               Lorain-ElyriaOH -0.587
## 98                               EvansvilleIN-KY -0.590
## 203                                    MuncieIN -0.591
## 248                                   ReadingPA -0.593
## 169                                  LawrenceKS -0.594
## 125                                  Green-BayWI -0.607
## 75                              Corpus-ChristiTX -0.608
## 96                                      EriePA -0.621
```

```
## 242                         PoughkeepsieNY -0.637
## 215                        Niagara-FallsNY -0.658
## 58                           Cedar-RapidsIA -0.662
## 10                              AmarilloTX -0.682
## 52                  Bryan-College-StationTX -0.692
## 164                            LancasterPA -0.707
## 92                               El-PasoTX -0.724
## 289                          SpringfieldMO -0.743
## 204                             MuskegonMI -0.748
## 89                             DuluthMN-WI -0.781
## 315                            MaterburyCT -0.792
## 7                  AllentownBethlehemPA-NJ -0.824
## 219                                OcalaFL -0.826
## 309                            VancouverWA -0.828
## 183                            LynchburgVA -0.838
## 255                            RochesterMN -0.845
## 146      Johnson-City-Kingsport-BristolTN-VA -0.875
## 244                            Provo-OremUT -0.879
## 17                 Appleton-Oshkosh-NeenahWI -0.882
## 128                            HagerstownMD -0.922
## 106                             FlorenceSC -0.940
## 100                      Fargo-MoorheadND-MN -0.948
## 30                      Beaumont-Port-ArthurTX -0.958
## 245                               PuebloCO -0.991
## 174                                 LimaOH -1.008
## 283                         Sioux-CityIA-NE -1.014
## 40                           BloomingtonIN -1.015
## 49                              BristolCT -1.017
## 257                            RockfordIL -1.020
## 22                             AugustaGA-SC -1.021
## 101                          FayettevilleNC -1.030
## 284                          Sioux-FallsSD -1.036
## 140                              JacksonMI -1.060
## 186                           ManchesterNH -1.090
## 291                        State-CollegePA -1.098
## 189                              MedfordOR -1.138
## 305                            TuscaloosaAL -1.141
## 238                           PittsfieldMA -1.145
## 208                           New-BedsfordMA -1.163
```

```
## 222                          OlympiaWA -1.185
## 123                      Great-FallsMT -1.204
## 307                      Utica-RomeNY -1.232
## 326                           YakimaWA -1.250
## 195                          MidlandTX -1.269
## 29                      Battle-CreekMI -1.281
## 163           Lakeland-Winter-HavenFL -1.284
## 172               Lewiston-AuburnME -1.300
## 56                            CantonOH -1.325
## 94                            ElmiraNY -1.334
## 121                     Grand-ForksND -1.337
## 73                      ColumbusGA-AL -1.368
## 202                      MontgomeryAL -1.368
## 144               Janesville-BeloitWI -1.371
## 136      Huntington-AshlandWV-KY-OH -1.383
## 161                     Lake-CharlesLA -1.383
## 313                             WacoTX -1.384
## 306                            TylerTX -1.386
## 19                            AthensGA -1.390
## 124                          GreeleyCO -1.402
## 241   Portsmouth-Dover-RochesterNH-ME -1.415
## 64                     ChattanoogaTN-GA -1.437
## 102         Fayettteville-SprindaleAR -1.444
## 46                          BrazoriaTX -1.456
## 137                       HuntsvilleAL -1.480
## 57                            CasperWY -1.481
## 312      Visalia-Tulare-PortervilleCA -1.491
## 184             MaconWarner-RobbinsGA -1.495
## 298                      Terre-HauteIN -1.500
## 39                          BismarckND -1.526
## 83                           DecaturIL -1.545
## 1                            AbileneTX -1.591
## 91                        Eau-ClaireWI -1.609
## 321                    Wichita-FallsTX -1.625
## 201                           MonroeLA -1.629
## 36                    Biloxi-GulfportMS -1.639
## 45                         BradentonFL -1.646
## 228                      Panama-CityFL -1.658
## 199                          ModestoCA -1.665
```

```
## 317                          WausauWI -1.672
## 88                          DubuqueIA -1.673
## 327                            YorkPA -1.679
## 171                          LawtonOK -1.731
## 47                        BremertonWA -1.734
## 260                       St.-CloudMN -1.744
## 267                      San-AngeloTX -1.813
## 31                    Beaver-CountyPA -1.836
## 143                    JacksonvilleNC -1.891
## 76                    CumberlandMD-WV -1.892
## 187                       MansfieldOH -1.907
## 155                   Kileen-TempleTX -1.968
## 151                        KankakeeIL -1.972
## 95                             EnidOK -1.973
## 112               Fort-Walton-BeachFL -1.984
## 220                          OdessaTX -2.018
## 261                      St.-JosephMO -2.046
## 147                       JohnstownPA -2.105
## 226                       OwensboroKY -2.125
## 177               Longview-MarshallTX -2.127
## 132                         HickoryNC -2.183
## 251        Richland-Kinnewick-PascoWA -2.188
## 111                     Fort-SmithAR-OK -2.198
## 103             Fitchburg-LeominsterMA -2.207
## 280                       SheboyganWI -2.214
## 93                   Elkhart-GoshenIN -2.221
## 319                     WheelingWV-OH -2.235
## 6                        AlexandriaLA -2.268
## 33                   Benton-HarborMI -2.279
## 3                            AlbanyGA -2.363
## 229          Parkerburg-MariettaWV-OH -2.417
## 322                     WilliamsportPA -2.487
## 134                  Houma-ThibodauxLA -2.512
## 16                         AnnistonAL -2.519
## 9                           AltoonaPA -2.542
## 68       Clarksville-HopkinsvilleTN-KY -2.585
## 329                        Yuba-CityCA -2.643
## 105                         FlorenceAL -2.684
## 13                         AndersonIN -2.690
```

```
## 236                           Pine-BluffAR -2.693
## 310                             VictoriaTX -2.722
## 14                              AndersonSC -2.800
## 166                               LaredoTX -2.807
## 157                               KokomoIN -2.816
## 188              McAllen-Edinburg-MissionTX -2.881
## 54                            BurlingtonNC -2.907
## 292             Steubenville-WeirtonOH-WV -3.076
## 279                               SharonPA -3.081
## 120                          Glens-FallsNY -3.225
## 51                Brownsville-HarlingtonTX -3.236
## 281                     Sherman-DenisonTX -3.237
## 149                               JoplinMO -3.298
## 230                           PascagoulaMS -3.488
## 299               TexarkanaTX-TexarkanaAR -3.596
## 87                               DothganAL -3.618
## 79                              DanvilleVA -3.730
## 116                              GadsdenAL -4.142
```

```
PC2.rank <- PC1PC2.scores[order(PC1PC2.scores[,3],decreasing = TRUE),c(1,3)]
PC2.rank
```

```
##                                   city_names   PC2
## 195                                MidlandTX  3.336
## 312              Visalia-Tulare-PortervilleCA  3.306
## 265                Salinas-Seaside-MontereyCA  3.061
## 293                               StocktonCA  2.996
## 318 West-Palm-Beach-Boca-Raton-Delray-BeachFL  2.922
## 160                               LafayetteLA  2.896
## 115                                 FresnoCA  2.875
## 168                               Las-VegasNV  2.822
## 227                          Oxnard-VenturaCA  2.704
## 25                              BakersfieldCA  2.692
## 272       Santa-Barbara-Santa-Maria-LompocCA  2.640
## 228                            Panama-CityFL  2.595
## 303                                 TusconAZ  2.590
## 110                            Fort-PierceFL  2.548
## 192                           Miami-HialeahFL  2.452
## 108 Fort-Lauderdale-Hollywood-Pompano-BeachFL  2.436
## 190          Melbourne-Titusville-Palm-BayFL  2.391
## 220                                 OdessaTX  2.326
## 133                               HonoluluHI  2.320
## 329                               Yuba-CityCA  2.313
## 82                           Daytona-BeachFL  2.282
## 275                               SarasotaFL  2.270
## 271                               San-JoseCA  2.249
## 45                               BradentonFL  2.243
## 225                                OrlandoFL  2.185
## 51                   Brownsville-HarlingtonTX  2.184
## 161                            Lake-CharlesLA  2.132
## 219                                  OcalaFL  2.128
## 310                               VictoriaTX  2.109
## 269                               San-DiegoCA  2.076
## 253               Riverside-San-BernardinoCA  2.054
## 11                        Anaheim-Santa-AnaCA  2.050
## 199                                ModestoCA  2.033
## 308                  Vallejo-Fairfield-NapaCA  2.026
## 218                                OaklandCA  2.023
## 28                             Baton-RougeLA  2.002
## 109                              Fort-MyersFL  1.930
## 235                                PhoenixAZ  1.925
```

```
## 273                      Santa-CruzCA  1.914
## 232                       PensacolaFL  1.907
## 274             Santa-Rosa-PetalumaCA  1.873
## 297  Tampa-St.-Petersburg-ClearwaterFL  1.873
## 70                 Colorado-SpringsCO  1.868
## 267                      San-AngeloTX  1.822
## 179          Los-AngelesLong-BeachCA  1.805
## 230                      PascagoulaMS  1.768
## 134                 Houma-ThibodauxLA  1.736
## 258                      SacramentoCA  1.734
## 249                         ReddingCA  1.698
## 163          Lakeland-Winter-HavenFL  1.691
## 12                        AnchorageAK  1.677
## 270                   San-FranciscoCA  1.654
## 276                        SavannahGA  1.638
## 137                      HuntsvilleAL  1.626
## 107         Fort-Collins-Lover=landCO  1.625
## 75                  Corpus-ChristiTX  1.619
## 167                      Las-CrucesNM  1.592
## 44                 Boulder-LongmontCO  1.551
## 296                     TallahasseeFL  1.546
## 212                     New-OrleansLA  1.495
## 16                        AnnistonAL  1.493
## 171                          LawtonOK  1.493
## 182                         LubbockTX  1.435
## 201                          MonroeLA  1.399
## 87                          DothganAL  1.391
## 1                           AbileneTX  1.352
## 198                          MobileAL  1.352
## 118           Galveston-Texas-CityTX  1.313
## 114                 Forth-ArlingtonTX  1.306
## 92                          El-PasoTX  1.295
## 250                            RenoNV  1.289
## 21                    Atlantic-CityNJ  1.282
## 36                   Biloxi-GulfportMS  1.272
## 66                            ChicoCA  1.249
## 245                          PuebloCO  1.227
## 52            Bryan-College-StationTX  1.192
## 305                       TuscaloosaAL  1.163
```

```
## 321                       Wichita-FallsTX  1.151
## 30                   Beaumont-Port-ArthurTX  1.132
## 282                           ShreveportLA  1.119
## 221                        Oklahoma-CityOK  1.109
## 281                      Sherman-DenisonTX  1.102
## 176        Little-RockNorth-Little-RockAR  1.094
## 112                    Fort-Walton-BeachFL  1.086
## 251             Richland-Kinnewick-PascoWA  1.066
## 236                           Pine-BluffAR  1.064
## 95                                  EnidOK  1.028
## 142                         JacksonvilleFL  0.993
## 313                                 WacoTX  0.976
## 202                           MontgomeryAL  0.941
## 117                          GainesvilleFL  0.934
## 304                                TulsaOK  0.926
## 188             McAllen-Edinburg-MissionTX  0.923
## 3                                 AlbanyGA  0.921
## 166                               LaredoTX  0.858
## 268                          San-AntonioTX  0.854
## 46                              BrazoriaTX  0.850
## 177                    Longview-MarshallTX  0.826
## 24                                AustinTX  0.781
## 324                           WilmingtonNC  0.748
## 90             East-St.-Louis-BellevilleIL  0.737
## 320                             WichitaKS  0.732
## 5                            AlbuquerqueNM  0.728
## 135                              HoustonTX  0.719
## 84                               DenverCO  0.712
## 184                  MaconWarner-RobbinsGA  0.642
## 289                          SpringfieldMO  0.630
## 19                               AthensGA  0.626
## 77                               DallasTX  0.616
## 295                              TacomaWA  0.592
## 42                           Boise-CityID  0.571
## 143                        JacksonvilleNC  0.561
## 124                             GreeleyCO  0.554
## 102             Fayettteville-SprindaleAR  0.545
## 261                          St.-JosephMO  0.524
## 326                              YakimaWA  0.500
```

```
## 111                        Fort-SmithAR-OK  0.448
## 306                                TylerTX  0.407
## 10                              AmarilloTX  0.398
## 169                             LawrenceKS  0.382
## 162                          Lake-CountyIL  0.372
## 73                           ColumbusGA-AL  0.369
## 266                Salt-Lake-City-OgdenUT  0.343
## 38                            BirminghamAL  0.342
## 57                                CasperWY  0.340
## 116                              GadsdenAL  0.321
## 6                             AlexandriaLA  0.315
## 47                              BremertonWA  0.284
## 105                             FlorenceAL  0.262
## 309                            VancouverWA  0.183
## 173                   Lexington-FayetteKY  0.150
## 71                              ColumbiaMO  0.136
## 20                               AtlantaGA  0.113
## 155                        Kileen-TempleTX  0.113
## 204                             MuskegonMI  0.100
## 301                               TopekaKS  0.095
## 278                              SeattleWA  0.086
## 23                           Aurora-ElginIL  0.065
## 50                              BrocktonMA  0.055
## 152                          Kansas-CityKS  0.053
## 151                             KankakeeIL  0.049
## 226                            OwensboroKY  0.045
## 98                          EvansvilleIN-KY  0.035
## 85                            Des-MoinesIA  0.020
## 60                            CharlestonSC -0.017
## 208                          New-BedsfordMA -0.022
## 323                     WilmingtonDE-NJ-MD -0.043
## 299                  TexarkanaTX-TexarkanaAR -0.045
## 189                               MedfordOR -0.048
## 191                        MemphisTN-AR-MS -0.052
## 64                        ChattanoogaTN-GA -0.054
## 233                               PeoriaIL -0.067
## 68          Clarksville-HopkinsvilleTN-KY -0.075
## 22                            AugustaGA-SC -0.086
## 222                              OlympiaWA -0.116
```

```
## 153                        Kansas-CityMO -0.118
## 62        Charlotte-Gastonia-Rock-HillNC-SC -0.126
## 170                Lawrence-HaverhillMA-NH -0.130
## 48                    Bridgeport-MilfordCT -0.138
## 72                              ColumbiaSC -0.150
## 141                              JacksonMS -0.154
## 33                           Benton-HarborMI -0.168
## 149                               JoplinMO -0.169
## 54                            BurlingtonNC -0.179
## 257                             RockfordIL -0.205
## 206                            NashvilleTN -0.221
## 287                          SpringfieldIL -0.228
## 240                             PortlandOR -0.233
## 32                            BellinghamWA -0.234
## 104                                FlintMI -0.251
## 83                               DecaturIL -0.290
## 290                             StamfordCT -0.293
## 285                  South-Bend-MishawakaIN -0.320
## 311            Vineland-Millville-BridgetonNJ -0.340
## 181                            LowellMA-NH -0.382
## 244                            Provo-OremUT -0.386
## 40                            BloomingtonIN -0.394
## 59                 Champaign-Urbana-RantoulIL -0.399
## 35                               BillingsMT -0.430
## 138                          IndianapolisIN -0.435
## 99                             Fall-RiverMA-RI -0.436
## 211                  New-London-NorwichCT-RI -0.437
## 101                          FayettevilleNC -0.443
## 132                               HickoryNC -0.477
## 283                          Sioux-CityIA-NE -0.477
## 8                        AltonGranite-CityIL -0.478
## 263                                SalemOR -0.479
## 200                         Monmouth-OceanNJ -0.491
## 180                         LouisvilleKY-IN -0.493
## 41                    Bloomington-NormalIL -0.498
## 187                            MansfieldOH -0.500
## 120                           Glens-FallsNY -0.502
## 97                    Eugene-SpringfieldOR -0.505
## 58                          Cedar-RapidsIA -0.523
```

```
## 156                              KnoxvilleTN -0.531
## 80          Davenport-Rock-Island-MolineIA-IL -0.534
## 254                               RoanokeVA -0.536
## 123                           Great-FallsMT -0.547
## 217                               NorwalkCT -0.551
## 29                            Battle-CreekMI -0.553
## 216     Norfolk-Virginia-Beach-Newport-NewsVA -0.555
## 315                             MaterburyCT -0.564
## 106                              FlorenceSC -0.568
## 13                               AndersonIN -0.572
## 150                             KalamazooMI -0.572
## 209                           New-BritainCT -0.580
## 140                               JacksonMI -0.588
## 139                             Iowa-CityIA -0.592
## 127                 Greenville-SpartanburgSC -0.602
## 194                            MiddletownCT -0.640
## 126     Greensboro-Winston-Salem-High-PointNC -0.650
## 119                            Gary-HammondIN -0.651
## 122                           Grand-RapidsMI -0.652
## 242                           PoughkeepsieNY -0.664
## 14                               AndersonSC -0.676
## 262                           St.-LouisMO-IL -0.682
## 298                            Terre-HauteIN -0.692
## 145                            Jersey-CityNJ -0.697
## 148                                JolietIL -0.705
## 129                  Hamilton-MiddletownOH -0.752
## 223                              OmahaNE-IA -0.752
## 175                               LincolnNE -0.757
## 286                               SpokaneWA -0.764
## 302                               TrentonNJ -0.776
## 49                                BristolCT -0.792
## 259                 Saginaw-Bay-City-MidlandMI -0.797
## 241           Portsmouth-Dover-RochesterNH-ME -0.799
## 316                  Waterloo-Cedar-FallsIA -0.809
## 239                              PortlandME -0.816
## 78                                DanburyCT -0.824
## 26                              BaltimoreMD -0.852
## 247                           Raleigh-DurhamNC -0.854
## 174                                  LimaOH -0.866
```

```
## 74                        ColumbusOH -0.872
## 246                         RacineWI -0.875
## 314                WashingtonDC-MD-VA -0.883
## 213                        New-YorkNY -0.885
## 229        Parkerburg-MariettaWV-OH -0.893
## 264                    Salem-GlousterMA -0.899
## 252             Richmond-PetersburgVA -0.902
## 67                CincinnatiOH-KY-IN -0.917
## 2                            AkronOH -0.918
## 255                      RochesterMN -0.920
## 224                   Orange-CountyNY -0.958
## 144              Janesville-BeloitWI -0.967
## 215                   Niagara-FallsNY -0.969
## 88                          DubuqueIA -0.974
## 18                        AshevilleNC -0.983
## 131                        HartfordCT -0.987
## 214                          NewarkNJ -1.006
## 203                          MuncieIN -1.035
## 93                    Elkhart-GoshenIN -1.049
## 113                     Fort-WayneIN -1.096
## 186                     ManchesterNH -1.127
## 183                      LynchburgVA -1.140
## 81             Dayton-SpringfieldOH -1.146
## 300                          ToledoOH -1.152
## 205                          NashuaNH -1.153
## 56                           CantonOH -1.162
## 154                         KenoshaWI -1.174
## 128                     HagerstownMD -1.180
## 207                  Nassua-SuffolkNY -1.185
## 165            Lansing-East-LansingMI -1.186
## 288                     SpringfieldMA -1.202
## 172                Lewiston-AuburnME -1.249
## 103            Fitchburg-LeominsterMA -1.259
## 86                         DetroitMI -1.271
## 15                        Ann-ArborMI -1.295
## 328              Youngstown-WarrenOH -1.301
## 159                      LafayetteIN -1.307
## 210                New-Haven-MeridenCT -1.315
## 136        Huntington-AshlandWV-KY-OH -1.350
```

```
## 69                              ClevelandOH -1.353
## 238                            PittsfieldMA -1.388
## 146       Johnson-City-Kingsport-BristolTN-VA -1.396
## 43                                 BostonMA -1.422
## 61                             CharlestonWV -1.441
## 292              Steubenville-WeirtonOH-WV -1.448
## 197              Minneapolis-St.-PaulMN-WI -1.467
## 63                        CharlottesvilleVA -1.530
## 125                              Green-BayWI -1.531
## 96                                   EriePA -1.538
## 248                               ReadingPA -1.548
## 256                             RochesterNY -1.573
## 157                                KokomoIN -1.592
## 284                            Sioux-FallsSD -1.606
## 178                          Lorain-ElyriaOH -1.615
## 158                              La-CrosseWI -1.645
## 280                              SheboyganWI -1.648
## 231     Pawtucket-Woonsocket-AttleboroRI-MA -1.660
## 53                                BuffaloNY -1.684
## 34                          Bergen-PassaicNJ -1.701
## 94                                 ElmiraNY -1.710
## 260                              St.-CloudMN -1.710
## 65                                ChicagoIL -1.715
## 291                         State-CollegePA -1.740
## 193          Middlesex-SomersetHunterdonNJ -1.752
## 327                                  YorkPA -1.760
## 196                              MilwaukeeWI -1.818
## 17               Appleton-Oshkosh-NeenahWI -1.820
## 39                               BismarckND -1.854
## 307                             Utica-RomeNY -1.857
## 27                                 BangorME -1.866
## 185                                MadisonWI -1.881
## 325                              WorcesterMA -1.910
## 100                        Fargo-MoorheadND-MN -1.928
## 294                               SyracuseNY -1.968
## 7                  AllentownBethlehemPA-NJ -1.992
## 243                             ProvidenceRI -2.005
## 9                                 AltoonaPA -2.026
## 279                                SharonPA -2.104
```

```
## 37                                     BinghamptonNY -2.117
## 130             Harrisburg-Lebanon-CarlislePA -2.150
## 234                            PhiladelphiaPA-NJ -2.171
## 79                                      DanvilleVA -2.193
## 164                                    LancasterPA -2.205
## 89                                     DuluthMN-WI -2.259
## 237                                   PittsburghPA -2.262
## 76                               CumberlandMD-WV -2.264
## 317                                       WausauWI -2.299
## 147                                    JohnstownPA -2.301
## 319                                 WheelingWV-OH -2.355
## 31                               Beaver-CountyPA -2.399
## 322                                WilliamsportPA -2.433
## 91                                   Eau-ClaireWI -2.476
## 4                     Albany-Schenectady-TroyNY -2.494
## 277                       Scranton-Wilkes-BarrePA -2.591
## 55                                   BurlingtonVT -2.613
## 121                                 Grand-ForksND -2.669
```

Factor Analysis

```
non_zero_var <- apply(data_log, 2, var) != 0
data_log_filtered <- data_log[, non_zero_var]
fa.data <- factanal(data_log_filtered, 3, rotation = "none")
fa.data
```

```
##
## Call:
## factanal(x = data_log_filtered, factors = 3, rotation = "none")
##
## Uniquenesses:
## HousingCost    HlthCare       Crime      Transp        Educ        Arts
##       0.922       0.582       0.247       0.542       0.588       0.629
##     Recreat        Econ        <NA>        NA.1        NA.2        NA.3
##       0.264       0.600       0.797       0.983       0.451       0.005
##        NA.4        NA.5
##       0.510       0.928
##
## Loadings:
##             Factor1 Factor2 Factor3
## HousingCost  0.232          -0.147
## HlthCare     0.560   0.212  -0.245
## Crime        0.802   0.154   0.292
## Transp       0.434  -0.408  -0.322
## Educ         0.590   0.223  -0.122
## Arts         0.461           0.387
## Recreat      0.844   0.121
## Econ         0.510          -0.373
## <NA>         0.195  -0.397
## NA.1                        -0.122
## NA.2                         0.739
## NA.3                 0.997
## NA.4         0.700
## NA.5        -0.125   0.185   0.147
##
##                Factor1 Factor2 Factor3
## SS loadings      3.278   1.500   1.174
## Proportion Var   0.234   0.107   0.084
## Cumulative Var   0.234   0.341   0.425
##
## Test of the hypothesis that 3 factors are sufficient.
## The chi square statistic is 231.32 on 52 degrees of freedom.
## The p-value is 1.83e-24
```

```
fa.dataRot = factanal(data_log_filtered, 3, rotation = "varimax")
fa.dataRot
```

```
##
## Call:
## factanal(x = data_log_filtered, factors = 3, rotation = "varimax")
##
## Uniquenesses:
## HousingCost    HlthCare       Crime      Transp        Educ        Arts
##       0.922       0.582       0.247       0.542       0.588       0.629
##     Recreat        Econ        <NA>        NA.1        NA.2        NA.3
##       0.264       0.600       0.797       0.983       0.451       0.005
##        NA.4        NA.5
##       0.510       0.928
##
## Loadings:
##             Factor1 Factor2 Factor3
## HousingCost  0.202   0.144   0.130
## HlthCare     0.587           0.272
## Crime        0.824          -0.269
## Transp       0.289   0.568   0.228
## Educ         0.623           0.153
## Arts         0.483          -0.369
## Recreat      0.839   0.144   0.104
## Econ         0.482   0.187   0.364
## <NA>                 0.444
## NA.1                         0.127
## NA.2                -0.152  -0.721
## NA.3         0.275  -0.938   0.199
## NA.4         0.669   0.205
## NA.5                -0.238  -0.106
##
##                Factor1 Factor2 Factor3
## SS loadings      3.247   1.600   1.105
## Proportion Var   0.232   0.114   0.079
## Cumulative Var   0.232   0.346   0.425
##
## Test of the hypothesis that 3 factors are sufficient.
## The chi square statistic is 231.32 on 52 degrees of freedom.
## The p-value is 1.83e-24
```

```
fa.dataRot = factanal(data_log_filtered, 4, rotation = "varimax")
fa.dataRot
```

```
##
## Call:
## factanal(x = data_log_filtered, factors = 4, rotation = "varimax")
##
## Uniquenesses:
## HousingCost    HlthCare       Crime      Transp        Educ        Arts
##       0.897       0.005       0.257       0.501       0.557       0.626
##     Recreat        Econ        <NA>        NA.1        NA.2        NA.3
##       0.266       0.616       0.688       0.981       0.411       0.005
##        NA.4        NA.5
##       0.494       0.888
##
## Loadings:
##             Factor1 Factor2 Factor3 Factor4
## HousingCost  0.176  -0.107   0.225  -0.100
## HlthCare     0.375           0.919
## Crime        0.769           0.181   0.344
## Transp       0.407  -0.496          -0.295
## Educ         0.643   0.113          -0.109
## Arts         0.436                   0.421
## Recreat      0.828           0.215
## Econ         0.460           0.298  -0.278
## <NA>                -0.435   0.345
## NA.1                                -0.104
## NA.2                        -0.113   0.755
## NA.3         0.150   0.981
## NA.4         0.690  -0.125   0.108
## NA.5                 0.219  -0.241
##
##                Factor1 Factor2 Factor3 Factor4
## SS loadings      2.930   1.507   1.289   1.083
## Proportion Var   0.209   0.108   0.092   0.077
## Cumulative Var   0.209   0.317   0.409   0.486
##
## Test of the hypothesis that 4 factors are sufficient.
## The chi square statistic is 130.3 on 41 degrees of freedom.
## The p-value is 3.13e-11
```

```
fa.dataRot = factanal(data_log_filtered, 2, rotation = "varimax")
fa.dataRot
```

```
##
## Call:
## factanal(x = data_log_filtered, factors = 2, rotation = "varimax")
##
## Uniquenesses:
## HousingCost    HlthCare       Crime      Transp        Educ        Arts
##       0.926       0.670       0.344       0.345       0.611       0.749
##     Recreat        Econ        <NA>        NA.1        NA.2        NA.3
##       0.259       0.701       0.855       0.997       0.877       0.617
##        NA.4        NA.5
##       0.519       0.921
##
## Loadings:
##             Factor1 Factor2
## HousingCost  0.202   0.184
## HlthCare     0.570
## Crime        0.806
## Transp       0.291   0.755
## Educ         0.621
## Arts         0.480  -0.144
## Recreat      0.851   0.134
## Econ         0.484   0.255
## <NA>                 0.372
## NA.1
## NA.2                -0.343
## NA.3         0.209  -0.582
## NA.4         0.673   0.169
## NA.5                -0.276
##
##                Factor1 Factor2
## SS loadings      3.185   1.425
## Proportion Var   0.228   0.102
## Cumulative Var   0.228   0.329
##
## Test of the hypothesis that 2 factors are sufficient.
## The chi square statistic is 430.63 on 64 degrees of freedom.
## The p-value is 9.29e-56
```

```
fa.dataRot = factanal(data_log_filtered, 1, rotation = "varimax")
fa.dataRot
```

```
##
## Call:
## factanal(x = data_log_filtered, factors = 1, rotation = "varimax")
##
## Uniquenesses:
## HousingCost    HlthCare       Crime      Transp        Educ        Arts
##       0.950       0.657       0.416       0.860       0.614       0.806
##     Recreat        Econ        <NA>        NA.1        NA.2        NA.3
##       0.240       0.718       0.980       0.998       1.000       0.986
##        NA.4        NA.5
##       0.534       0.991
##
## Loadings:
##             Factor1
## HousingCost  0.224
## HlthCare     0.585
## Crime        0.764
## Transp       0.375
## Educ         0.621
## Arts         0.440
## Recreat      0.872
## Econ         0.531
## <NA>         0.143
## NA.1
## NA.2
## NA.3         0.120
## NA.4         0.683
## NA.5
##
##                Factor1
## SS loadings      3.249
## Proportion Var   0.232
##
## Test of the hypothesis that 1 factor is sufficient.
## The chi square statistic is 636.54 on 77 degrees of freedom.
## The p-value is 5.74e-89
```

Canonical Correlation Analysis

```r
# One group -> Arts and Health Care
```

```r
X= data_log_filtered[,c(3,7)]
Y= data_log_filtered[,-c(3,7)]
cor(X)
```

```
##             Crime   Recreat
## Crime   1.0000000 0.6781286
## Recreat 0.6781286 1.0000000
```

```r
cor(Y)
```

```
##             HousingCost    HlthCare      Transp        Educ       Arts
## HousingCost  1.00000000  0.27296448  0.22775093  0.03424105 0.07745819
## HlthCare     0.27296448  1.00000000  0.13923425  0.32428769 0.20208781
## Transp       0.22775093  0.13923425  1.00000000  0.27559314 0.05550755
## Educ         0.03424105  0.32428769  0.27559314  1.00000000 0.32230122
## Arts         0.07745819  0.20208781  0.05550755  0.32230122 1.00000000
## Econ         0.12060965  0.46069631  0.29212402  0.39390231 0.09300112
## <NA>        -0.10429920  0.29032351  0.26817467  0.05924675 0.11549945
## NA.1         0.09501600  0.09298513  0.03831948 -0.01130171 0.01554301
## NA.2        -0.11705350 -0.14638998 -0.24881019 -0.06147827 0.35253448
## NA.3        -0.05381434  0.20935822 -0.40815361  0.22012207 0.08817433
## NA.4         0.20809655  0.34544939  0.34113491  0.40221425 0.33969890
## NA.5        -0.06505669 -0.22173325 -0.22292407 -0.01292504 0.12302572
##                    Econ          <NA>         NA.1          NA.2        NA.3
## HousingCost  0.12060965 -0.1042991959  0.095015998 -0.1170534964 -0.05381434
## HlthCare     0.46069631  0.2903235124  0.092985132 -0.1463899813  0.20935822
## Transp       0.29212402  0.2681746726  0.038319477 -0.2488101862 -0.40815361
## Educ         0.39390231  0.0592467535 -0.011301715 -0.0614782729  0.22012207
## Arts         0.09300112  0.1154994504  0.015543006  0.3525344776  0.08817433
## Econ         1.00000000  0.1722302876  0.058535433 -0.2016984139  0.02915801
## <NA>         0.17223029  1.0000000000  0.009677032  0.0005405777 -0.39740006
## NA.1         0.05853543  0.0096770315  1.000000000 -0.1074371900  0.03843321
## NA.2        -0.20169841  0.0005405777 -0.107437190  1.0000000000  0.02150614
## NA.3         0.02915801 -0.3974000570  0.038433206  0.0215061428  1.00000000
## NA.4         0.34528737  0.0597583731  0.014569723  0.0008033670 -0.01293795
## NA.5        -0.08809709 -0.0766658507  0.010948639  0.0753732601  0.18525107
##                     NA.4        NA.5
## HousingCost  0.208096552 -0.06505669
## HlthCare     0.345449386 -0.22173325
## Transp       0.341134909 -0.22292407
## Educ         0.402214251 -0.01292504
## Arts         0.339698897  0.12302572
## Econ         0.345287369 -0.08809709
## <NA>         0.059758373 -0.07666585
## NA.1         0.014569723  0.01094864
## NA.2         0.000803367  0.07537326
## NA.3        -0.012937948  0.18525107
```

```
## NA.4         1.000000000 -0.03839843
## NA.5        -0.038398426  1.00000000
```

```
cor(X,Y)
```

```
##         HousingCost  HlthCare    Transp      Educ      Arts      Econ
## Crime     0.1505609 0.4319355 0.1836245 0.4473941 0.4647636 0.2540362
## Recreat   0.1726830 0.5085013 0.3464617 0.5523397 0.3478985 0.4965191
##               <NA>        NA.1        NA.2      NA.3      NA.4        NA.5
## Crime   0.02262154 0.003321376  0.25532857 0.1494006 0.5945858 -0.08063887
## Recreat 0.10685220 0.027538373 -0.03294129 0.1167302 0.5665396 -0.05281775
```

```
cca.almanac = cc(X,Y)
cca.almanac$cor # 2 canonical Correlations
```

```
## [1] 0.7932054 0.4774861
```

The CCA analysis indicates two canonical correlations: 0.793 and 0.477. These values represent the strength of the relationship between the two sets of variables (X and Y) in a reduced-dimensional space. A higher canonical correlation suggests a stronger relationship between the sets of variables.

```
cca.almanac$xcoef; cca.almanac$ycoef
```

```
##               [,1]       [,2]
## Crime   -0.7444834  1.6866868
## Recreat -0.4320033 -0.9941881
```

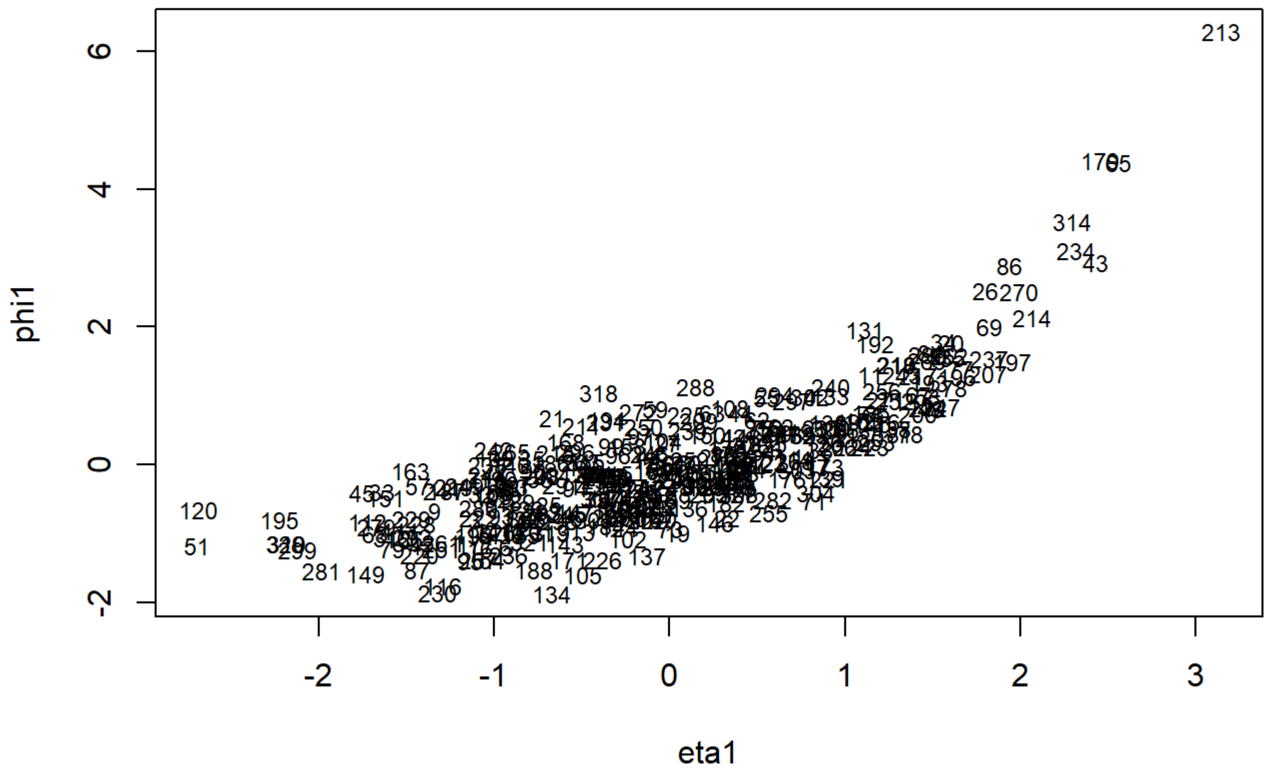
```
##                    [,1]          [,2]
## HousingCost  1.042019e-01  2.580476e-02
## HlthCare    -1.575696e+00  2.203967e-01
## Transp      -4.386140e-01 -6.006368e-01
## Educ        -1.842730e-04 -1.056164e-04
## Arts        -1.451181e+00  1.189129e+00
## Econ        -2.098991e-01 -1.265259e+00
## <NA>         1.196040e-04 -1.129163e-04
## NA.1         6.299739e-05  2.775650e-04
## NA.2        -1.526817e-02  3.780540e-02
## NA.3        -8.645051e-03 -2.578585e-04
## NA.4        -4.777664e-07  3.709736e-07
## NA.5        -9.772853e-05 -1.456368e-02
```

The coefficient for the first canonical variable (x1) is -0.744 for Crime and -0.432 for Recreat. This indicates that Crime has a stronger influence on the first canonical variable compared to Recreat. In other words, a higher value of the first canonical variable indicates higher Crime and lower Recreat.

The coefficient for HousingCost is 0.104 for y1 and 0.026 for y2. This means that HousingCost has a small positive influence on both the first and second canonical variables.

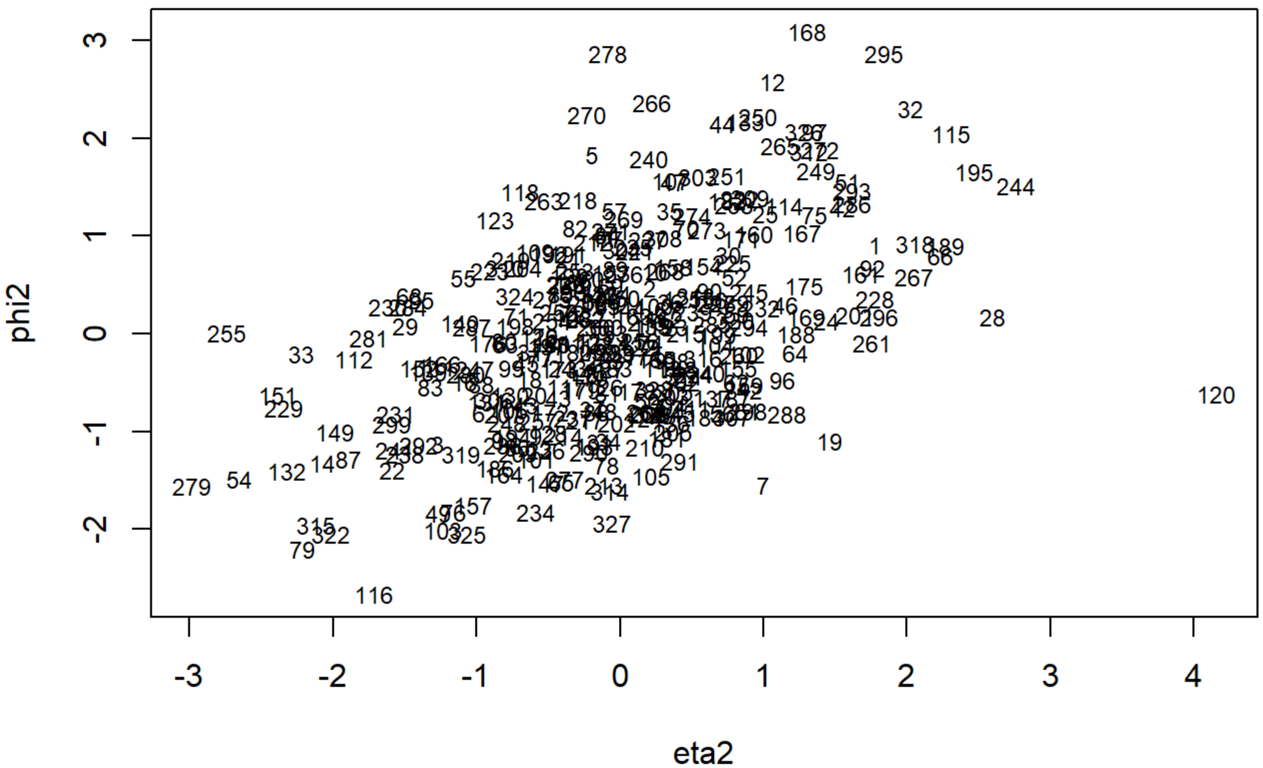
Similarly, the coefficients for HlthCare, Transp, Educ, Arts, and Econ indicate their contributions to the first and second canonical variables.

```
plot(-cca.almanac$scores$xscores[,1],-cca.almanac$scores$yscores[,1],
     type="n",xlab="eta1",ylab="phi1")

text(x = -cca.almanac$scores$xscores[,1], y = -cca.almanac$scores$yscores[,1],
     labels = row.names(places), cex=.75)
```



This graph verifies the correlation.

```
plot(-cca.almanac$scores$xscores[,2],-cca.almanac$scores$yscores[,2],
     type="n",xlab="eta2",ylab="phi2")

text(x = -cca.almanac$scores$xscores[,2], y = -cca.almanac$scores$yscores[,2],
     labels = row.names(places), cex=.75)
```



It is safe to say that we might consider second canonical correlation as less important.