COVID-19 patients, deaths, and death rate

04/27/2020

Source of the data

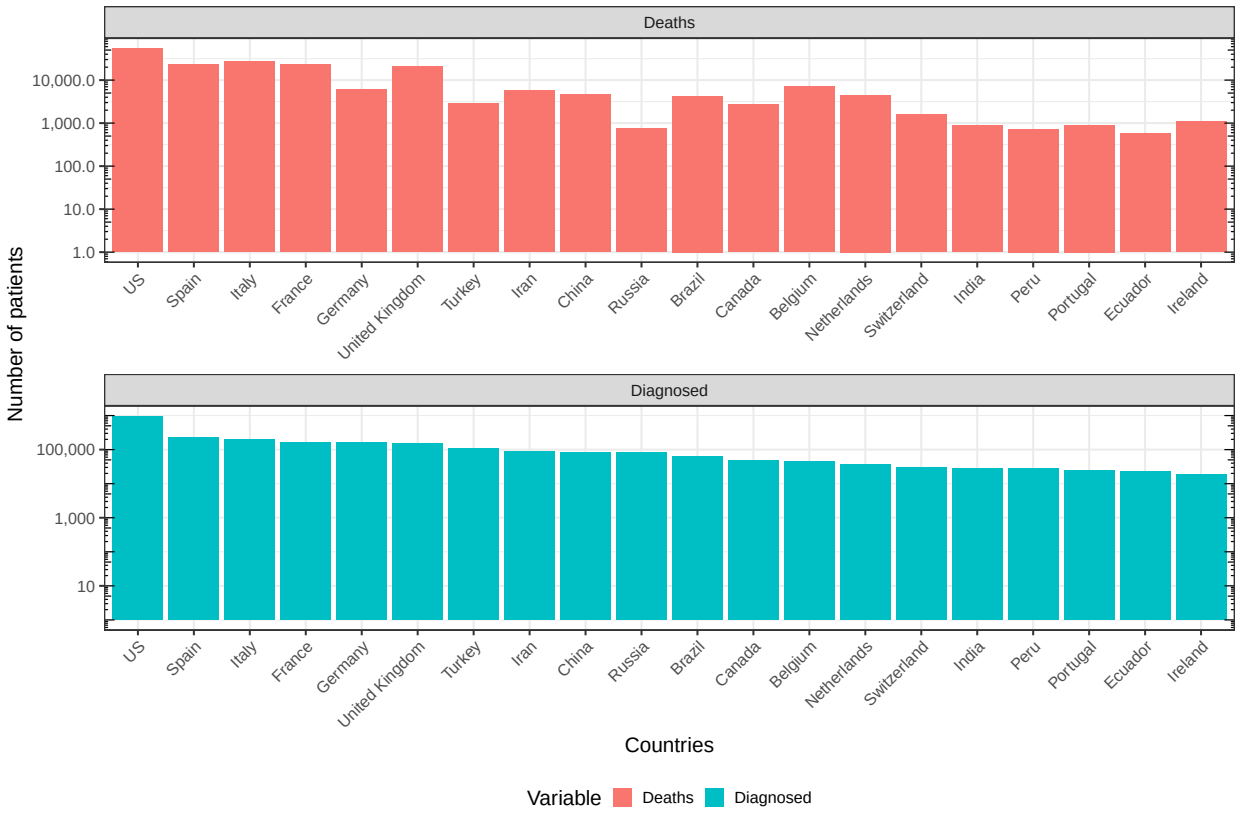
The data is compiled from https://github.com/CSSEGISandData/COVID-19.

The python script *script.py* is a modification of https://github.com/JacopoPan/JHU-2019nCoV-to-pandas-DF

Here I avoided any data modeling and am just showing the raw number of diagnosed patients, deaths, death rate, new cases by day, and new deaths by day.

Top countries by cases and deaths

```
deathmat = read.csv("deaths.tsv", header=T,
                    sep="\t", check.names=F, row.names=1)
countdeath = apply(deathmat[nrow(deathmat),1:(ncol(deathmat) - 1)], 2, sum)

casemat = read.csv("confirmed.tsv",
                   header=T, sep="\t", check.names=F, row.names=1)
countcases = apply(casemat[nrow(casemat),1:(ncol(casemat) - 1)], 2, sum)

totaldf = data.frame(Countries=c(names(countdeath), names(countcases)),
                     Values=as.numeric(c(countdeath, countcases)),
                     Variable=c(rep("Deaths", length(countdeath)),
                                rep("Diagnosed", length(countcases))))
select_countries = names(sort(countcases, TRUE))[1:20]

totaldf = totaldf[totaldf$Countries %in% select_countries, ]
totaldf$Countries = factor(totaldf$Countries, levels=select_countries)

P = ggplot(totaldf, aes(x=Countries, y=Values, fill=Variable)) +
  geom_bar(stat="identity", position="dodge") +
  facet_wrap(~Variable, nrow=2, scales="free") +
  theme_bw(base_size=18) +
  scale_y_log10("Number of patients", labels=comma) +
  theme(legend.position="bottom",
        axis.text.x=element_text(angle=45, hjust=1)) +
  annotation_logticks(sides="lr")
plot(P)
```



Calculate doubling rate for each country since April 1st

- Red line will show daily increase of twice.
- Purple line will show daily increase of 10%
- Blue line will show daily increase of 1%

```
get_expected = function(datadf, rate=2, init=100){
  list.data = lapply(unique(datadf$variable), function(country){
    tempdf = datadf[datadf$variable==country, ]
    # idx_st = min(which(tempdf$value >= init))
    idx_st = min(which(tempdf$date >= as.Date("2020-04-01")))
    init_val = tempdf$value[idx_st]
    advals = sapply(1:nrow(tempdf), function(x){
      if(x > idx_st){
        return(init_val * (rate**(x - idx_st)))
      }else{
        return(0)
      }
    })
    ad_df = data.frame(variable=country, Rate=rate,
                       date=tempdf$date, value=advals)
    return(ad_df)
  })
  out_df = do.call("rbind", list.data)
```

```
  return(out_df)
}
```

Total morbidity

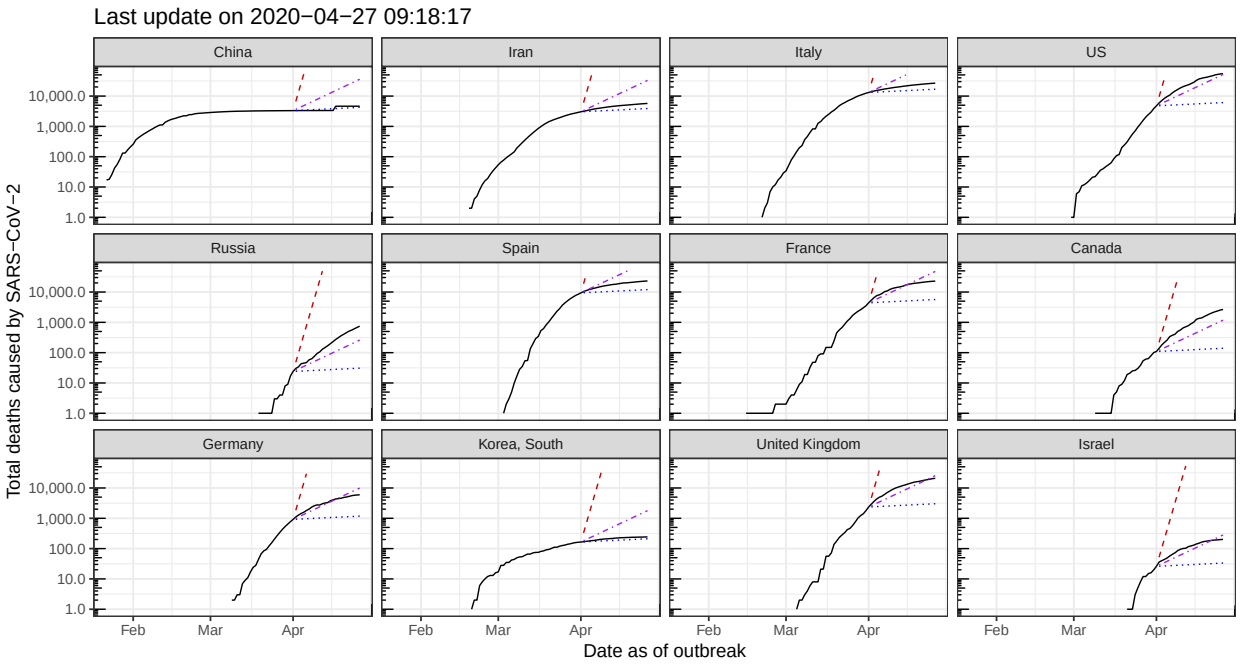
```
deathmat = read.csv("deaths.tsv", header=T,
                    sep="\t", check.names=F, row.names=1)
countries = c("China", "Iran", "Italy",
              "US", "Russia", "Spain",
              "France", "Canada", "Germany",
              "Korea, South", "United Kingdom", "Israel")
deathmat = deathmat[,c(countries, "date")]

moltendf = melt(deathmat)
```

```
## Using date as id variables
```

```
moltendf$date = as.Date(moltendf$date)

doubling_df = get_expected(moltendf, rate=2, init=100)
onepercent_df = get_expected(moltendf, rate=1.01, init=100)
tenpercent_df = get_expected(moltendf, rate=1.1, init=100)

P2 = ggplot(moltendf[moltendf$value > 0,],
            aes(x=date, y=(value),
                group=variable)) +
  geom_line() +
  geom_line(data=doubling_df[doubling_df$value > 0,], colour="red3", linetype=2) +
  geom_line(data=onepercent_df[onepercent_df$value > 0,], colour="blue", linetype=3) +
  geom_line(data=tenpercent_df[tenpercent_df$value > 0,], colour="purple", linetype=4) +
  theme_bw(base_size=14) +
  facet_wrap(~variable) +
  scale_y_log10(
    name="Total deaths caused by SARS-CoV-2", labels=comma, limits=c(1, max(moltendf$value))) +
  xlab("Date as of outbreak") +
  ggtitle(paste("Last update on", Sys.time())) +
  annotation_logticks()

plot(P2)
```

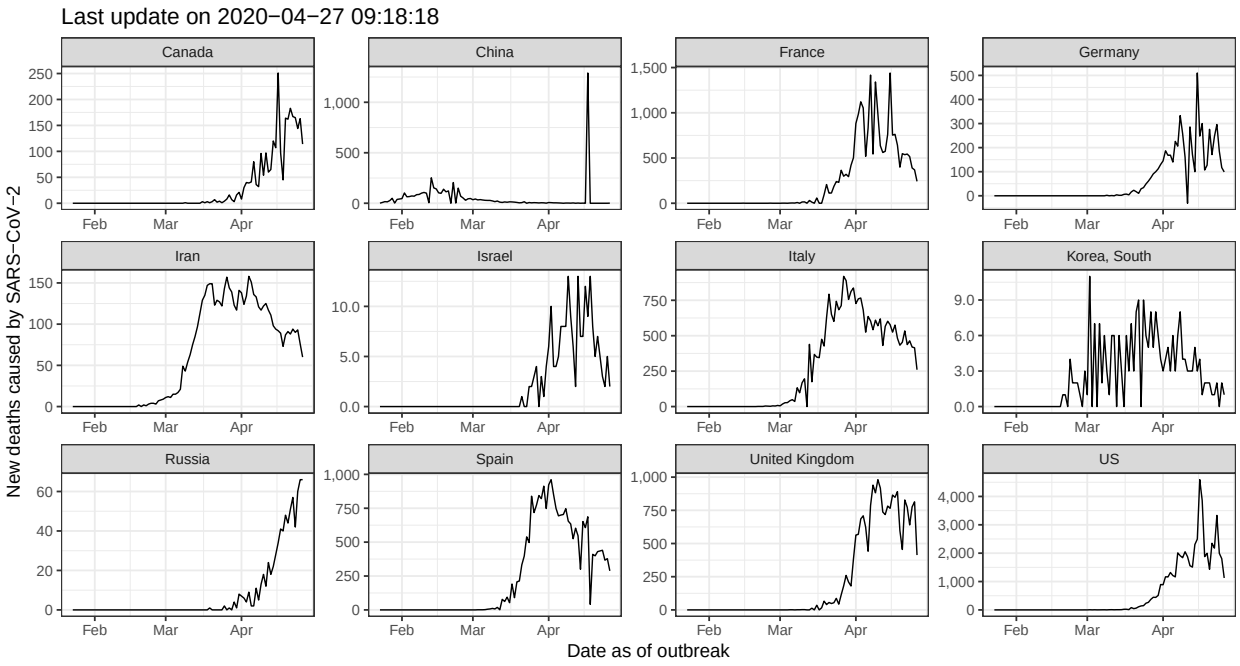
```
## Warning: Removed 235 row(s) containing missing values (geom_path).
```

```
## Warning: Removed 18 row(s) containing missing values (geom_path).
```



New deaths by day

```
list.data = lapply(colnames(deathmat)[1:(ncol(deathmat)-1)], function(country){
  new_cases = diff(deathmat[,country])
  addf = data.frame(date=deathmat$date[2:nrow(deathmat)],
                    variable=country,
                    value=new_cases)
})
moltendf = do.call("rbind", list.data)

moltendf$date = as.Date(moltendf$date)

P = ggplot(moltendf, aes(x=date, y=value, group=variable)) +
  geom_line() +
  theme_bw(base_size=14) +
  facet_wrap(~variable, scales="free") +
  scale_y_continuous(
    name="New deaths caused by SARS-CoV-2", labels=comma) +
  ggtitle(paste("Last update on", Sys.time())) +
  xlab("Date as of outbreak")
plot(P)
```



Total COVID-19 patients

```
casemat = read.csv("confirmed.tsv",
                   header=T, sep="\t", check.names=F, row.names=1)

casemat = casemat[,c(countries, "date")]

moltendf = melt(casemat)
```

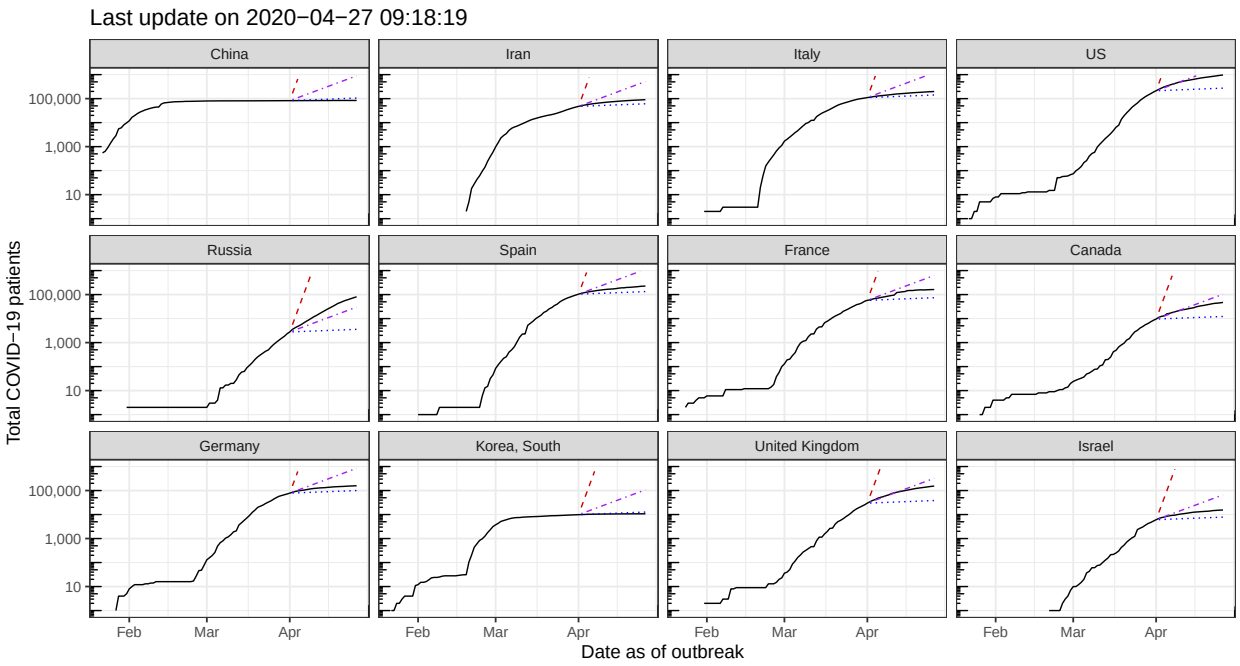
```
## Using date as id variables
```

```
moltendf$date = as.Date(moltendf$date)

doubling_df = get_expected(moltendf, rate=2, init=100)
onepercent_df = get_expected(moltendf, rate=1.01, init=100)
tenpercent_df = get_expected(moltendf, rate=1.1, init=100)


P2 = ggplot(moltendf[moltendf$value > 0, ], aes(x=date, y=(value), group=variable)) +
  geom_line() +
  theme_bw(base_size=14) +
  facet_wrap(~variable) +
  geom_line(data=doubling_df[doubling_df$value > 0,], colour="red3", linetype=2) +
  geom_line(data=onepercent_df[onepercent_df$value > 0,], colour="blue", linetype=3) +
  geom_line(data=tenpercent_df[tenpercent_df$value > 0,], colour="purple", linetype=4) +
  scale_y_log10(
    name="Total COVID-19 patients", labels=comma, limits=c(1, max(moltendf$value))) +
  xlab("Date as of outbreak") +
```

```
  ggtitle(paste("Last update on", Sys.time())) +
  annotation_logticks()

plot(P2)
```

```
## Warning: Removed 246 row(s) containing missing values (geom_path).
```

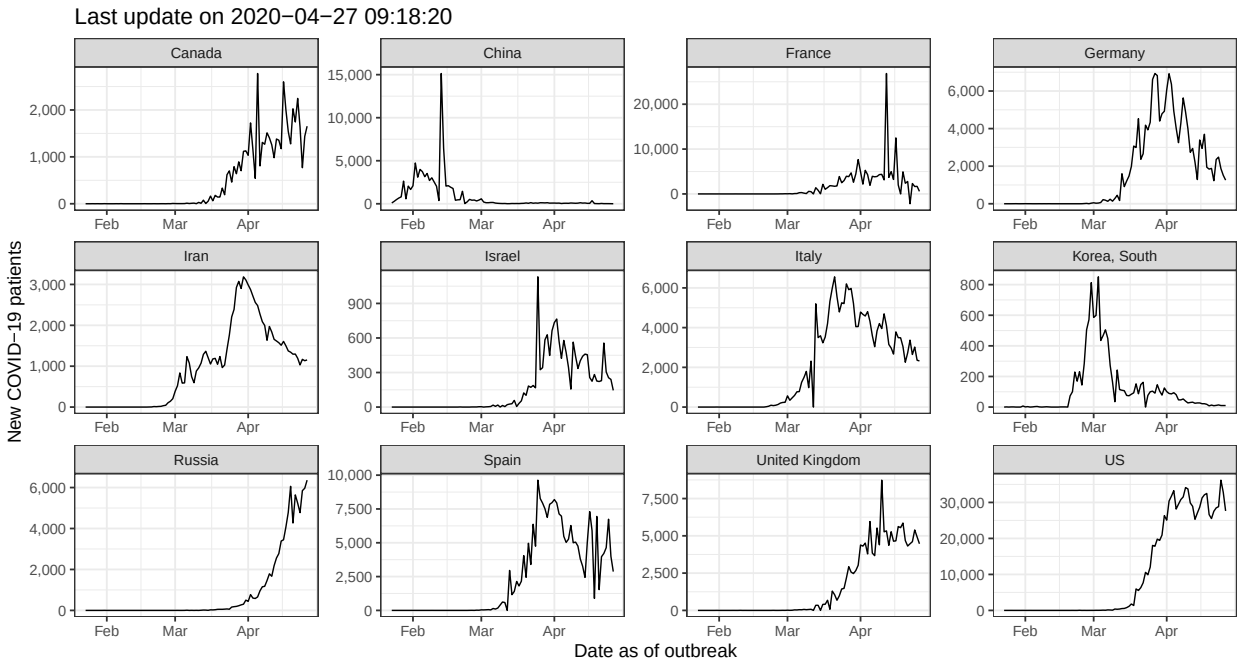
```
## Warning: Removed 15 row(s) containing missing values (geom_path).
```



New COVID-19 patients by day

```
list.data = lapply(colnames(casemat)[1:(ncol(casemat)-1)], function(country){
  new_cases = diff(casemat[,country])
  addf = data.frame(date=casemat$date[2:nrow(casemat)],
                    variable=country,
                    value=new_cases)
})
moltendf = do.call("rbind", list.data)

moltendf$date = as.Date(moltendf$date)

P = ggplot(moltendf, aes(x=date, y=value, group=variable)) +
  geom_line() +
  theme_bw(base_size=14) +
  facet_wrap(~variable, scales="free") +
  scale_y_continuous(
    name="New COVID-19 patients", labels=comma) +
  ggtitle(paste("Last update on", Sys.time())) +
```

```
  xlab("Date as of outbreak")
plot(P)
```

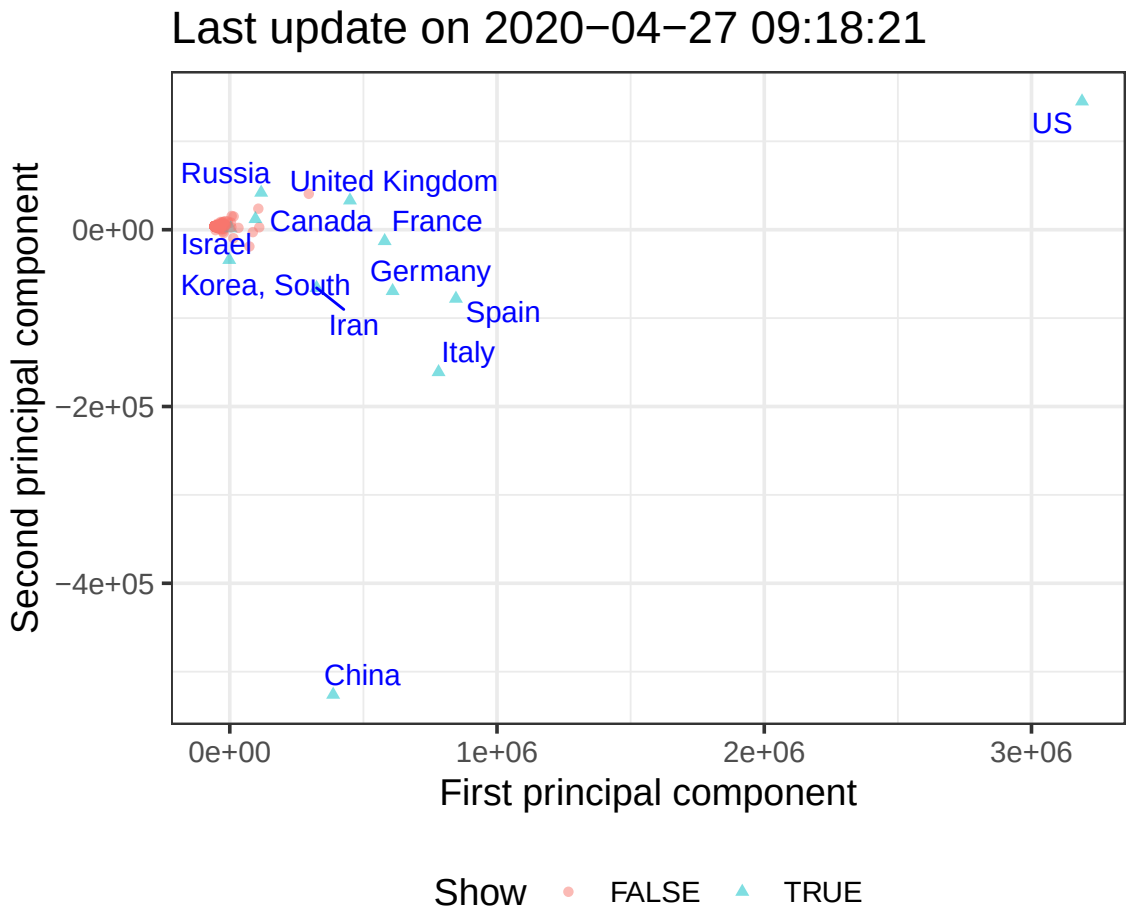


PCA of countries by total patients

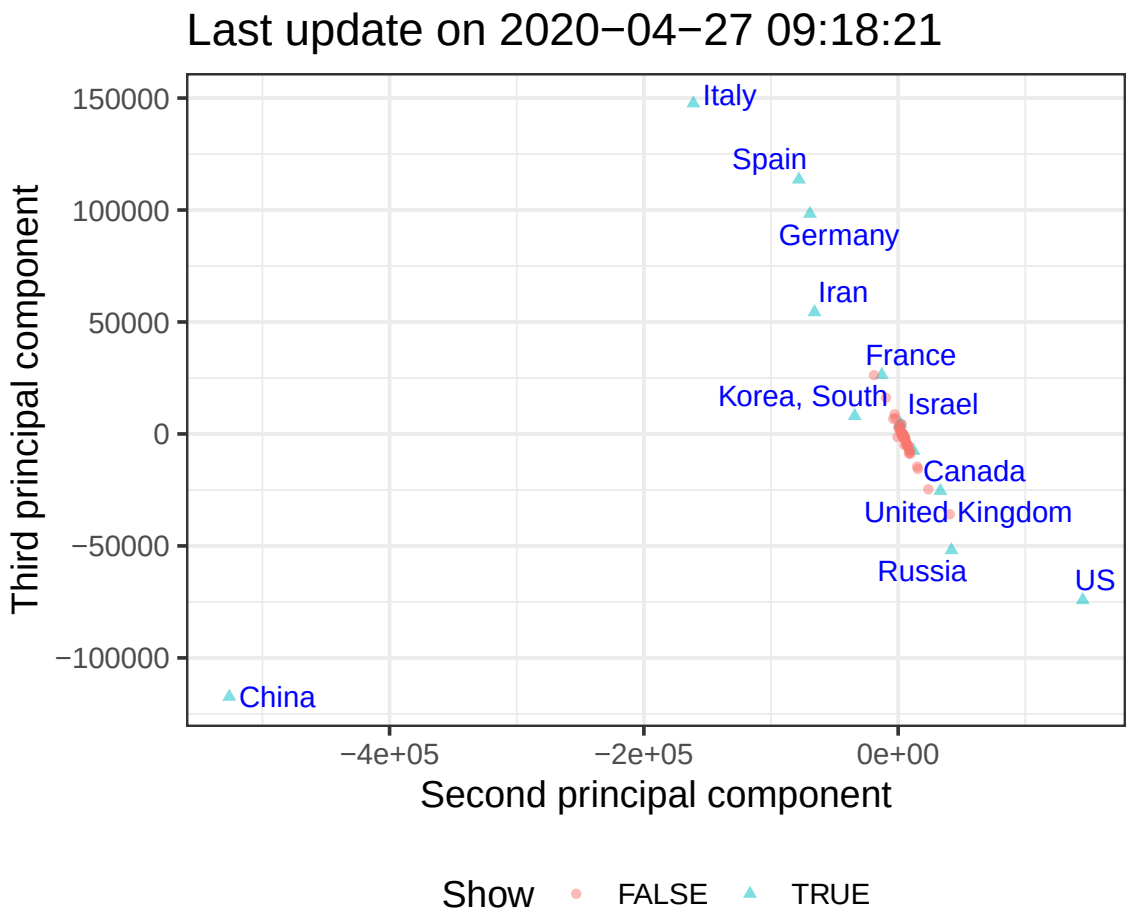
Principal component analysis identifies non-correlating variables (components) from the data and here can identify outlier countries according to a single variable.

In the following plots, I show the first three principal components for total diagnosed patients by day, total deaths by day, and also death rate by day.

```
casemat = read.csv("confirmed.tsv", header=T, sep="\t", check.names=F, row.names=1)

pcamat = casemat[,1:(ncol(casemat) - 1)]
PCA = prcomp(t(pcamat))
pcadf = as.data.frame(PCA$x)
pcadf$Country = colnames(casemat)[1:nrow(pcadf)]
pcadf$Show = ifelse(pcadf$Country %in% countries, TRUE, FALSE)

P = ggplot(pcadf, aes(x=PC1, y=PC2)) +
  geom_point(aes(colour=Show, shape=Show), alpha=0.5) +
  geom_text_repel(data=pcadf[pcadf$Show,], aes(label=Country), colour="blue", size=4) +
  theme_bw(base_size=14) +
  xlab("First principal component") +
  ylab("Second principal component") +
  ggtitle(paste("Last update on", Sys.time())) +
  theme(legend.position="bottom")
plot(P)
```

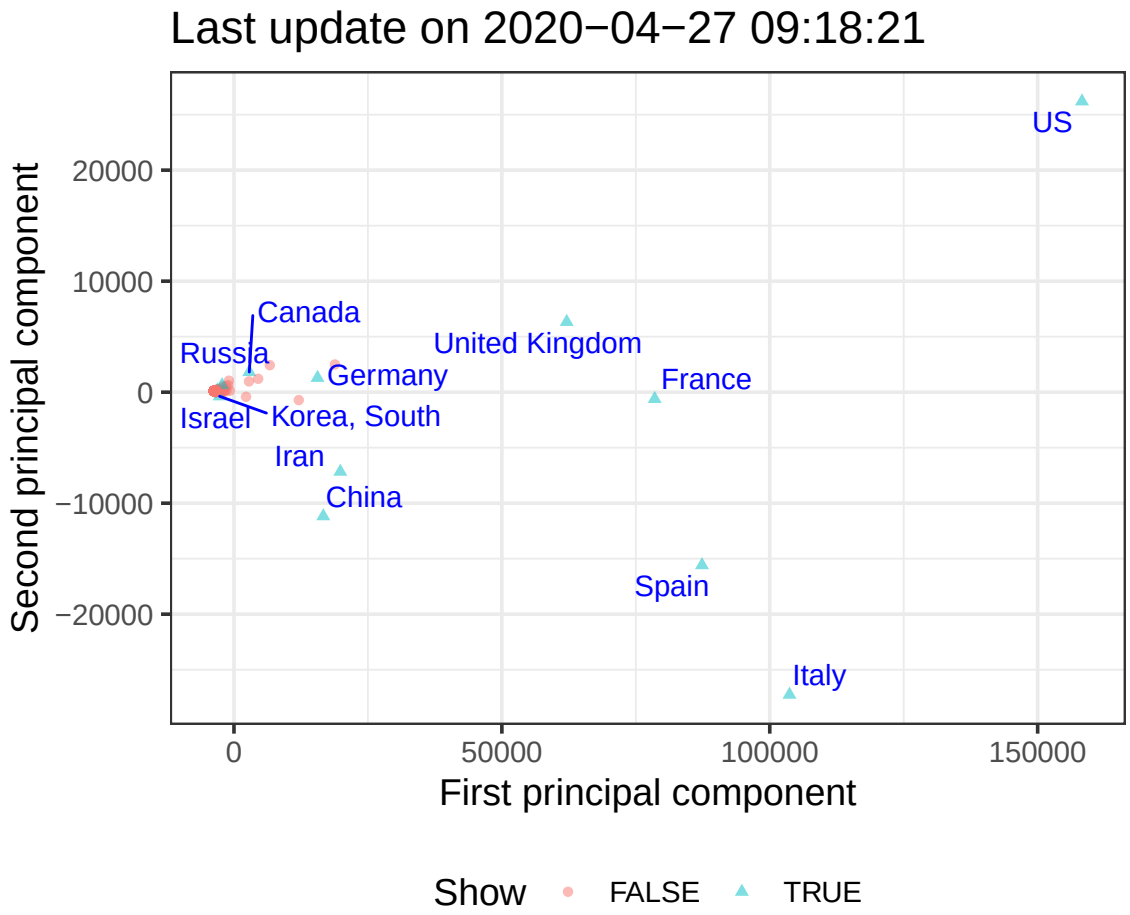



```
P = ggplot(pcadf, aes(x=PC2, y=PC3)) +
  geom_point(aes(colour=Show, shape=Show), alpha=0.5) +
  geom_text_repel(data=pcadf[pcadf$Show,], aes(label=Country), colour="blue", size=4) +
  theme_bw(base_size=14) +
  ylab("Third principal component") +
  xlab("Second principal component") +
  ggtitle(paste("Last update on", Sys.time())) +
  theme(legend.position="bottom")
plot(P)
```

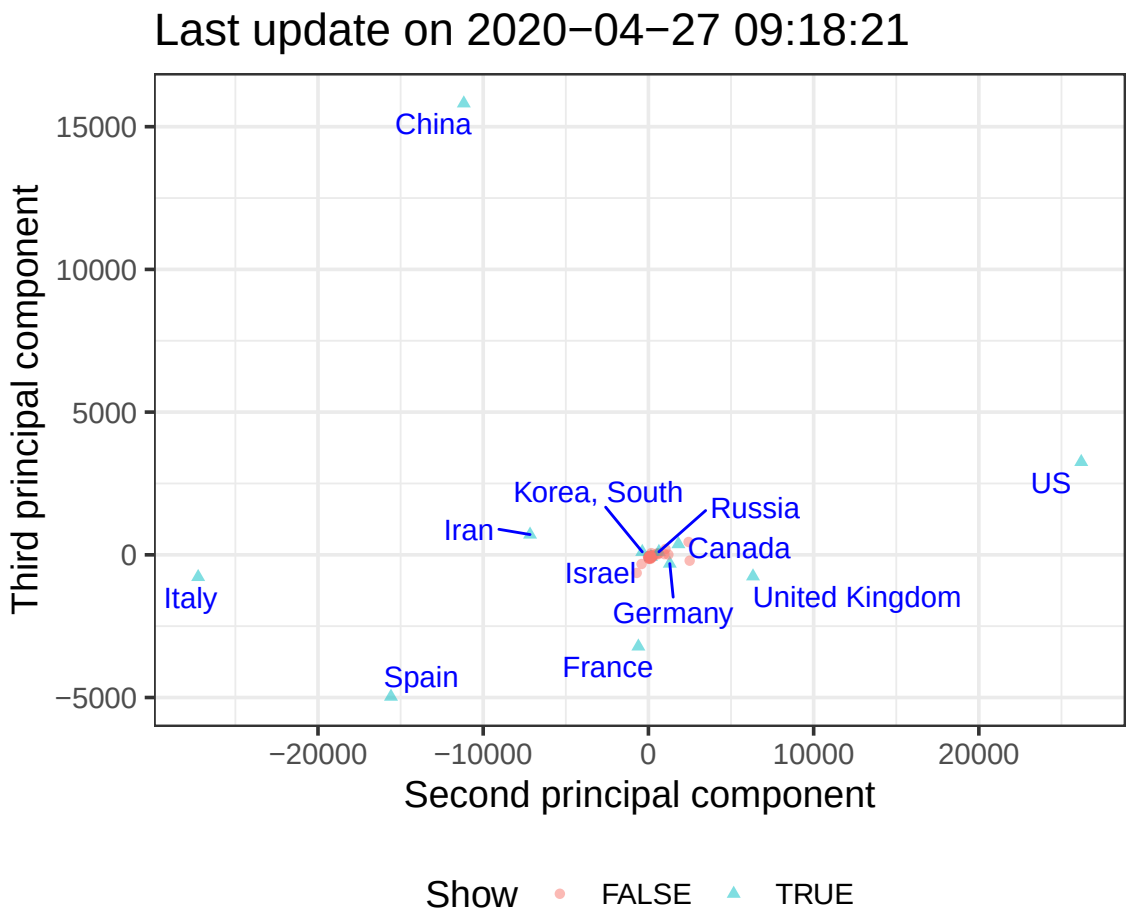


PCA of countries by morbidity

```
deathmat = read.csv("deaths.tsv", header=T,
                    sep="\t", check.names=F, row.names=1)

pcamat = deathmat[,1:(ncol(deathmat) - 1)]
PCA = prcomp(t(pcamat))
pcadf = as.data.frame(PCA$x)
pcadf$Country = colnames(deathmat)[1:nrow(pcadf)]
pcadf$Show = ifelse(pcadf$Country %in% countries, TRUE, FALSE)

P = ggplot(pcadf, aes(x=PC1, y=PC2)) +
  geom_point(aes(colour=Show, shape=Show), alpha=0.5) +
  geom_text_repel(data=pcadf[pcadf$Show,], aes(label=Country), colour="blue", size=4) +
  theme_bw(base_size=14) +
  xlab("First principal component") +
  ylab("Second principal component") +
  ggtitle(paste("Last update on", Sys.time())) +
  theme(legend.position="bottom")
plot(P)
```




```
P = ggplot(pcadf, aes(x=PC2, y=PC3)) +
  geom_point(aes(colour=Show, shape=Show), alpha=0.5) +
  geom_text_repel(data=pcadf[pcadf$Show,], aes(label=Country), colour="blue", size=4) +
  theme_bw(base_size=14) +
  ylab("Third principal component") +
  xlab("Second principal component") +
  ggtitle(paste("Last update on", Sys.time())) +
  theme(legend.position="bottom")
plot(P)
```



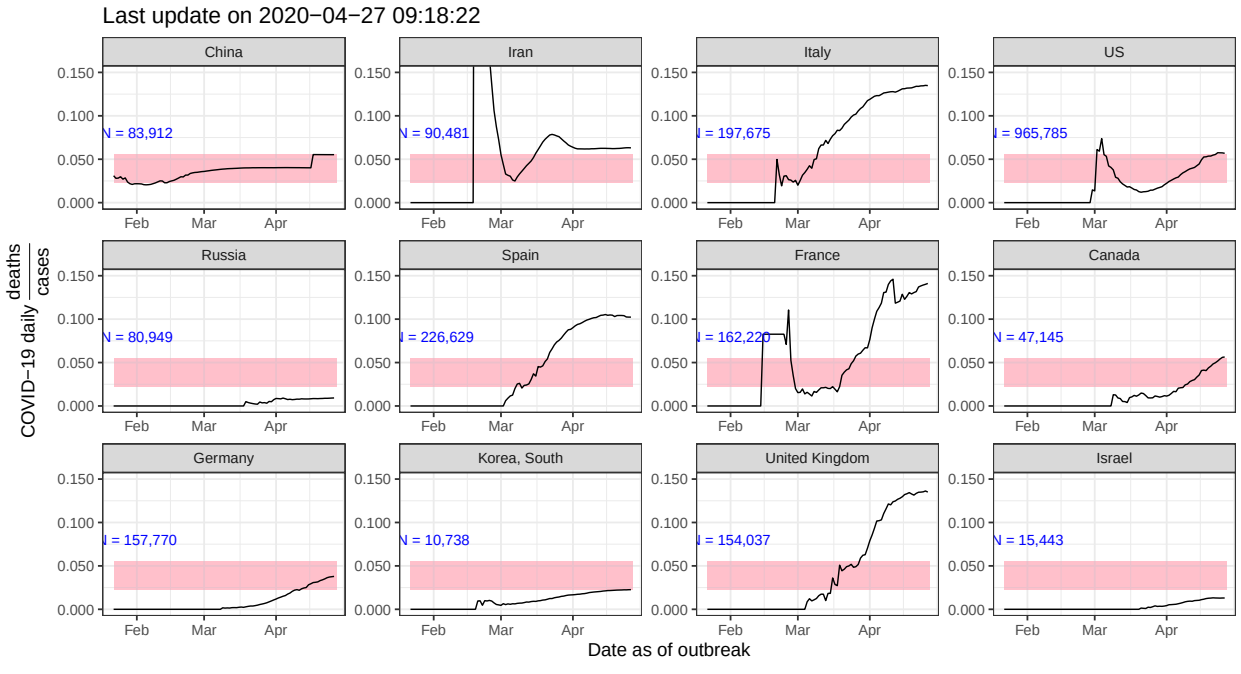
Death rate

The two countries which succeeded in stopping the spread, China and South Korea, provide the most accurate measurement of true death rate. In the death rate plot below, the range of the death rate of these two countries is shown by pink.

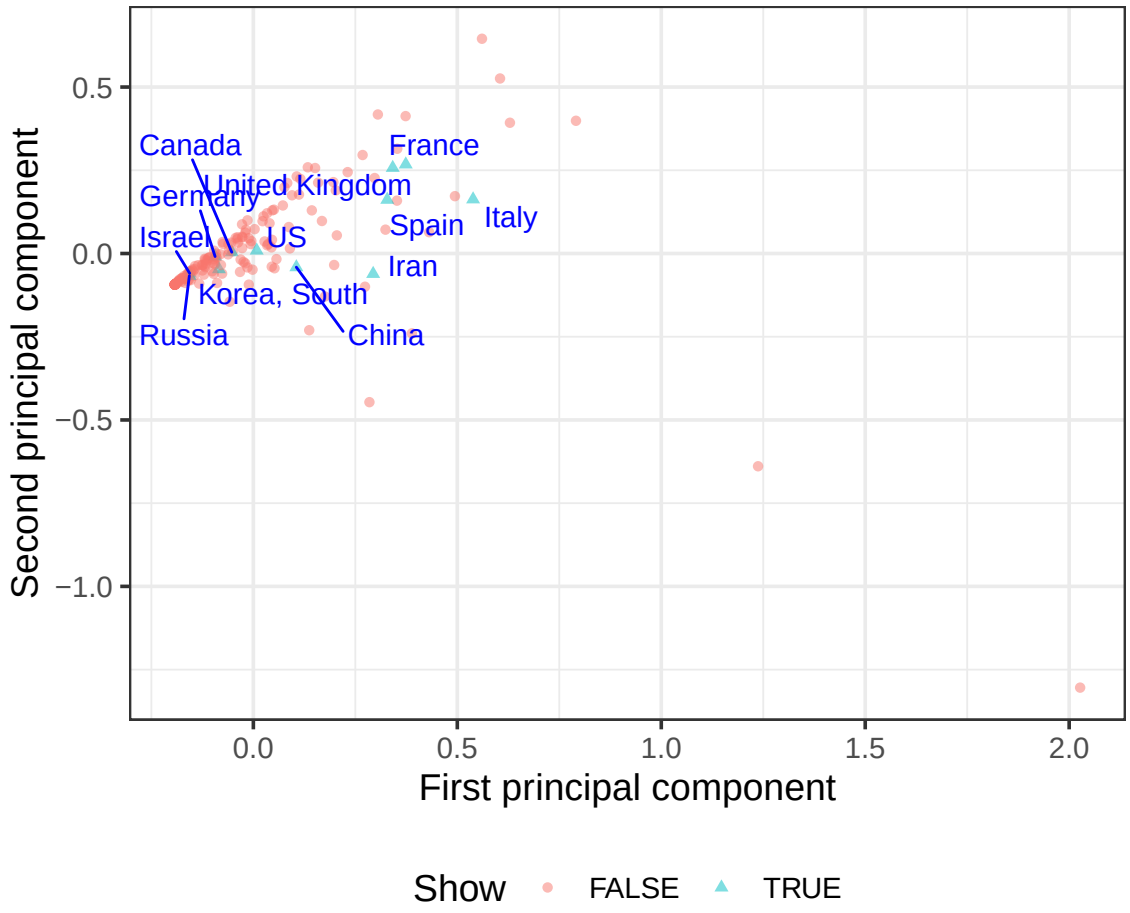
```
deathmat = read.csv("deaths.tsv", header=T,
                    sep="\t", check.names=F, row.names=1)
casemat = read.csv("confirmed.tsv", header=T, sep="\t", check.names=F, row.names=1)
deathrate = deathmat[,1:(ncol(deathmat) - 1)] / (0.1  + casemat[,setdiff(colnames(deathmat), "date")])

deathratedf = deathrate
deathratedf$date = casemat$date
moltendf = melt(deathratedf[,c(countries, "date")])


## Using date as id variables

moltendf$date = as.Date(moltendf$date)

moltendf$Label = NA
deathratedf$date = as.Date(deathratedf$date)
```

```
textmat = casemat[which.max(casemat[,"China"]), ]
textdf = melt(as.data.frame(textmat[,c(countries, "date")]))


## Using date as id variables
```

```
textdf$date = min(as.Date(deathratedf$date)) + 10
textdf$Label = paste("N =", comma(textdf$value))
textdf$value = 0.08

P = ggplot(moltendf, aes(x=date, y=value, group=variable)) +
  geom_rect(xmin=min(deathratedf$date),
            xmax=max(deathratedf$date+1),
            ymin=max(deathratedf$China),
            ymax=max(deathratedf[,"Korea, South"]),
            alpha=0.05,
            fill="pink") +
  geom_line() +
  geom_text(data=textdf, aes(x=date, y=value, label=Label), colour='blue') +
  theme_bw(base_size=14) +
  facet_wrap(~variable, scales="free") +
  scale_y_continuous(
    name=expression("COVID-19 daily "*frac("deaths", "cases")),
    labels=comma) +
  xlab("Date as of outbreak") +
  ggtitle(paste("Last update on", Sys.time())) +
  coord_cartesian(ylim=c(0, 0.15))
plot(P)
```

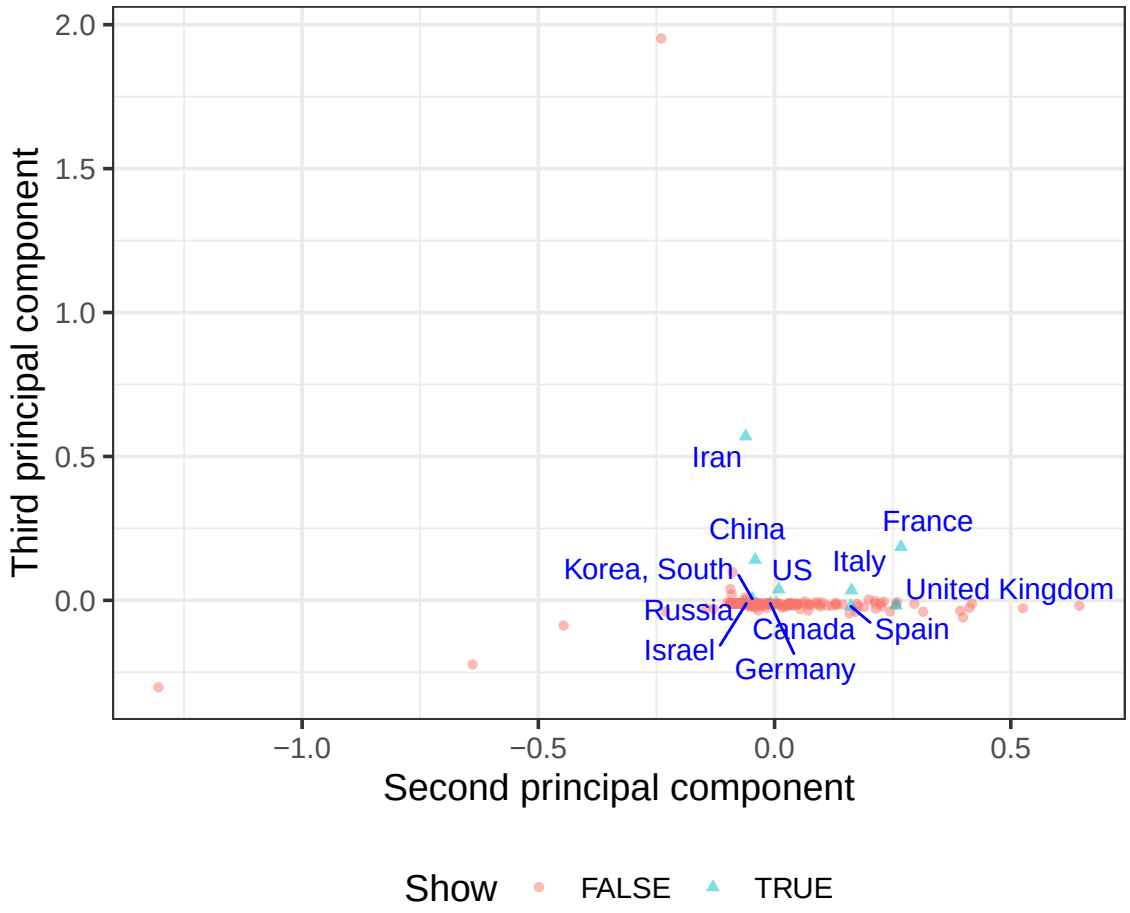


```
pcamat = deathrate
PCA = prcomp(t(pcamat))
pcadf = as.data.frame(PCA$x)
pcadf$Country = colnames(deathmat)[1:nrow(pcadf)]
pcadf$Show = ifelse(pcadf$Country %in% countries, TRUE, FALSE)

P = ggplot(pcadf, aes(x=PC1, y=PC2)) +
  geom_point(aes(colour=Show, shape=Show), alpha=0.5) +
  geom_text_repel(data=pcadf[pcadf$Show,], aes(label=Country), colour="blue", size=4) +
  theme_bw(base_size=14) +
  xlab("First principal component") +
  ylab("Second principal component") +
  theme(legend.position="bottom")
plot(P)
```




```
P = ggplot(pcadf, aes(x=PC2, y=PC3)) +
  geom_point(aes(colour=Show, shape=Show), alpha=0.5) +
  geom_text_repel(data=pcadf[pcadf$Show,], aes(label=Country), colour="blue", size=4) +
  theme_bw(base_size=14) +
  ylab("Third principal component") +
  xlab("Second principal component") +
  theme(legend.position="bottom")
```

```
plot(P)
```



Canada

```
casepath = "COVID-19/csse_covid_19_data/csse_covid_19_time_series/time_series_covid19_confirmed_global.
casedf = read.csv(casepath, header=T, check.names=F)
casedf = casedf[casedf[,2]=="Canada", c(1, 5:ncol(casedf))]
provinces = casedf[apply(casedf[,2:ncol(casedf)], 1, sum) > 0, 1]
casedf = casedf[casedf[,1] %in% provinces,]


moltendf = melt(casedf)
```

```
## Using Province/State as id variables
```

```
moltendf$date = as.Date(as.character(moltendf$variable), tryFormats="%m/%d/%y")

moltendf$variable = moltendf[,"Province/State"]
doubling_df = get_expected(moltendf, rate=2, init=100)
```

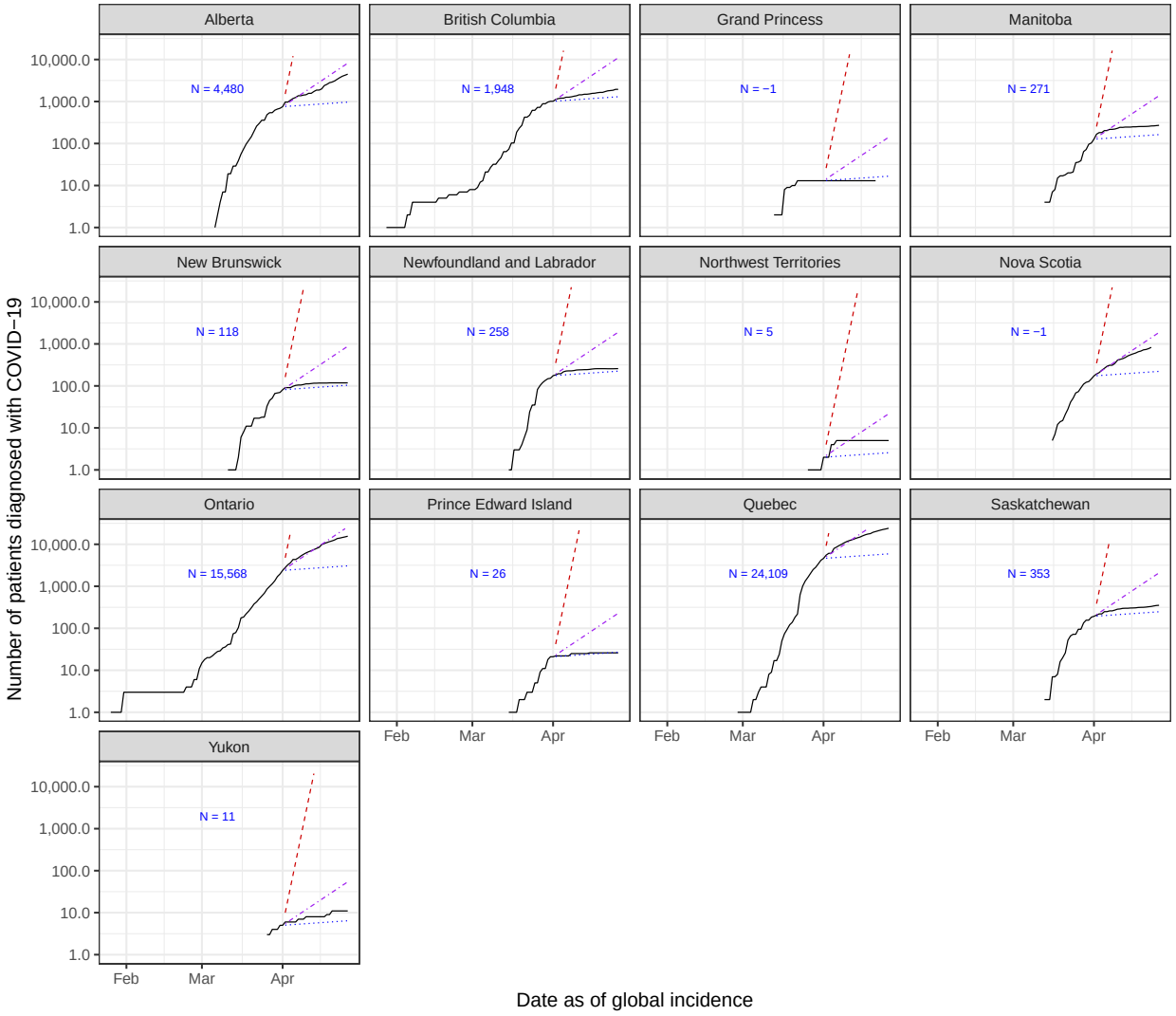
```
doubling_df[,"Province/State"] = doubling_df$variable
onepercent_df = get_expected(moltendf, rate=1.01, init=100)
onepercent_df[,"Province/State"] = onepercent_df$variable
tenpercent_df = get_expected(moltendf, rate=1.1, init=100)
tenpercent_df[,"Province/State"] = tenpercent_df$variable


textdf = melt(casedf[,c(1, ncol(casedf))])
```

```
## Using Province/State as id variables
```

```
textdf$date = as.Date(as.character(textdf$variable), tryFormats="%m/%d/%y")
textdf$date = min(as.Date(textdf$date)) - 50
textdf$Label = paste("N =", comma(round(textdf$value)))
textdf$value = 2000

P = ggplot(moltendf[moltendf$value > 0,], aes(x=date, y=value, group=`Province/State`)) +
  geom_line() +
  geom_line(data=doubling_df[doubling_df$value > 0,], colour="red3", linetype=2) +
  geom_line(data=onepercent_df[onepercent_df$value > 0,], colour="blue", linetype=3) +
  geom_line(data=tenpercent_df[tenpercent_df$value > 0,], colour="purple", linetype=4) +
  geom_text(data=textdf, aes(label=Label), colour="blue") +
  theme_bw(base_size=18) +
  facet_wrap(~`Province/State`) +
  scale_y_log10("Number of patients diagnosed with COVID-19", labels=comma, limits=c(1, max(moltendf$va
  xlab("Date as of global incidence")
plot(P)
```

```
## Warning: Removed 232 row(s) containing missing values (geom_path).
```

```
## Warning: Removed 9 row(s) containing missing values (geom_path).
```



Canada's deaths

```
casepath = "COVID-19/csse_covid_19_data/csse_covid_19_time_series/time_series_covid19_deaths_global.csv
casedf = read.csv(casepath, header=T, check.names=F)
casedf = casedf[casedf[,2]=="Canada", c(1, 5:ncol(casedf))]
provinces = casedf[apply(casedf[,2:ncol(casedf)], 1, sum) > 0, 1]
casedf = casedf[casedf[,1] %in% provinces,]


moltendf = melt(casedf)
```

```
## Using Province/State as id variables
```

```
moltendf$date = as.Date(as.character(moltendf$variable), tryFormats="%m/%d/%y")

moltendf$variable = moltendf[,"Province/State"]
```

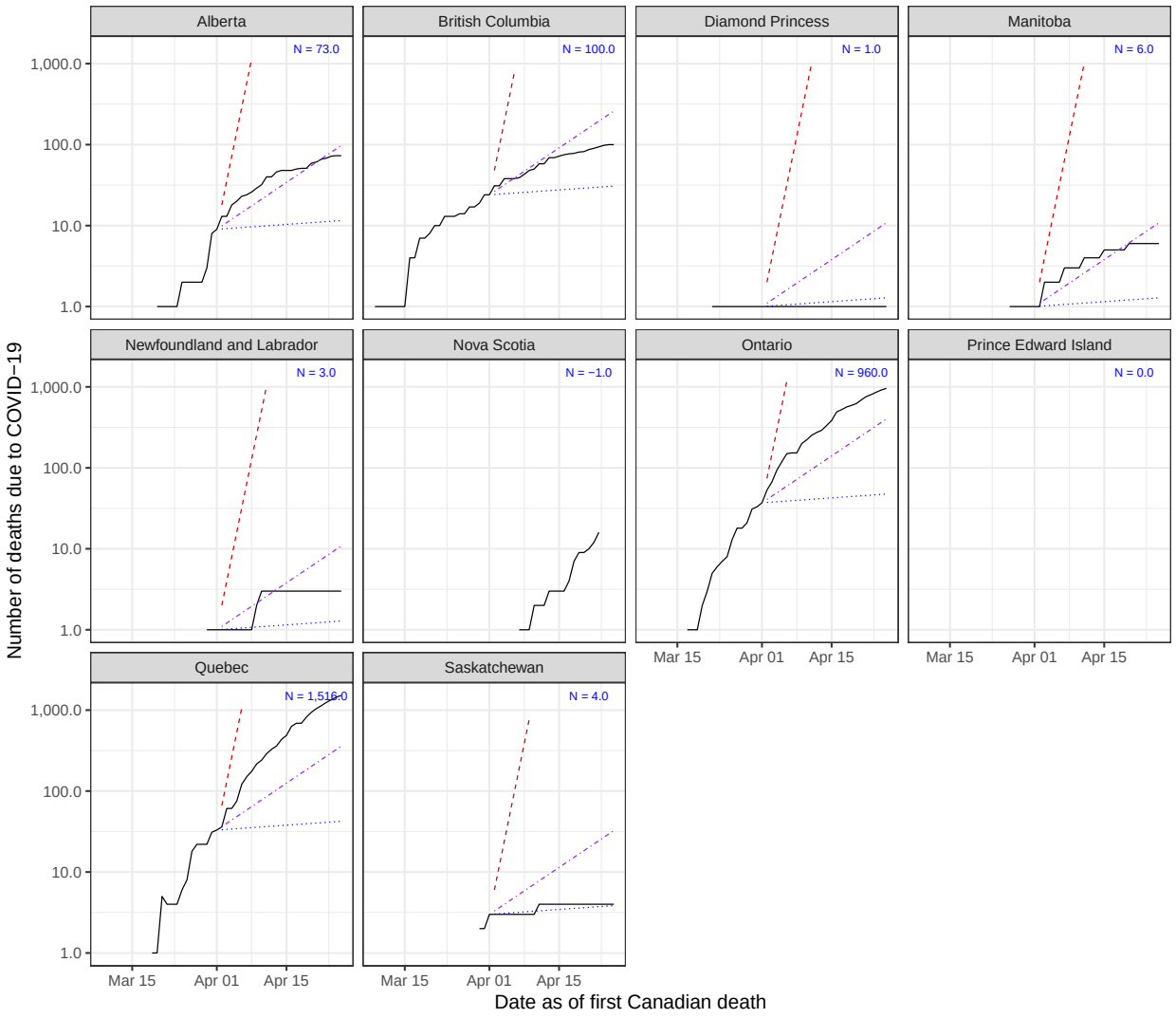
```
doubling_df = get_expected(moltendf, rate=2, init=100)
doubling_df[,"Province/State"] = doubling_df$variable
onepercent_df = get_expected(moltendf, rate=1.01, init=100)
onepercent_df[,"Province/State"] = onepercent_df$variable
tenpercent_df = get_expected(moltendf, rate=1.1, init=100)
tenpercent_df[,"Province/State"] = tenpercent_df$variable


textdf = melt(casedf[,c(1, ncol(casedf))])
```

```
## Using Province/State as id variables
```

```
textdf$date = as.Date(as.character(textdf$variable), tryFormats="%m/%d/%y")
textdf$date = min(as.Date(textdf$date)) - 5
textdf$Label = paste("N =", comma(round(textdf$value)))
textdf$value = max(moltendf$value)

P = ggplot(moltendf[moltendf$value > 0,], aes(x=date, y=value, group=`Province/State`)) +
  geom_line() +
  geom_line(data=doubling_df[doubling_df$value > 0,], colour="red3", linetype=2) +
  geom_line(data=onepercent_df[onepercent_df$value > 0,], colour="blue", linetype=3) +
  geom_line(data=tenpercent_df[tenpercent_df$value > 0,], colour="purple", linetype=4) +
  geom_text(data=textdf, aes(label=Label), colour="blue") +
  theme_bw(base_size=18) +
  facet_wrap(~`Province/State`) +
  scale_y_log10("Number of deaths due to COVID-19", labels=comma, limits=c(1, max(moltendf$value))) +
  xlab("Date as of first Canadian death")
plot(P)
```

```
## geom_path: Each group consists of only one observation. Do you need to adjust
## the group aesthetic?
```

```
## Warning: Removed 140 row(s) containing missing values (geom_path).
```


Alberta
N = 73.0
British Columbia
N = 100.0
Diamond Princess
N = 1.0
Manitoba
N = 6.0
Newfoundland and Labrador
N = 3.0
Nova Scotia
N = −1.0
Ontario
N = 960.0
Prince Edward Island
N = 0.0
Quebec
N = 1,516.0
Saskatchewan
N = 4.0
1,000.0
100.0
10.0
1.0
Mar 15
Apr 01
Apr 15
Number of deaths due to COVID−19
Date as of first Canadian death