Measuring Media Coverage of the Energy Trilemma

Contents

Introduction

This report analyses the the frequency of news media discussion of the three energy trilemma components: Accessibility, Security and Sustainability. It seeks to answer three research questions:

1. Overall, which components receive more attention in news media?
2. How does news coverage from different countries differ in terms of their emphases on different components.
3. How has the emphasis on different components changed over time?
4. How does the measure of news discussion compare to other measures of a country's prioritisation of the energy trilemma?

Key Terms

Discussion of each component of the energy trilemma was measured by measuring the frequency of key terms associated with each component. The tables below list the words included for each component.

Accessibility
ability to pay, able to pay, affordability, affordable, basic need, basic needs, budget, cheap, consumed, consumer, consumers, consuming, consumption, cooling, cost effective, cost-effective, development, economic class, economical, efficiency, electricity bill, electricity bills, energy bill, energy bills, energy burden, energy cost, energy efficiency, energy justice, energy poverty, energy prices, energy-efficiency, equity, fuel poverty, fuel-poverty, gas bill, gender, household, household cooling problems, household heating, household heating problems, households, inability to pay, inequalities, inequality, inequity, insurance, low cost, low income household, low income households, low-cost, low-income household, low-income households, lower class, lower-class, middle class, middle-class, minorities, personal finance, personal finances, race, reduced costs, reduces costs, reducing costs, social economic class, thermal comfort, transportation bills, trasportation poverty, unable to pay, underrepresented, underserved communities, unequal, upper class, upper-class, utility bill, utility bills, women, working class, working-class

Security
adequacy, aging infrastructure, agreement, black-out, black-outs, blackout, blackouts, certainty, conflicts, consistency, consistent, corrupted, corruption, disaster, disasters, energy crises, energy crisis, energy demand, geo-political, geo-politics, geopolitics, industries, industry, intermittancy, intermittent, nationalisation, nationalising, nationalization, nationalizing, neoliberalism, nuclear, peak hours, petro-politics, petropolitics, poor infrastructure, power cut, power cuts, power outage, power outages, reliability, reliable, resilience, resilient, secure, security, stability, war, wars

Sustainability
alternative, alternatives, bio-mass, biomass, c02, carbon capture, carbon neutral, carbon neutrality, carbon reduction, carbon-neutral, carbon-neutrality, CCS, CCU, centralised, centralized, clean energy, clean-energy, coal, decarbonisation, decarbonise, decarbonization, decarbonize, decentralised, decentralized, e-vehicles, eco-system, eco-systems, ecosystem, ecosystems, electric vehicles, electrical vehicles, emission, emissions, emits, emitted, emitting, energy storage, energy-storage, environmental health, EV, EVs, frack, fracked, fracking, geo-thermal, geothermal, green, greenhouse, hydrogen, low-carbon, natural gas, natural-gas, net zero, net-zero, nuclear, o-zone, ocean energy, ozone, paris agreement, photovoltaic, photovoltaics, pollutant, polluted, polluting, pollution, PV, PVs, re-newables, renewable energy, renewables, sea levels, sequester, sequestering, sequestration, solar, solar panel, solar panels, subsidies, subsidise, subsidising, subsidize, subsidizing, subsidy, sustainability, sustainable, tidal, transition, transitioning, transitions, wind, zero carbon, zero-carbon

Statistical analysis

Load libraries

```
library(ggtern)
library(ggrepel)
library(ggpubr)
library(openxlsx)
library(lme4)
library(mgcv)
library(tidyr)
source(file = "GAM_derivaties.R")
```

Load Data

```
d = read.csv("../data/LEXIS/TrilemmaScores_byCountry.csv",stringsAsFactors = F)

d$country[d$country=="South.Africa"] = "SA"
d$country[d$country=="Hong.Kong"] = "HK"
```

Load the keywords and adjust the total frequency to control for the number of keywords

```
kw = read.csv("../data/LEXIS/TrilemmaKeywords.csv",stringsAsFactors = F)

getKeywords= function(sub){
  kx = unique(unlist(strsplit(kw[kw$Subject==sub,]$concepts,";")))
  names(kx) = kx
  return(kx)
}
accessibilityKeywords = getKeywords("Accessibility")
securityKeywords = getKeywords("Security")
sustainabilityKeywords = getKeywords("Sustainability")

d$sustainability = d$sustainability / length(sustainabilityKeywords)
d$security = d$security / length(securityKeywords)
d$accessibility = d$accessibility / length(accessibilityKeywords)
```

Calculate proportional weighting of each component.

```
d$tot = d$accessibility + d$security + d$sustainability

d$Accessibility = d$accessibility / d$tot
d$Security = d$security / d$tot
d$Sustainability = d$sustainability / d$tot
```

Mean and sd for each component:

```
colMeans(d[,c("Sustainability","Security","Accessibility")])
```

```
## Sustainability       Security  Accessibility
##      0.5272599      0.3236735      0.1490666
```

```
apply(d[,c("Sustainability","Security","Accessibility")],2,sd)
```

```
## Sustainability       Security  Accessibility
##     0.04876250     0.03490054     0.03112543
```

Total number of words:

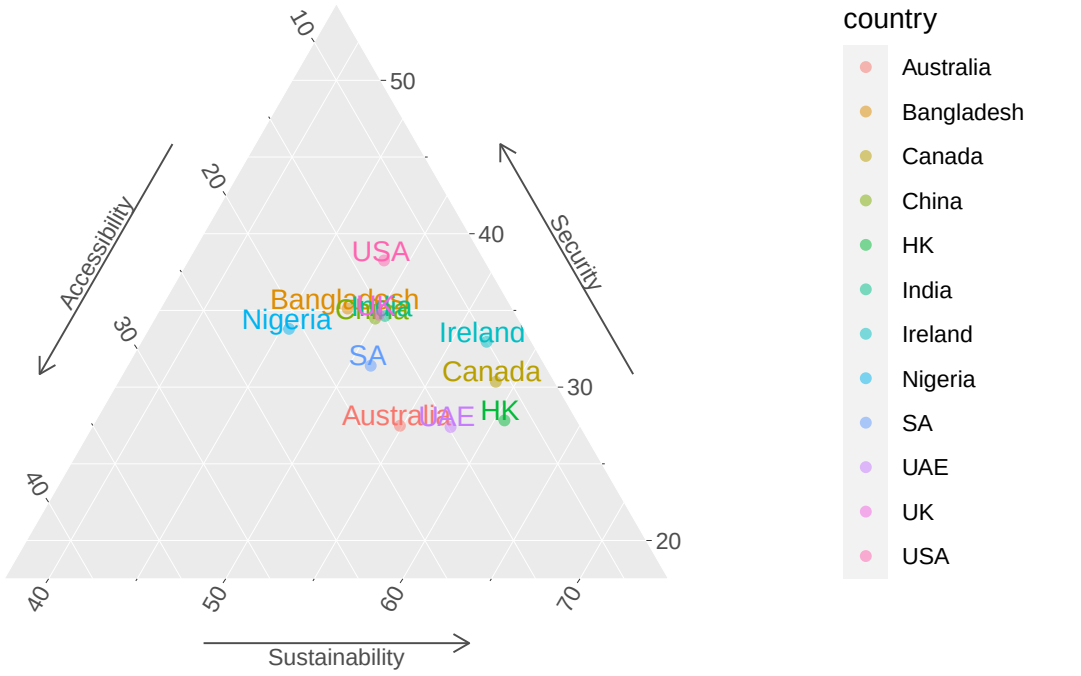
```
totalWords = sum(d$totalWords)
totalWords
```

```
## [1] 11609843
```

Analysis of overall scores

Create a ternary graph of the overall scores:

```
overallTern = ggtern(data=d,
       aes(x=Accessibility,y=Security, z=Sustainability)) +
  tern_limit(T=0.55,L=0.45,R=0.75) +
  theme_showarrows() +
  labs(x="",xarrow="Accessibility",
       y="",yarrow="Security",
       z="",zarrow="Sustainability")+
  geom_text(aes(label=country,colour=country),show.legend = FALSE,
            position = position_nudge_tern(y=0.01),
            alpha=1) +
  geom_point(aes(colour=country),alpha=0.5)
overallTern
```



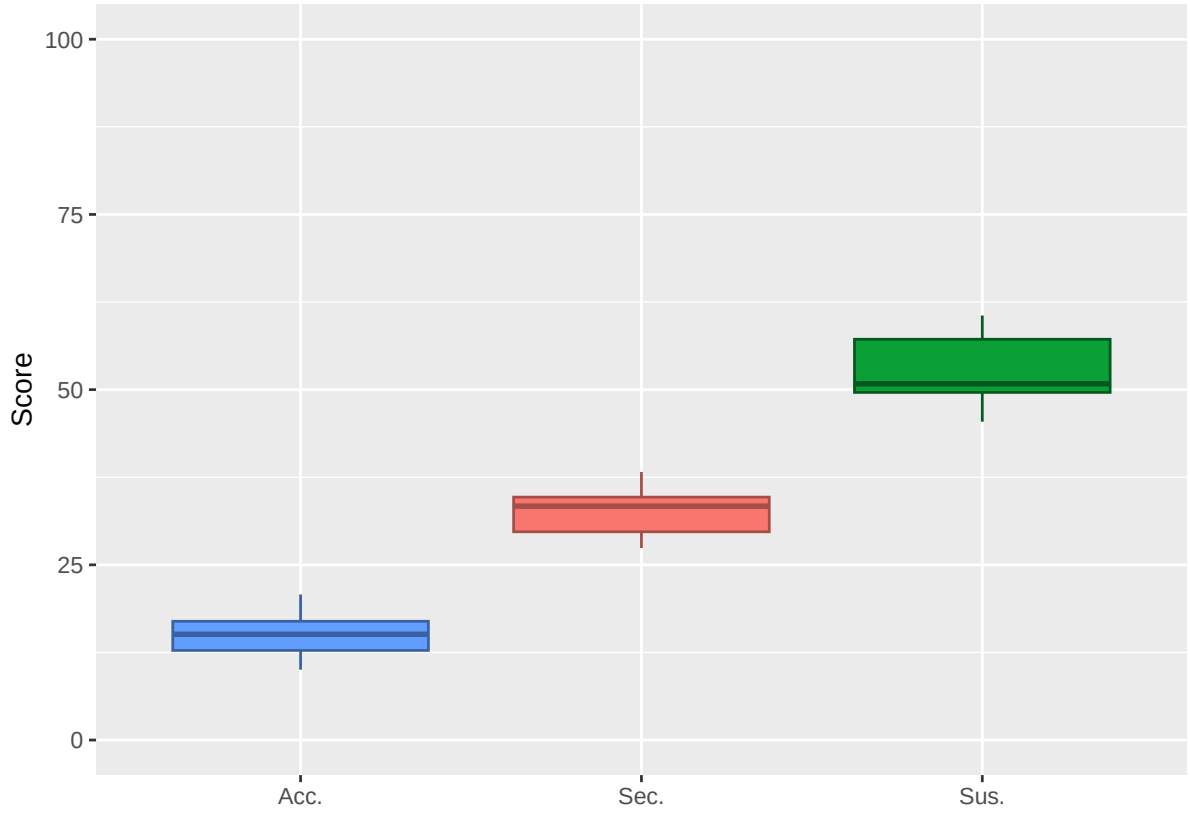

```
pdf(file="../results/COP_Overall_EnergyTrilemma.pdf")
overallTern
dev.off()
```

```
## pdf
##   2
```

Compare the weightings of the components:

```
boxplotData = data.frame(
  Score = c(d$Accessibility,d$Security,d$Sustainability)*100,
  Type = rep(c("Acc.","Sec.","Sus."),each=nrow(d)),
  Country = rep(d$country,3)
)

bpComp = ggplot(boxplotData,aes(y=Score,fill=Type,x=Type,color=Type))+
  geom_boxplot() +
```

```
  theme(axis.title.x = element_blank(), legend.position = "none") +
  ylim(c(0,100)) +
  scale_fill_manual(values=c("#619cffff","#f8766dff","#0a9f37ff")) +
  scale_color_manual(values=c("#3b61a1","#a34e48","#05591f"))

bpComp
```




```
pdf(file="../results/COP_Overall_EnergyTrilemma_Boxplot.pdf",
    width=1.7,height=3)
bpComp
dev.off()
```

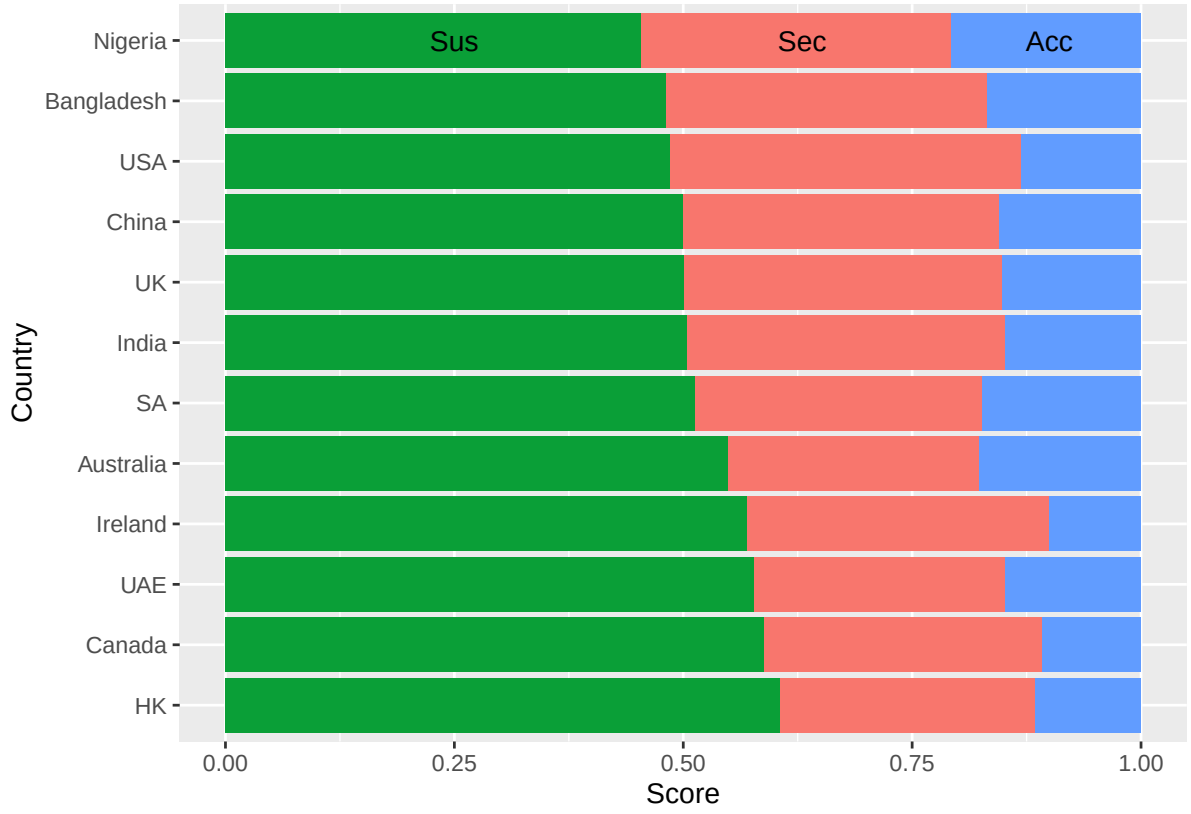
```
## pdf
##   2
```

Plot the overall results by country:

```
boxplotData$Country = factor(boxplotData$Country, levels =
  boxplotData[boxplotData$Type=="Sus.",]$Country[
    order(boxplotData[boxplotData$Type=="Sus.",]$Score,decreasing = T)])

balanceByCountry = ggplot(boxplotData,
                          aes(x=Country,y=Score,fill=Type)) +
  geom_bar(position="fill",stat="identity") +
  coord_flip() +
  theme(legend.position = "none") +
  annotate("text", x = 12, y = 0.25, label = "Sus")+
  annotate("text", x = 12, y = 0.63, label = "Sec")+
  annotate("text", x = 12, y = 0.9, label = "Acc") +
  scale_fill_manual(values=c("#619cffff","#f8766dff","#0a9f37ff"))
```

```
## Coordinate system already present. Adding new coordinate system, which will
## replace the existing one.
```

```
balanceByCountry
```




```
pdf("../results/COP_Overall_EnergyTrilemma_ByCountry.pdf",
    height=3,width=4)
balanceByCountry
dev.off()
```

```
## pdf
##   2
```

```
pdf("../results/COP_Boxplot_and_byCountry.pdf",
    width = 4.25,height=2.5)
ggarrange(bpComp+xlab("Component")+
            theme(axis.title.x=element_text()),
          balanceByCountry,nrow = 1,widths = c(1,2))
dev.off()
```

```
## pdf
##   2
```

The sustainability scores are clearly higher than security:

```
t.test(d$Sustainability,d$Security)
```

```
##
##  Welch Two Sample t-test
##
## data:  d$Sustainability and d$Security
## t = 11.761, df = 19.927, p-value = 2.028e-10
## alternative hypothesis: true difference in means is not equal to 0
## 95 percent confidence interval:
##  0.1674690 0.2397039
## sample estimates:
## mean of x mean of y
```

```
## 0.5272599 0.3236735
```

Check whether security is higher than accessibility:

```
t.test(d$Security,d$Accessibility)
```

```
##
##  Welch Two Sample t-test
##
## data:  d$Security and d$Accessibility
## t = 12.934, df = 21.718, p-value = 1.119e-11
## alternative hypothesis: true difference in means is not equal to 0
## 95 percent confidence interval:
##  0.1465895 0.2026243
## sample estimates:
## mean of x mean of y
## 0.3236735 0.1490666
```

Yes. So Sustainability > Security > Accessibility.

Analysis of change over time

Load data for each year:

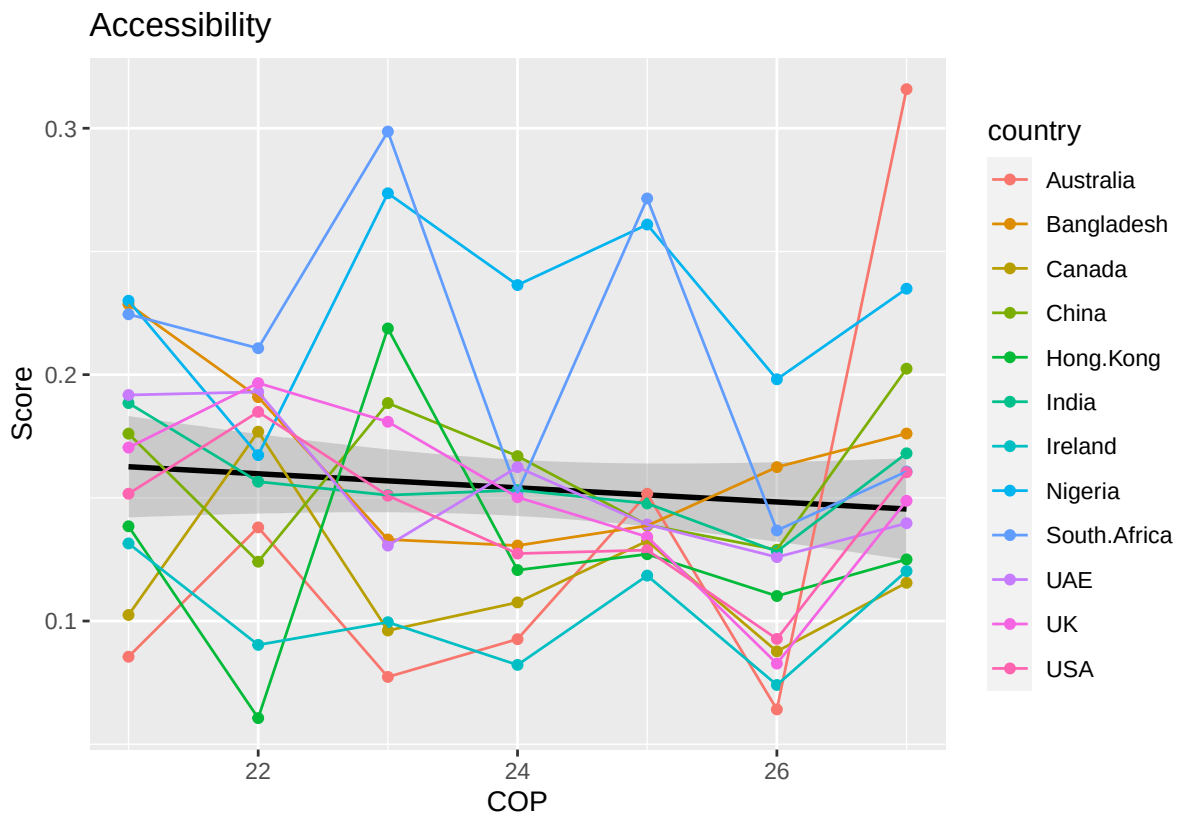
```
dy = read.csv("../data/LEXIS/TrilemmaScores_byCountryAndYear.csv",stringsAsFactors = F)
dy$COP = gsub("COP","",dy$COP)

# Total frequency
dy$tot = dy$accessibility + dy$security + dy$sustainability

# Weighting of frequency
dy$Accessibility = dy$accessibility / dy$tot
dy$Security = dy$security / dy$tot
dy$Sustainability = dy$sustainability / dy$tot
```

Graph of overall change over time:

```
g1 = ggplot(dy,aes(x=as.numeric(COP),y=Accessibility)) +
  stat_smooth(method = "lm",group=1,color="black")+
  geom_point(aes(group=country,color=country)) +
  geom_line(aes(group=country,color=country)) +
  ggtitle("Accessibility")+
  ylab("Score")+
  xlab("COP")+
  theme(legend.position = "none")

g2 =  ggplot(dy,aes(x=as.numeric(COP),y=Security)) +
  stat_smooth(group=1,color="black",n=14)+
  geom_point(aes(group=country,color=country)) +
  geom_line(aes(group=country,color=country)) +
  ggtitle("Security")+
  xlab("COP")+
  theme(legend.position = "none",axis.title.y = element_blank())

g3 =  ggplot(dy,aes(x=as.numeric(COP),y=Sustainability)) +
  stat_smooth(group=1,color="black")+
  geom_point(aes(group=country,color=country)) +
  geom_line(aes(group=country,color=country)) +
  ggtitle("Sustainability")+
  ylab("Score")+
  xlab("COP")+
```

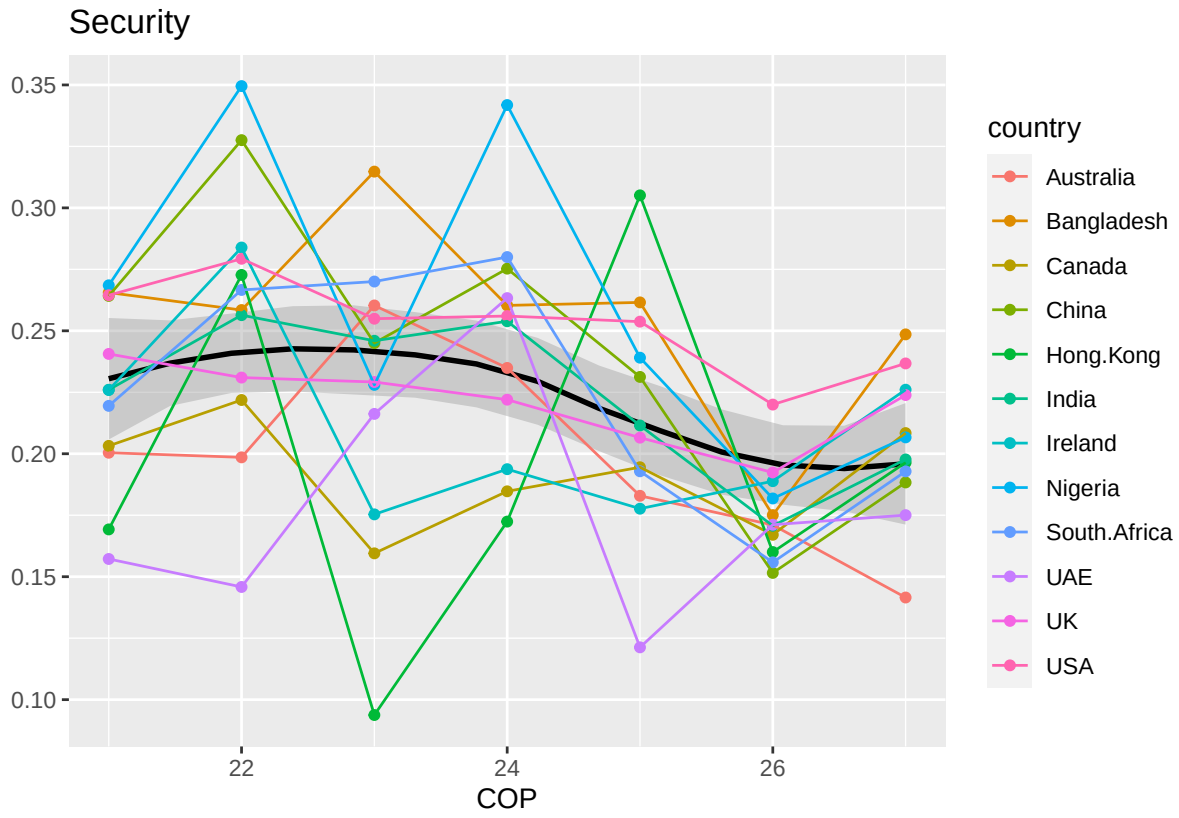
```
  theme(axis.title.y = element_blank())

g1 + theme(legend.position = "right")
```

```
## `geom_smooth()` using formula = 'y ~ x'
```



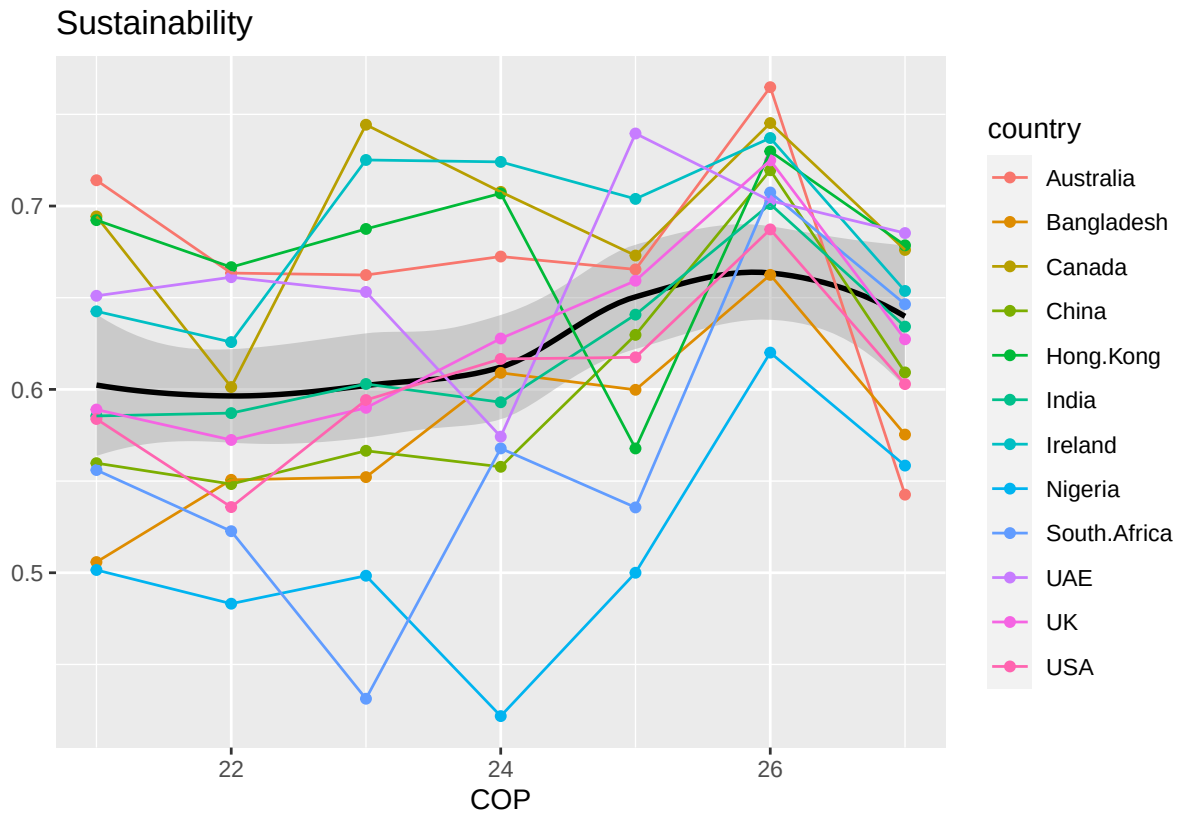

```
g2 + theme(legend.position = "right")
```

```
## `geom_smooth()` using method = 'loess' and formula = 'y ~ x'
```




```
g3 + theme(legend.position = "right")
```

```
## `geom_smooth()` using method = 'loess' and formula = 'y ~ x'
```



```
# Write to file
pdf("../results/COP_Trilemma_ChangeOverTime.pdf",height=4,width=12)
ggarrange(g1,g2,g3,nrow = 1,widths = c(1.1,1.05,1.45))
```

```
## `geom_smooth()` using formula = 'y ~ x'
## `geom_smooth()` using method = 'loess' and formula = 'y ~ x'
## `geom_smooth()` using method = 'loess' and formula = 'y ~ x'
```

```
dev.off()
```

```
## pdf
##   2
```

There appears to be a general trend over time. For sustainability, there is an increase in values around COP26, and this is compensated by a drop in security values. Below, we use a General Additive Model (GAM) to test the change in the proportional coverage of sustainability. The model includes a random intercept for each country. A random slope for year by country does not significantly improve the mode fit.

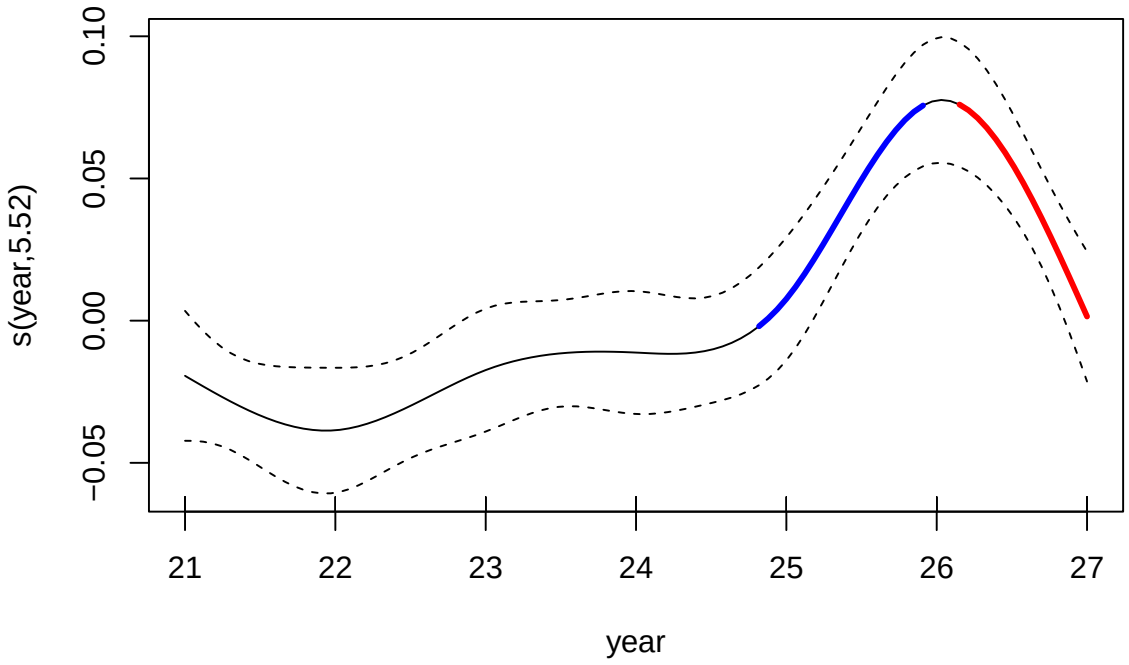
```
dy$year = as.numeric(dy$COP)
dy$countryFac = factor(dy$country)
gm0 = gam(Sustainability ~
            s(year,k=7) +
            s(countryFac,bs='re'),
          data = dy)
summary(gm0)
```

```
##
## Family: gaussian
## Link function: identity
##
## Formula:
## Sustainability ~ s(year, k = 7) + s(countryFac, bs = "re")
##
## Parametric coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept)  0.62508    0.01605   38.95   <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Approximate significance of smooth terms:
##                  edf Ref.df      F p-value
## s(year)        5.515  5.908  9.345  <2e-16 ***
## s(countryFac) 10.057 11.000 10.659  <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## R-sq.(adj) =  0.674   Deviance explained = 73.5%
## GCV = 0.0023113  Scale est. = 0.0018553  n = 84
```

The EDF value for the smooth term of year is significantly greater than 1, indicating that there is evidence for non-linear change.

The plot below highlights which sections of the GAM spline are significantly increasing or decreasing. This method comes from this source, and also used in Monaghan & Roberts (2019). The basic idea is to calculate the derivatives of the slope (how much the slope is increasing or decreasing) and then compute confidence intervals for the derivatives from their standard errors. If the confidence intervals of the derivatives do not overlap zero, then they are considered significant.

```
plotGAMSignificantSlopes(gm0,"year","Year")
```



The plot suggests that there is a significant increase in media coverage about sustainability during COP26, but that reduced back to the baseline for COP27.

The correlation between sustainability and both security and accessibility is highly negative, suggesting that the coverage of sustainability is at the expense of covering both the other topics:

```
cor.test(dy$Sustainability, dy$Security)
```

```
##
##  Pearson's product-moment correlation
##
## data:  dy$Sustainability and dy$Security
## t = -9.4076, df = 82, p-value = 1.114e-14
## alternative hypothesis: true correlation is not equal to 0
## 95 percent confidence interval:
##  -0.8097787 -0.5985202
## sample estimates:
##        cor
## -0.7204654
```

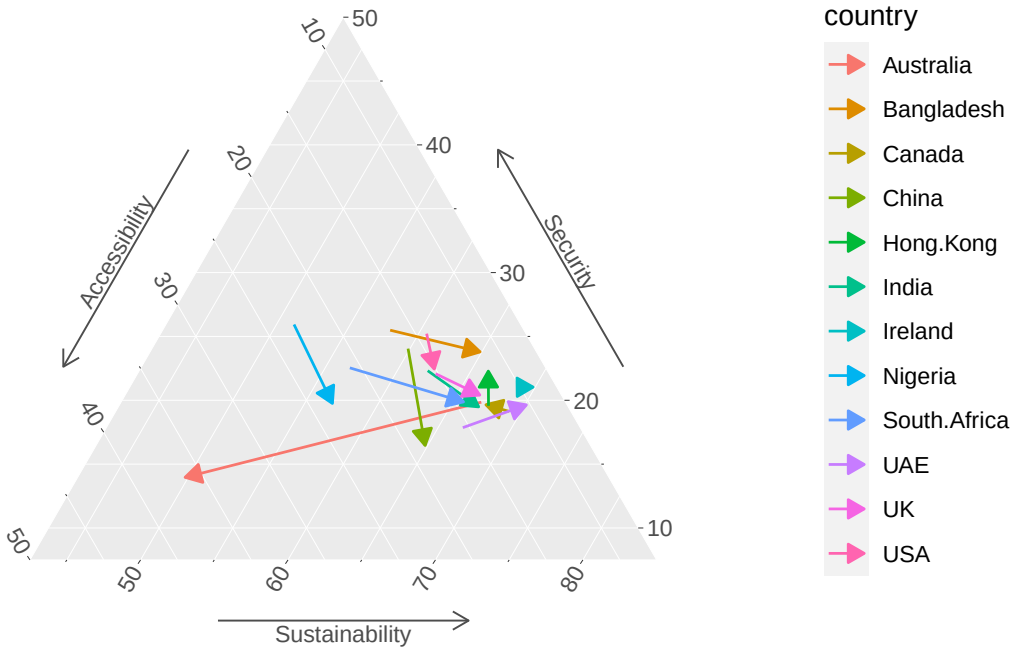
```
cor.test(dy$Sustainability, dy$Accessibility)
```

```
##
##  Pearson's product-moment correlation
##
## data:  dy$Sustainability and dy$Accessibility
## t = -10.643, df = 82, p-value < 2.2e-16
## alternative hypothesis: true correlation is not equal to 0
## 95 percent confidence interval:
##  -0.8390253 -0.6540387
## sample estimates:
##        cor
## -0.7616353
```

Absolute and relative change over time

```
vec = NULL
vecCenter = NULL
for(country in unique(dy$country)){
  dx = dy[dy$country==country,]
  meanA = mean(dx$Accessibility)
  meanSec = mean(dx$Security)
  meanSus = mean(dx$Sustainability)

  dA = sum(diff(dx$Accessibility))
  dSec = sum(diff(dx$Security))
  dSus = sum(diff(dx$Sustainability))

  vec = rbind(vec,data.frame(
    country = country,
    Accessibility = c(meanA,meanA+dA),
    Security = c(meanSec,meanSec+dSec),
    Sustainability = c(meanSus,meanSus+dSus)
  ))
  centerPoint = 1/3
  vecCenter = rbind(vecCenter,data.frame(
    country = country,
    Accessibility = c(centerPoint,centerPoint+dA*4),
    Security = c(centerPoint,centerPoint+dSec*4),
    Sustainability = c(centerPoint,centerPoint+dSus*4)
  ))
}

avChange = ggtern(data=vec,
       aes(x=Accessibility,y=Security, z=Sustainability,colour=country)) +
  tern_limit(T=0.5,L=0.5,R=0.85) +
  theme_showarrows() +
  labs(x="",xarrow="Accessibility",
       y="",yarrow="Security",
       z="",zarrow="Sustainability")+
  geom_path(arrow=arrow(type = "closed",length =unit(0.1, "inches") )) +
  ggtitle("Average change over time")

avChange
```

Average change over time

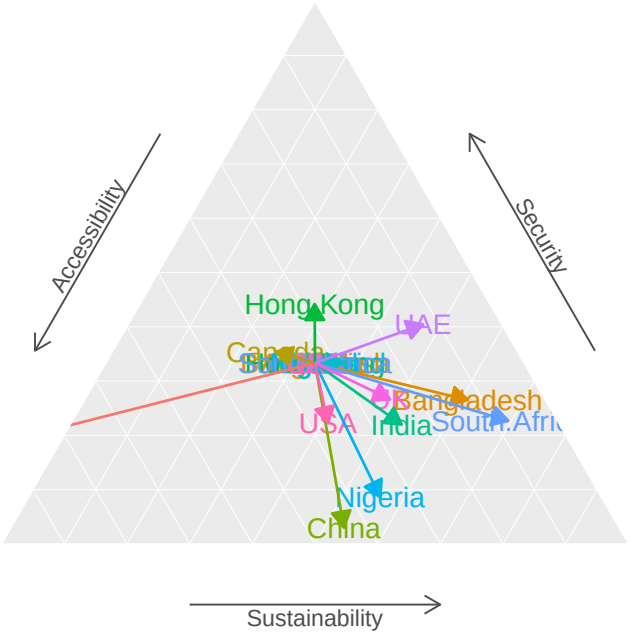



```
pdf("../results/COP_Overall_AvChangeOverTime.pdf",
    width=6,height=6)
avChange
dev.off()
```

```
## pdf
##   2
```

```
relChange = ggtern(data=vecCenter,
       aes(x=Accessibility,y=Security, z=Sustainability,colour=country)) +
  tern_limit(T=1,L=1,R=1) +
  theme_showarrows() +
  theme_nolabels()+
  theme_noticks()+
  theme(legend.position = "none")+
  labs(x="",xarrow="Accessibility",
       y="",yarrow="Security",
       z="",zarrow="Sustainability")+
  geom_text(aes(label=country,colour=country),show.legend = FALSE,
            alpha=1) +
  geom_path(arrow=arrow(type = "closed",length =unit(0.1, "inches") )) +
  ggtitle("Average change over time")

relChange
```

Average change over time



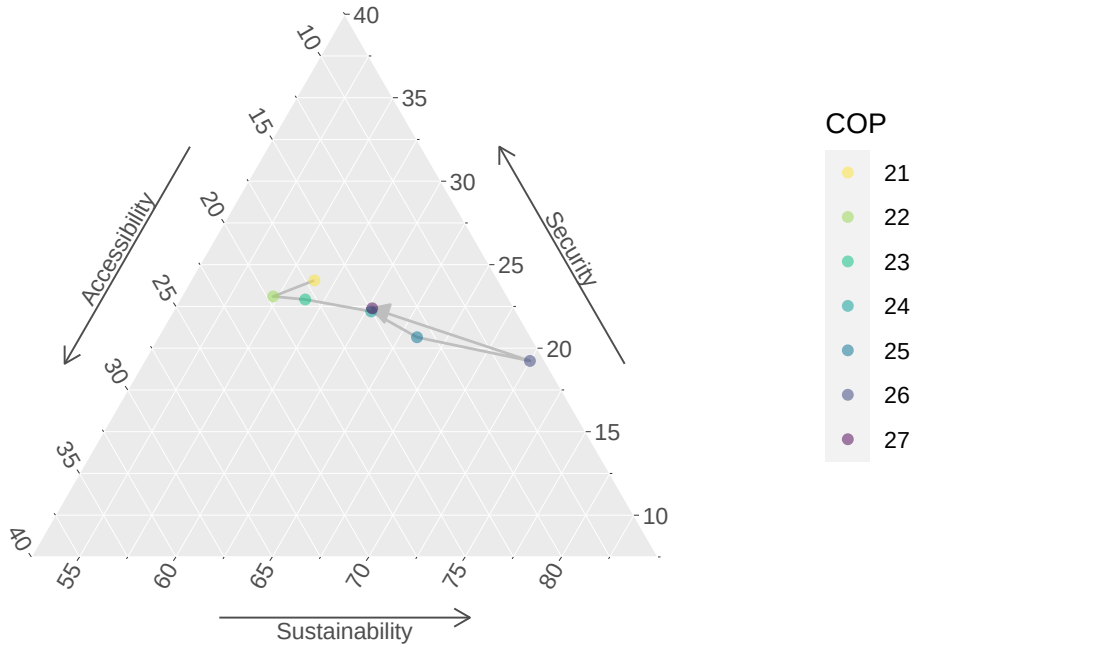

```
pdf("../results/COP_Overall_RelChangeOverTime.pdf",width=6,height=6)
relChange
dev.off()
```

```
## pdf
##   2
```

COP Trilemma scores over time by country:

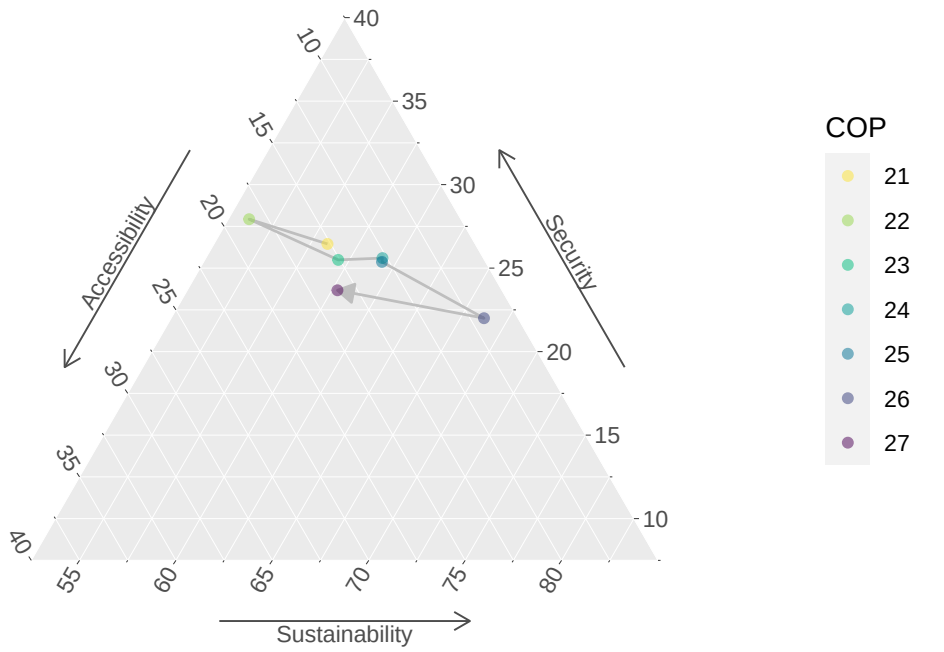
```
fillColours = rev(hcl.colors(length(unique(dy$COP))))

ggtern(data=dy[dy$country=="UK",],
       aes(x=Accessibility,y=Security, z=Sustainability)) +
  tern_limit(T=0.4,L=0.4,R=0.85) +
  theme_showarrows() +
  labs(x="",xarrow="Accessibility",
       y="",yarrow="Security",
       z="",zarrow="Sustainability")+
  geom_path(arrow=arrow(type = "closed",length =unit(0.1, "inches") ),color="gray",alpha=1) +
  #geom_text(aes(label=COP,colour=COP),show.legend = FALSE,
  #          position = position_nudge_tern(y=0.01),
  #          alpha=1) +
  scale_color_manual(values = fillColours)+
  geom_point(aes(colour=COP),alpha=0.5) +
  ggtitle("UK")
```

UK



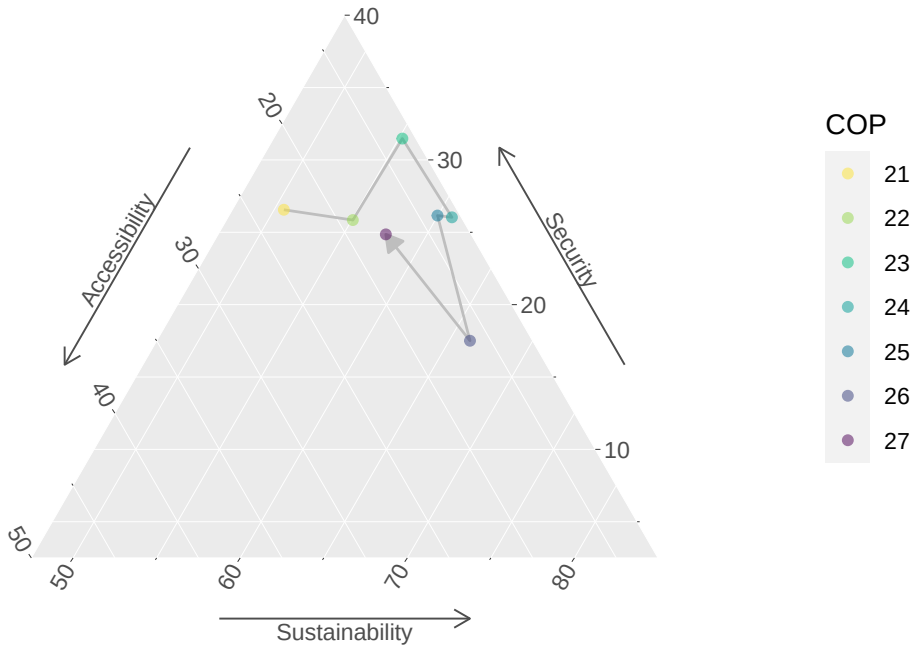

```
ggtern(data=dy[dy$country=="USA",],
       aes(x=Accessibility,y=Security, z=Sustainability)) +
  tern_limit(T=0.4,L=0.4,R=0.85) +
  theme_showarrows() +
  labs(x="",xarrow="Accessibility",
       y="",yarrow="Security",
       z="",zarrow="Sustainability")+
  geom_path(arrow=arrow(type = "closed",length =unit(0.1, "inches") ),color="gray",alpha=1) +
  #geom_text(aes(label=COP,colour=COP),show.legend = FALSE,
  #          position = position_nudge_tern(y=0.01),
  #          alpha=1) +
  scale_color_manual(values = fillColours)+
```

```
  geom_point(aes(colour=COP),alpha=0.5) +
  ggtitle("USA")
```



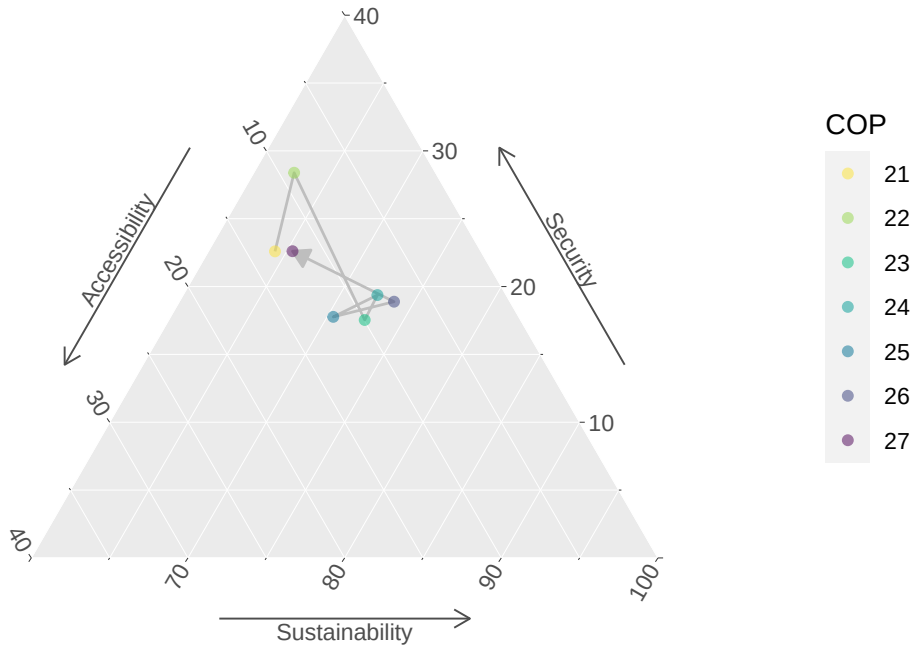

```
ggtern(data=dy[dy$country=="Bangladesh",],
       aes(x=Accessibility,y=Security, z=Sustainability)) +
  tern_limit(T=0.4,L=0.5,R=0.85) +
  theme_showarrows() +
  labs(x="",xarrow="Accessibility",
       y="",yarrow="Security",
       z="",zarrow="Sustainability")+
  geom_path(arrow=arrow(type = "closed",length =unit(0.1, "inches") ),color="gray",alpha=1) +
  #geom_text(aes(label=COP,colour=COP),show.legend = FALSE,
  #          position = position_nudge_tern(y=0.01),
  #          alpha=1) +
  scale_color_manual(values = fillColours)+
  geom_point(aes(colour=COP),alpha=0.5) +
  ggtitle("Bangladesh")
```

Bangladesh



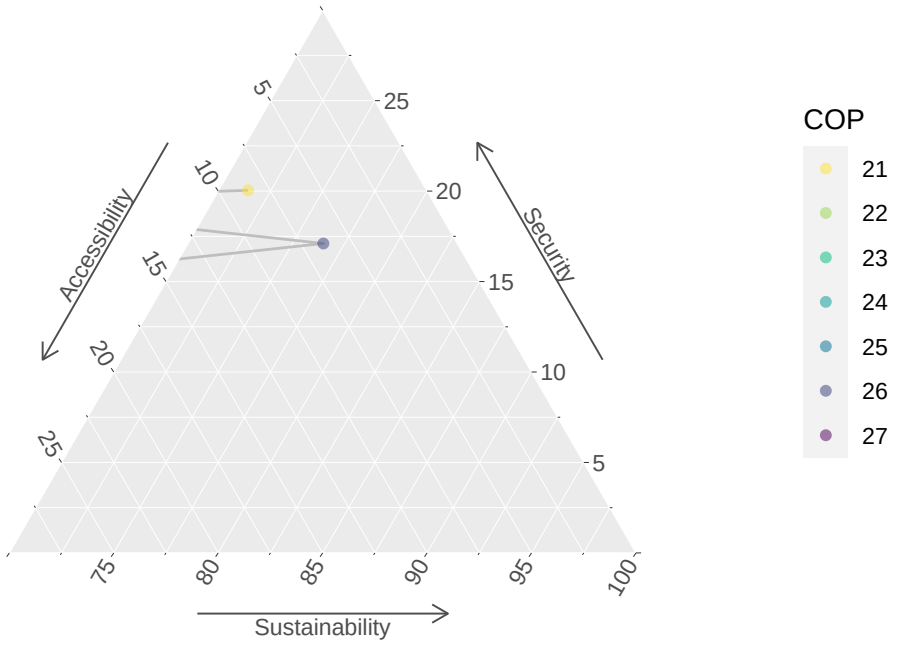

```
ggtern(data=dy[dy$country=="Ireland",],
       aes(x=Accessibility,y=Security, z=Sustainability)) +
  tern_limit(T=0.4,L=0.4,R=1) +
  theme_showarrows() +
  labs(x="",xarrow="Accessibility",
       y="",yarrow="Security",
       z="",zarrow="Sustainability")+
  geom_path(arrow=arrow(type = "closed",length =unit(0.1, "inches") ),color="gray",alpha=1) +
  #geom_text(aes(label=COP,colour=COP),show.legend = FALSE,
  #          position = position_nudge_tern(y=0.01),
  #          alpha=1) +
  scale_color_manual(values = fillColours)+
  geom_point(aes(colour=COP),alpha=0.5) +
  ggtitle("Ireland")
```

Ireland



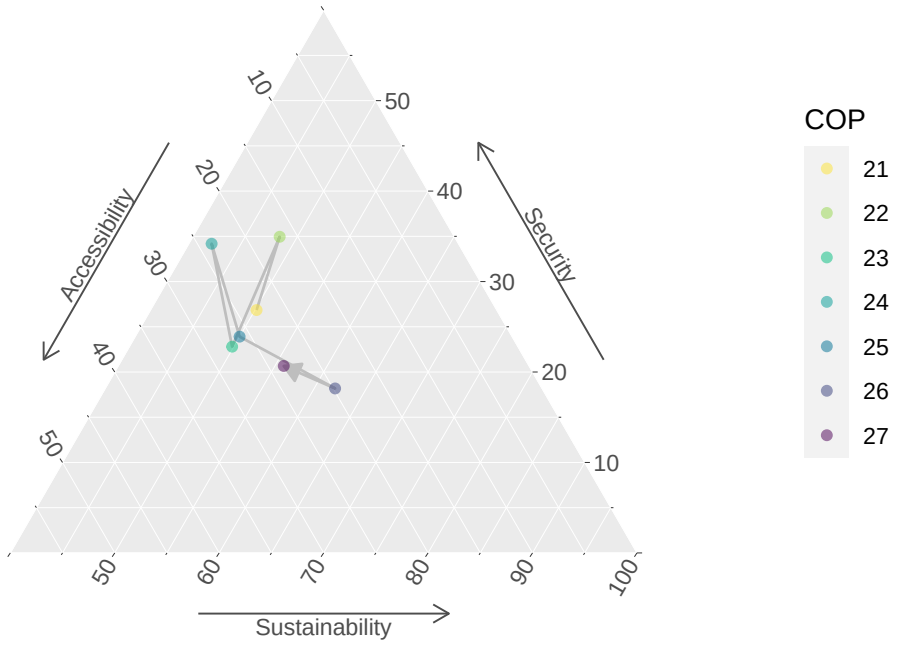

```
ggtern(data=dy[dy$country=="Australia",],
       aes(x=Accessibility,y=Security, z=Sustainability)) +
  tern_limit(T=0.3,L=0.3,R=1) +
  theme_showarrows() +
  labs(x="",xarrow="Accessibility",
       y="",yarrow="Security",
       z="",zarrow="Sustainability")+
  geom_path(arrow=arrow(type = "closed",length =unit(0.1, "inches") ),color="gray",alpha=1) +
  #geom_text(aes(label=COP,colour=COP),show.legend = FALSE,
  #          position = position_nudge_tern(y=0.01),
  #          alpha=1) +
  scale_color_manual(values = fillColours)+
  geom_point(aes(colour=COP),alpha=0.5) +
  ggtitle("Australia")
```

Australia



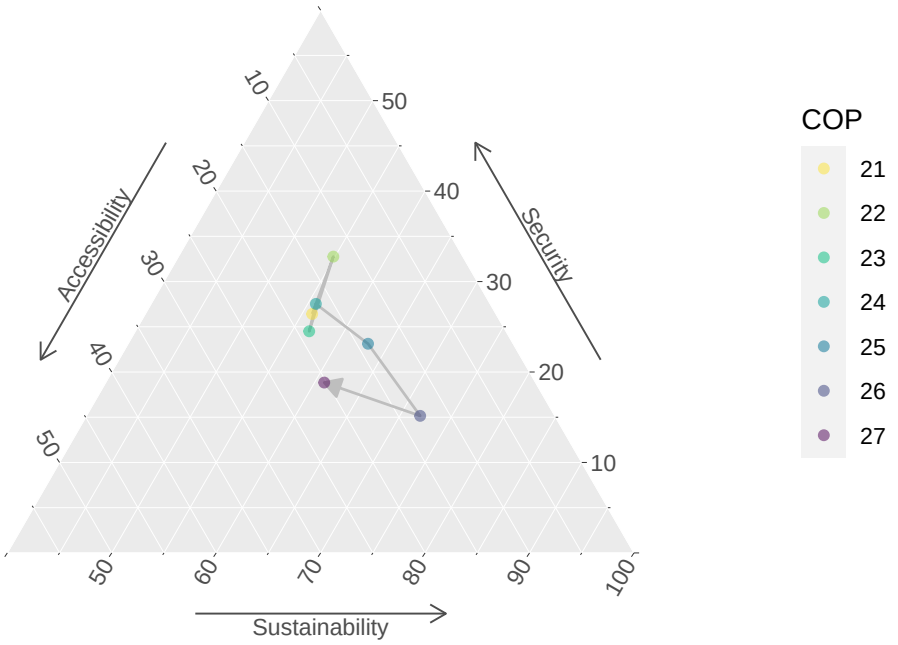

```
ggtern(data=dy[dy$country=="Nigeria",],
       aes(x=Accessibility,y=Security, z=Sustainability)) +
  tern_limit(T=0.6,L=0.6,R=1) +
  theme_showarrows() +
  labs(x="",xarrow="Accessibility",
       y="",yarrow="Security",
       z="",zarrow="Sustainability")+
  geom_path(arrow=arrow(type = "closed",length =unit(0.1, "inches") ),color="gray",alpha=1) +
  #geom_text(aes(label=COP,colour=COP),show.legend = FALSE,
  #          position = position_nudge_tern(y=0.01),
  #          alpha=1) +
  scale_color_manual(values = fillColours)+
  geom_point(aes(colour=COP),alpha=0.5) +
  ggtitle("Nigeria")
```

Nigeria



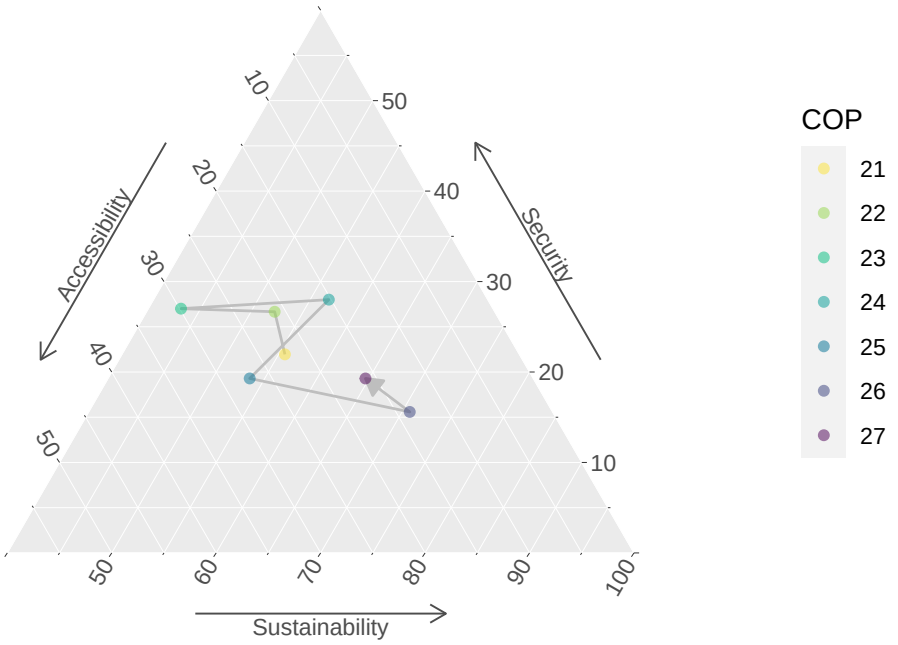

```
ggtern(data=dy[dy$country=="China",],
       aes(x=Accessibility,y=Security, z=Sustainability)) +
  tern_limit(T=0.6,L=0.6,R=1) +
  theme_showarrows() +
  labs(x="",xarrow="Accessibility",
       y="",yarrow="Security",
       z="",zarrow="Sustainability")+
  geom_path(arrow=arrow(type = "closed",length =unit(0.1, "inches") ),color="gray",alpha=1) +
  #geom_text(aes(label=COP,colour=COP),show.legend = FALSE,
  #          position = position_nudge_tern(y=0.01),
  #          alpha=1) +
  scale_color_manual(values = fillColours)+
  geom_point(aes(colour=COP),alpha=0.5) +
  ggtitle("China")
```

China



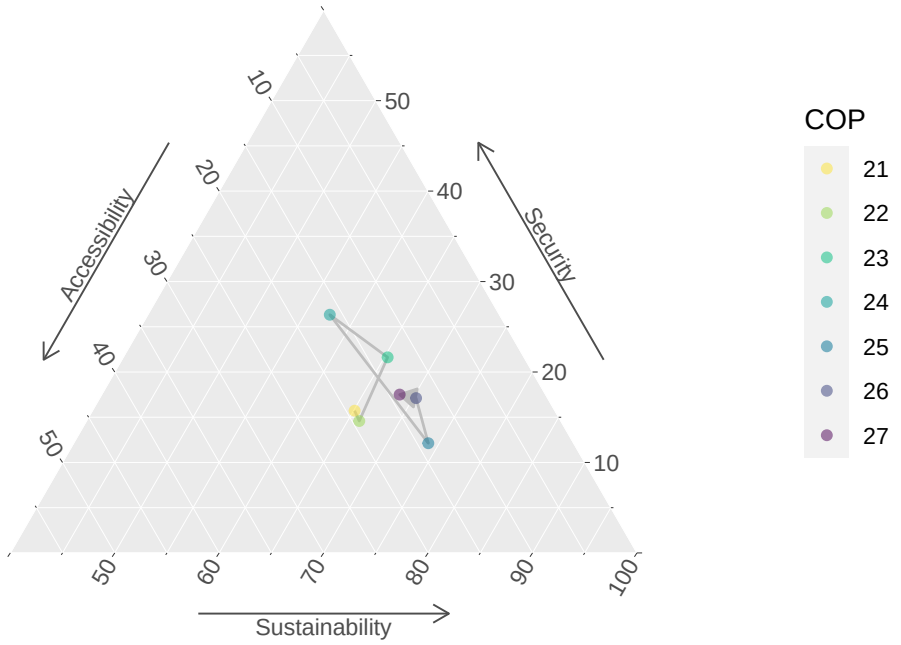

```
ggtern(data=dy[dy$country=="South.Africa",],
       aes(x=Accessibility,y=Security, z=Sustainability)) +
  tern_limit(T=0.6,L=0.6,R=1) +
  theme_showarrows() +
  labs(x="",xarrow="Accessibility",
       y="",yarrow="Security",
       z="",zarrow="Sustainability")+
  geom_path(arrow=arrow(type = "closed",length =unit(0.1, "inches") ),color="gray",alpha=1) +
  #geom_text(aes(label=COP,colour=COP),show.legend = FALSE,
  #          position = position_nudge_tern(y=0.01),
  #          alpha=1) +
  scale_color_manual(values = fillColours)+
  geom_point(aes(colour=COP),alpha=0.5) +
  ggtitle("South Africa")
```

South Africa



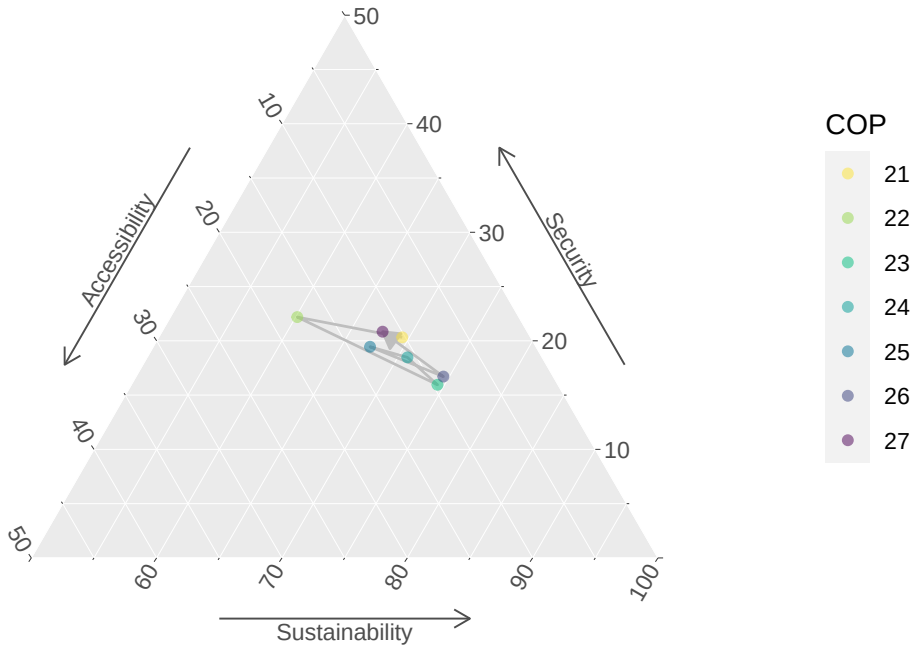

```
ggtern(data=dy[dy$country=="UAE",],
       aes(x=Accessibility,y=Security, z=Sustainability)) +
  tern_limit(T=0.6,L=0.6,R=1) +
  theme_showarrows() +
  labs(x="",xarrow="Accessibility",
       y="",yarrow="Security",
       z="",zarrow="Sustainability")+
  geom_path(arrow=arrow(type = "closed",length =unit(0.1, "inches") ),color="gray",alpha=1) +
  #geom_text(aes(label=COP,colour=COP),show.legend = FALSE,
  #          position = position_nudge_tern(y=0.01),
  #          alpha=1) +
  scale_color_manual(values = fillColours)+
  geom_point(aes(colour=COP),alpha=0.5) +
  ggtitle("UAE")
```

UAE



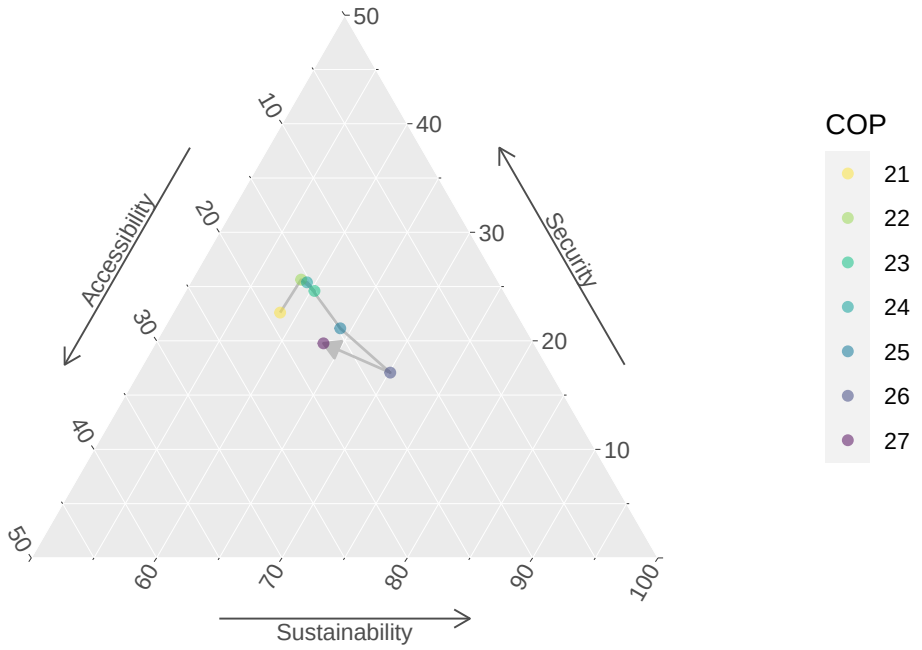

```
ggtern(data=dy[dy$country=="Canada",],
       aes(x=Accessibility,y=Security, z=Sustainability)) +
  tern_limit(T=0.5,L=0.5,R=1) +
  theme_showarrows() +
  labs(x="",xarrow="Accessibility",
       y="",yarrow="Security",
       z="",zarrow="Sustainability")+
  geom_path(arrow=arrow(type = "closed",length =unit(0.1, "inches") ),color="gray",alpha=1) +
  #geom_text(aes(label=COP,colour=COP),show.legend = FALSE,
  #          position = position_nudge_tern(y=0.01),
  #          alpha=1) +
  scale_color_manual(values = fillColours)+
  geom_point(aes(colour=COP),alpha=0.5) +
  ggtitle("Canada")
```

Canada




```
ggtern(data=dy[dy$country=="India",],
       aes(x=Accessibility,y=Security, z=Sustainability)) +
  tern_limit(T=0.5,L=0.5,R=1) +
  theme_showarrows() +
  labs(x="",xarrow="Accessibility",
       y="",yarrow="Security",
       z="",zarrow="Sustainability")+
  geom_path(arrow=arrow(type = "closed",length =unit(0.1, "inches") ),color="gray",alpha=1) +
  #geom_text(aes(label=COP,colour=COP),show.legend = FALSE,
  #          position = position_nudge_tern(y=0.01),
  #          alpha=1) +
  scale_color_manual(values = fillColours)+
  geom_point(aes(colour=COP),alpha=0.5) +
  ggtitle("India")
```

India

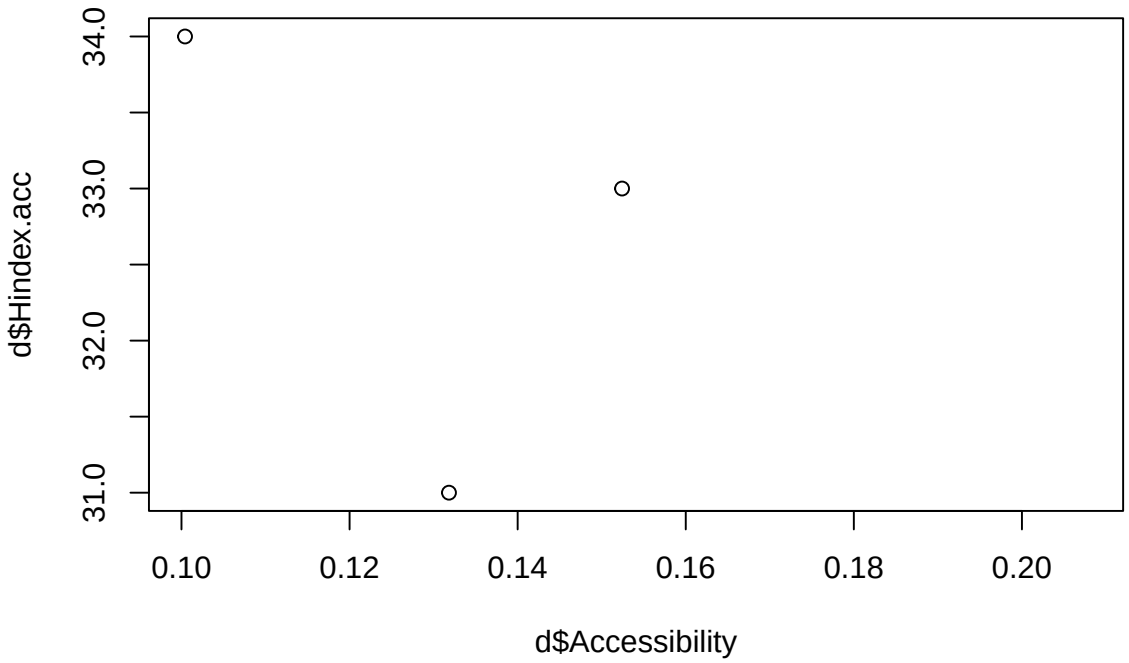

50
10
40
Accessibility
20
30
Security
30
20
40
10
50
60
70
80
90
100
Sustainability
COP
21
22
23
24
25
26
27

Comparing the frequency measure to other measures

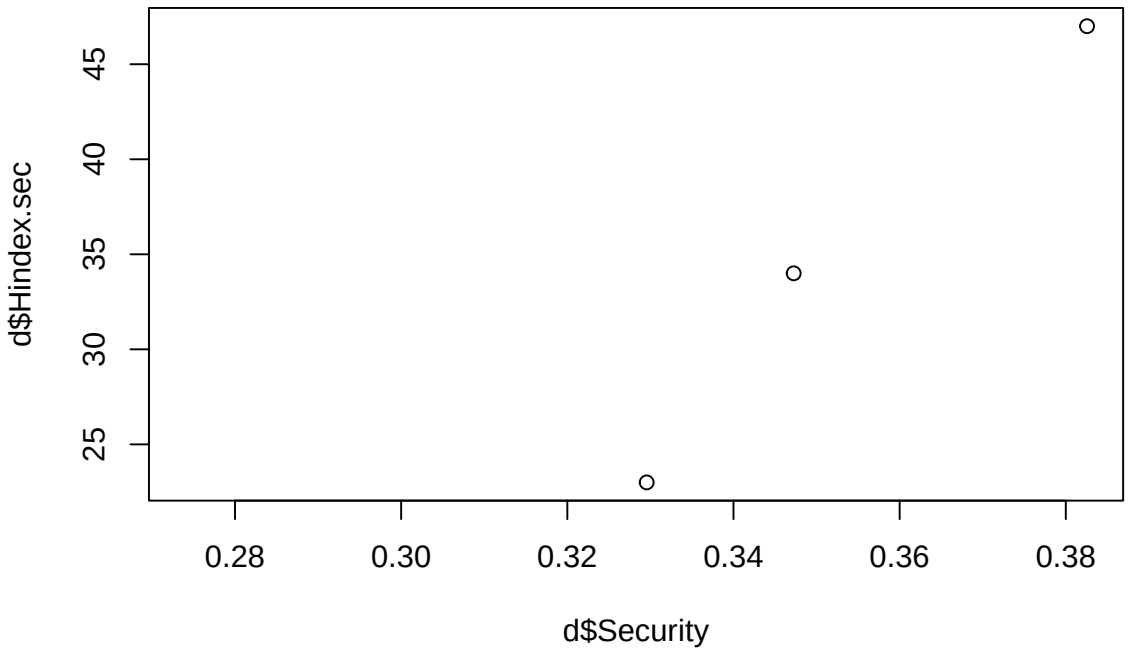
Energy Justice Metric

First, we compare our measures to the Energy Justice Metric (EJM) from Heffron et al. (2015). This involves estimating the costs of various processes associated with each component. Below we plot the two measures against each other:

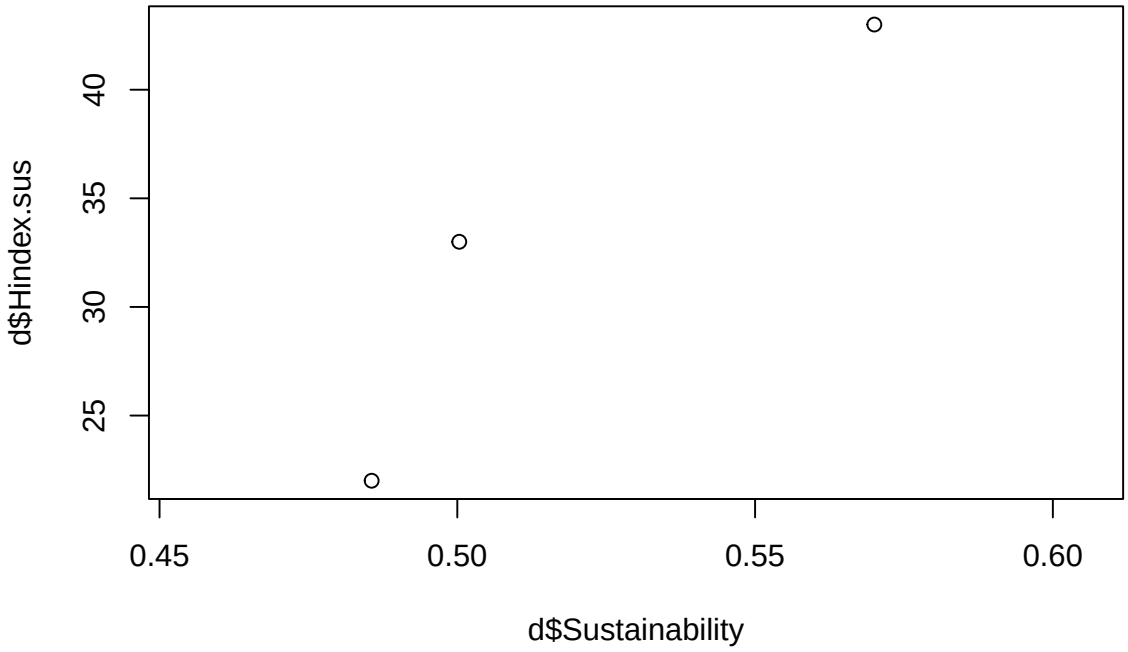
```
hi = read.csv("../data/Heffron_2018_Metric.csv",stringsAsFactors = F)
d[,c("Hindex.acc","Hindex.sec","Hindex.sus")] =
  hi[match(d$country,hi$country),
     c("accessibility","security","sustainability")]

plot(d$Accessibility,d$Hindex.acc)
```




```
plot(d$Security,d$Hindex.sec)
```




```
plot(d$Sustainability,d$Hindex.sus)
```



It is difficult to assess the similarity with only three datapoints. The ranking for Security and Sustainability is the same, but there is a difference for Accessibility.

WEC Energy Trilemma Index

Next, we compare our measure to the Energy Trilemma Index (ETI) from the WEC.

```
wec = read.xlsx("../data/Trielemma_scores.xlsx",sheet = 1,startRow = 3)
names(wec)[1:2] = c("Conference","Year")
names(wec)[3:ncol(wec)] = paste0(rep(names(wec)[3:14]), rep(c(".SEC",".SUS",".ACC"),each=12))

# Match WEC to our data
dy[,c("WEC.SEC","WEC.SUS","WEC.ACC")] = NA
for(i in 1:nrow(dy)){
  country= dy[i,]$country
  conf = dy[i,]$COP
  dy[i,c("WEC.SEC","WEC.SUS","WEC.ACC")] =
      wec[wec$Conference==paste0("COP",conf),paste0(country,".",c("SEC","SUS","ACC"))]
}

xsus = dy[,c("COP","country","Sustainability","WEC.SUS")]
xsec = dy[,c("COP","country","Security","WEC.SEC")]
xacc = dy[,c("COP","country","Accessibility","WEC.ACC")]
names(xsus) = c("COP","country","D","WEC")
names(xsec) = c("COP","country","D","WEC")
names(xacc) = c("COP","country","D","WEC")
xsus$Comp = "Sustainability"
xsec$Comp = "Security"
xacc$Comp = "Accessibility"
dyLong = rbind(xsus,xsec,xacc)

m0 = lmer(WEC ~ 1 + (1|country) + (1 |Comp),data=dyLong)
m1 = lmer(WEC ~ D + (1|country) + (1 |Comp),data=dyLong)
anova(m0,m1)
```

```
## refitting model(s) with ML (instead of REML)
```

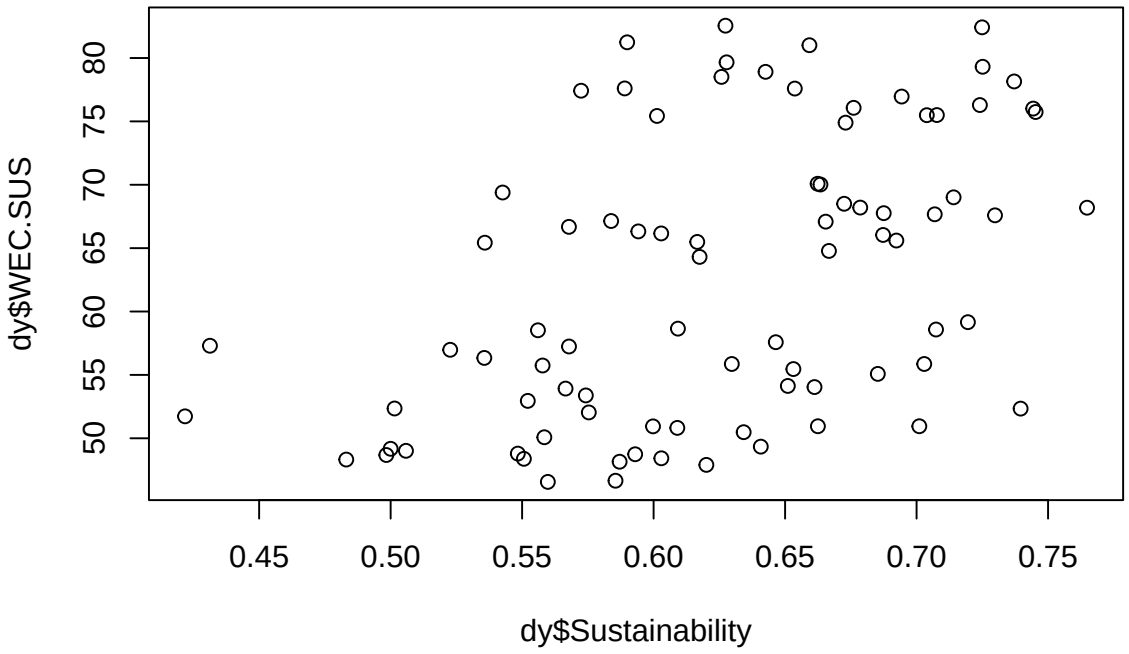
```
## Data: dyLong
## Models:
## m0: WEC ~ 1 + (1 | country) + (1 | Comp)
## m1: WEC ~ D + (1 | country) + (1 | Comp)
##    npar    AIC    BIC  logLik deviance  Chisq Df Pr(>Chisq)
## m0    4 1998.6 2012.7 -995.29   1990.6
## m1    5 1992.8 2010.5 -991.41   1982.8 7.7446  1   0.005387 **
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
summary(m1)
```

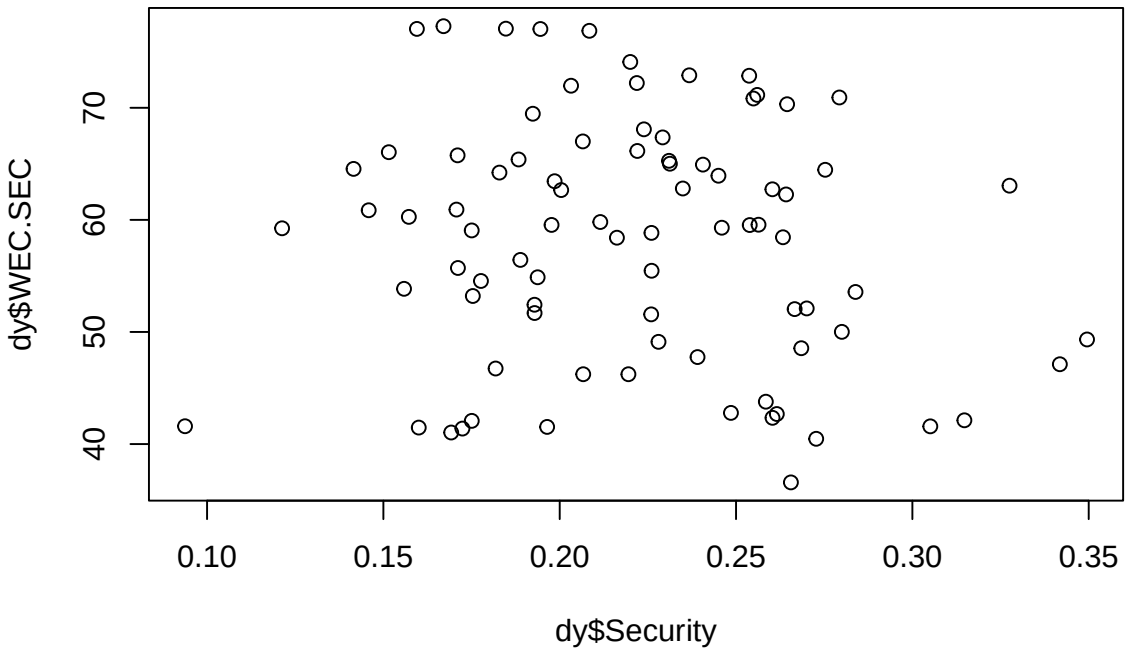
```
## Linear mixed model fit by REML ['lmerMod']
## Formula: WEC ~ D + (1 | country) + (1 | Comp)
##    Data: dyLong
##
## REML criterion at convergence: 1970.7
##
## Scaled residuals:
##     Min      1Q  Median      3Q     Max
## -2.4145 -0.6264  0.1263  0.7716  1.9212
##
## Random effects:
##  Groups   Name        Variance Std.Dev.
##  country  (Intercept) 231.18   15.205
##  Comp     (Intercept)  84.02    9.166
##  Residual             124.95   11.178
```

```
## Number of obs: 252, groups:  country, 12; Comp, 3
##
## Fixed effects:
##             Estimate Std. Error t value
## (Intercept)   74.819      7.777   9.620
## D            -30.350     10.700  -2.837
##
## Correlation of Fixed Effects:
##   (Intr)
## D -0.459
```

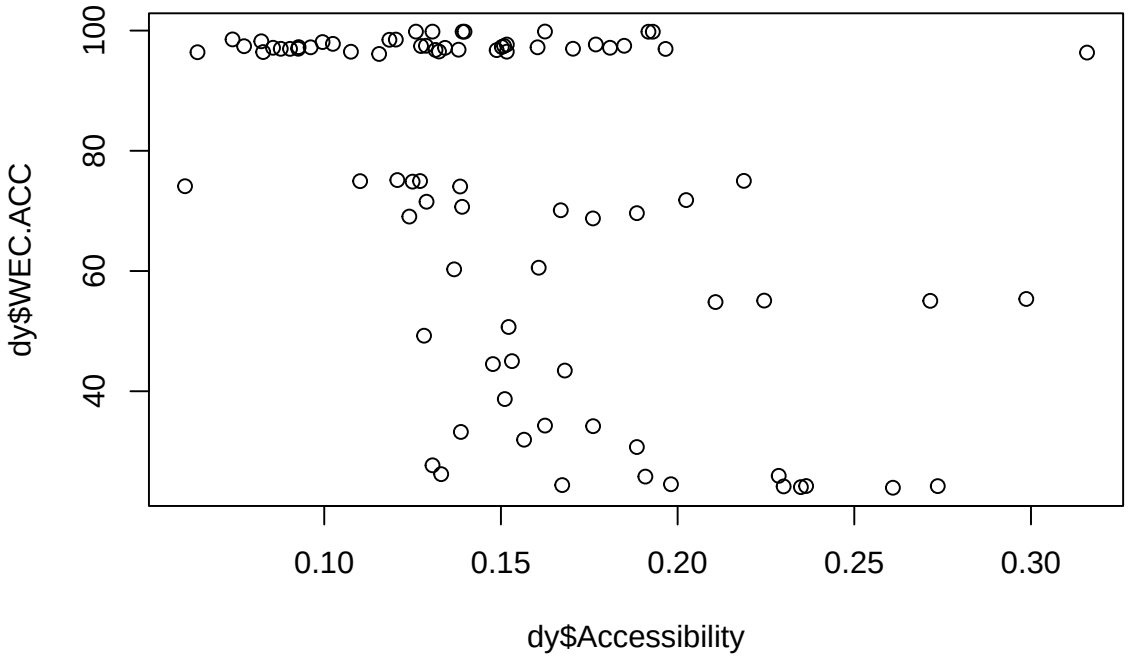
```
plot(dy$Sustainability,dy$WEC.SUS)
```




```
plot(dy$Security,dy$WEC.SEC)
```




```
plot(dy$Accessibility,dy$WEC.ACC)
```




```
cor.test(dy$Sustainability,dy$WEC.SUS)
```

```
##
```

```
##  Pearson's product-moment correlation
##
## data:  dy$Sustainability and dy$WEC.SUS
## t = 4.9689, df = 82, p-value = 3.622e-06
## alternative hypothesis: true correlation is not equal to 0
## 95 percent confidence interval:
##  0.2973323 0.6304352
## sample estimates:
##       cor
## 0.4810614
```

```
cor.test(dy$Security,dy$WEC.SEC)
```

```
##
##  Pearson's product-moment correlation
##
## data:  dy$Security and dy$WEC.SEC
## t = -1.2314, df = 82, p-value = 0.2217
## alternative hypothesis: true correlation is not equal to 0
## 95 percent confidence interval:
##  -0.33933876  0.08201785
## sample estimates:
##        cor
## -0.1347468
```

```
cor.test(dy$Accessibility,dy$WEC.ACC)
```

```
##
##  Pearson's product-moment correlation
##
## data:  dy$Accessibility and dy$WEC.ACC
## t = -4.9489, df = 82, p-value = 3.921e-06
## alternative hypothesis: true correlation is not equal to 0
## 95 percent confidence interval:
##  -0.6292666 -0.2955653
## sample estimates:
##        cor
## -0.4795712
```

The measures for sustainability are highly correlated. However, the measures for security are not, and the measures for accessibility are significantly negatively correlated.

Before, during, and after the conferences

```
dy$beforeAccProp = dy$beforeAcc/(dy$beforeAcc+dy$beforeSec+dy$beforeSus)
dy$duringAccProp = dy$duringAcc/(dy$duringAcc+dy$duringSec+dy$duringSus)
dy$afterAccProp = dy$afterAcc/(dy$afterAcc+dy$afterSec+dy$afterSus)

dy$beforeSecProp = dy$beforeSec/(dy$beforeAcc+dy$beforeSec+dy$beforeSus)
dy$duringSecProp = dy$duringSec/(dy$duringAcc+dy$duringSec+dy$duringSus)
dy$afterSecProp = dy$afterSec/(dy$afterAcc+dy$afterSec+dy$afterSus)

dy$beforeSusProp = dy$beforeSus/(dy$beforeAcc+dy$beforeSec+dy$beforeSus)
dy$duringSusProp = dy$duringSus/(dy$duringAcc+dy$duringSec+dy$duringSus)
dy$afterSusProp = dy$afterSus/(dy$afterAcc+dy$afterSec+dy$afterSus)

phaseCats = c("beforeAccProp", "duringAccProp", "afterAccProp",
              "beforeSecProp", "duringSecProp", "afterSecProp",
              "beforeSusProp", "duringSusProp", "afterSusProp")

phaseData = dy[,c("COP","country",phaseCats)]
phaseData = gather(phaseData, phase, frequency, beforeAccProp:afterSusProp)
phaseData$component = "Accessibility"
phaseData$component[grepl("Sus",phaseData$phase)] = "Sustainability"
phaseData$component[grepl("Sec",phaseData$phase)] = "Security"
phaseData$phase = substr(phaseData$phase,0,nchar(phaseData$phase)-7)

phaseData$phase = factor(phaseData$phase,levels=c("before","during","after"))
```

Plot the distribution of scores before/during/after

```
pg1 = ggplot(phaseData[phaseData$component=="Accessibility",],
       aes(x=phase,y=frequency)) +
  geom_boxplot() +
  ylab("Score") +
  ggtitle("Accessibility")+
  stat_summary(geom="point",fun="mean", size=3, col="red") +
  stat_summary(fun=mean, colour="red", geom="line", aes(group = 1)) +
  ylim(c(0,0.8))

pg2 = ggplot(phaseData[phaseData$component=="Security",],
       aes(x=phase,y=frequency)) +
  geom_boxplot() +
  theme(axis.title.y=element_blank(),
        axis.text.y = element_blank(),
        axis.ticks.y = element_blank())+
  ggtitle("Security")+
  stat_summary(geom="point",fun="mean", size=3, col="red") +
  stat_summary(fun=mean, colour="red", geom="line", aes(group = 1))+
  ylim(c(0,0.8))

pg3 = ggplot(phaseData[phaseData$component=="Sustainability",],
       aes(x=phase,y=frequency)) +
  geom_boxplot()+
  theme(axis.title.y=element_blank(),
        axis.text.y = element_blank(),
        axis.ticks.y = element_blank())+
  ggtitle("Sustainability") +
  stat_summary(geom="point",fun="mean", size=3, col="red") +
  stat_summary(fun=mean, colour="red", geom="line", aes(group = 1))+
```

```
  ylim(c(0,0.8))

ggarrange(pg1,pg2,pg3,nrow=1)
```

```
## Warning: Removed 3 rows containing non-finite values (`stat_boxplot()`).
```

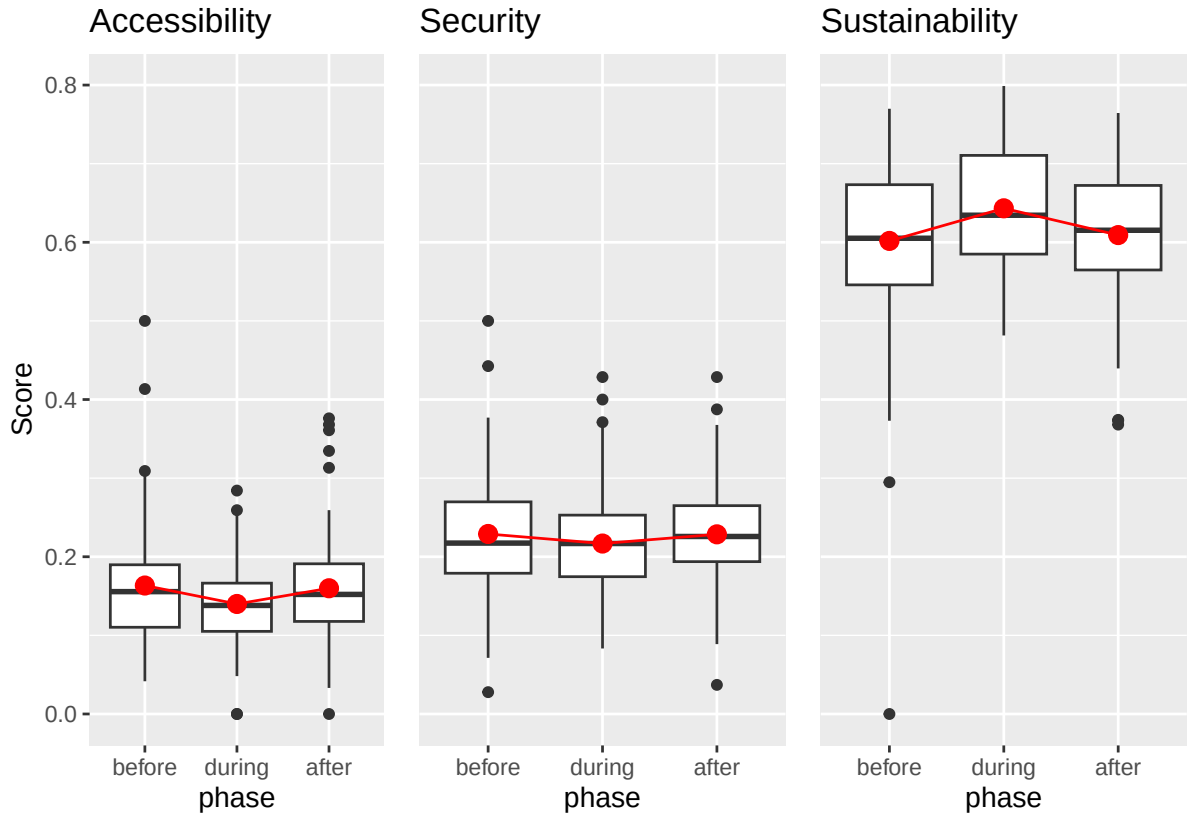
```
## Warning: Removed 3 rows containing non-finite values (`stat_summary()`).
## Removed 3 rows containing non-finite values (`stat_summary()`).
```

```
## Warning: Removed 3 rows containing non-finite values (`stat_boxplot()`).
```

```
## Warning: Removed 3 rows containing non-finite values (`stat_summary()`).
## Removed 3 rows containing non-finite values (`stat_summary()`).
```

```
## Warning: Removed 6 rows containing non-finite values (`stat_boxplot()`).
```

```
## Warning: Removed 6 rows containing non-finite values (`stat_summary()`).
## Removed 6 rows containing non-finite values (`stat_summary()`).
```




```
pdf("../results/COP_BeforeDuringAfter.pdf",
    width=5.5,height=3)
ggarrange(pg1,pg2,pg3,nrow=1,
          widths = c(1.2,1,1))
```

```
## Warning: Removed 3 rows containing non-finite values (`stat_boxplot()`).
```

```
## Warning: Removed 3 rows containing non-finite values (`stat_summary()`).
## Removed 3 rows containing non-finite values (`stat_summary()`).
```

```
## Warning: Removed 3 rows containing non-finite values (`stat_boxplot()`).
```

```
## Warning: Removed 3 rows containing non-finite values (`stat_summary()`).
## Removed 3 rows containing non-finite values (`stat_summary()`).
```

```
## Warning: Removed 6 rows containing non-finite values (`stat_boxplot()`).
```

```
## Warning: Removed 6 rows containing non-finite values (`stat_summary()`).
## Removed 6 rows containing non-finite values (`stat_summary()`).
```

```
dev.off()
```

```
## pdf
##   2
```

Is there a significant difference between phases? Use an ANOVA:

```
summary(aov(frequency~phase*component,data=phaseData))
```

```
##                   Df Sum Sq Mean Sq  F value  Pr(>F)
## phase              2  0.000   0.000    0.000 1.00000
## component          2 31.478  15.739 2486.693 < 2e-16 ***
## phase:component    4  0.098   0.024    3.863 0.00409 **
## Residuals        738  4.671   0.006
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
## 9 observations deleted due to missingness
```

Component is significant, since sustainability is talked about more than security and accessibility. But there is also a significant interaction. Look at individual t-tests:

```
pSus = phaseData[phaseData$component=="Sustainability",]
t.test(pSus[pSus$phase=="before",]$frequency,
       pSus[pSus$phase=="during",]$frequency)
```

```
##
##  Welch Two Sample t-test
##
## data:  pSus[pSus$phase == "before", ]$frequency and pSus[pSus$phase == "during", ]$frequency
## t = -2.246, df = 143.58, p-value = 0.02623
## alternative hypothesis: true difference in means is not equal to 0
## 95 percent confidence interval:
##  -0.066974041 -0.004271976
## sample estimates:
## mean of x mean of y
## 0.6075993 0.6432223
```

```
t.test(pSus[pSus$phase=="during",]$frequency,
       pSus[pSus$phase=="after",]$frequency)
```

```
##
##  Welch Two Sample t-test
##
## data:  pSus[pSus$phase == "during", ]$frequency and pSus[pSus$phase == "after", ]$frequency
## t = 2.4218, df = 162.83, p-value = 0.01654
## alternative hypothesis: true difference in means is not equal to 0
## 95 percent confidence interval:
##  0.005851026 0.057524562
## sample estimates:
## mean of x mean of y
## 0.6432223 0.6115345
```

```
pSec = phaseData[phaseData$component=="Security",]
t.test(pSec[pSec$phase=="before",]$frequency,
       pSec[pSec$phase=="during",]$frequency)
```

```
##
##  Welch Two Sample t-test
##
## data:  pSec[pSec$phase == "before", ]$frequency and pSec[pSec$phase == "during", ]$frequency
```

```
## t = 1.1216, df = 159.64, p-value = 0.2637
## alternative hypothesis: true difference in means is not equal to 0
## 95 percent confidence interval:
##  -0.009254329  0.033582681
## sample estimates:
## mean of x mean of y
## 0.2289795 0.2168154
```

```
t.test(pSec[pSec$phase=="during",]$frequency,
       pSec[pSec$phase=="after",]$frequency)
```

```
##
##  Welch Two Sample t-test
##
## data:  pSec[pSec$phase == "during", ]$frequency and pSec[pSec$phase == "after", ]$frequency
## t = -1.1619, df = 163.8, p-value = 0.247
## alternative hypothesis: true difference in means is not equal to 0
## 95 percent confidence interval:
##  -0.031642104  0.008198962
## sample estimates:
## mean of x mean of y
## 0.2168154 0.2285369
```

```
pAcc = phaseData[phaseData$component=="Accessibility",]
t.test(pAcc[pSec$phase=="before",]$frequency,
       pAcc[pSec$phase=="during",]$frequency)
```

```
##
##  Welch Two Sample t-test
##
## data:  pAcc[pSec$phase == "before", ]$frequency and pAcc[pSec$phase == "during", ]$frequency
## t = 2.2313, df = 144.43, p-value = 0.0272
## alternative hypothesis: true difference in means is not equal to 0
## 95 percent confidence interval:
##  0.002678607 0.044239058
## sample estimates:
## mean of x mean of y
## 0.1634212 0.1399624
```

```
t.test(pAcc[pSec$phase=="during",]$frequency,
       pAcc[pSec$phase=="after",]$frequency)
```

```
##
##  Welch Two Sample t-test
##
## data:  pAcc[pSec$phase == "during", ]$frequency and pAcc[pSec$phase == "after", ]$frequency
## t = -2.0381, df = 152.69, p-value = 0.04327
## alternative hypothesis: true difference in means is not equal to 0
## 95 percent confidence interval:
##  -0.0393206237 -0.0006118223
## sample estimates:
## mean of x mean of y
## 0.1399624 0.1599286
```

It seems like sustainability is talked about slightly more during the conference than outside it, at the cost of talking about accessibility. Comparing during to not-during is also significant:

```
t.test(pSus[pSus$phase=="during",]$frequency,
       pSus[pSus$phase!="during",]$frequency)
```

```
##
```

```
##  Welch Two Sample t-test
##
## data:  pSus[pSus$phase == "during", ]$frequency and pSus[pSus$phase != "during", ]$frequency
## t = 2.7999, df = 205.94, p-value = 0.005599
## alternative hypothesis: true difference in means is not equal to 0
## 95 percent confidence interval:
##  0.009956729 0.057354073
## sample estimates:
## mean of x mean of y
## 0.6432223 0.6095669
```

A mixed effects model controlling for year and a random effect of country also suggests that sustainability talk increases during the conference:

```
pm0 = lmer(frequency~ 1+
             as.numeric(COP) + (1|country),
  data = phaseData[phaseData$component=="Sustainability",])
pm1 = lmer(frequency~ phase+
             as.numeric(COP) + (1|country),
  data = phaseData[phaseData$component=="Sustainability",])
anova(pm0,pm1)
```

```
## refitting model(s) with ML (instead of REML)
```

```
## Data: phaseData[phaseData$component == "Sustainability", ]
## Models:
## pm0: frequency ~ 1 + as.numeric(COP) + (1 | country)
## pm1: frequency ~ phase + as.numeric(COP) + (1 | country)
##     npar     AIC     BIC logLik deviance  Chisq Df Pr(>Chisq)
## pm0    4 -503.44 -489.37 255.72  -511.44
## pm1    6 -508.87 -487.76 260.43  -520.87 9.4253  2   0.008981 **
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
summary(pm1)
```

```
## Linear mixed model fit by REML ['lmerMod']
## Formula: frequency ~ phase + as.numeric(COP) + (1 | country)
##    Data: phaseData[phaseData$component == "Sustainability", ]
##
## REML criterion at convergence: -490.1
##
## Scaled residuals:
##     Min      1Q  Median      3Q     Max
## -7.8306 -0.3805  0.0273  0.5208  2.9802
##
## Random effects:
##  Groups   Name        Variance Std.Dev.
##  country  (Intercept) 0.002649 0.05147
##  Residual             0.006598 0.08123
## Number of obs: 249, groups:  country, 12
##
## Fixed effects:
##                 Estimate Std. Error t value
## (Intercept)     0.349112   0.063995   5.455
## phaseduring     0.035493   0.012609   2.815
## phaseafter      0.004065   0.012609   0.322
## as.numeric(COP) 0.010774   0.002565   4.200
##
## Correlation of Fixed Effects:
##             (Intr) phsdrn phsftr
```

```
## phaseduring -0.096
## phaseafter  -0.101  0.500
## as.nmr(COP) -0.963 -0.002  0.002
```

Summary

This analysis found the following patterns:

- Sustainability is talked about most, followed by Security and Accessibility.
- There was significant increase in media coverage about sustainability during COP26, but that reduced back to the baseline for COP27.
- There was a small increase in discourse about sustainability during the conferences, compared to before and after, at the cost of talking about security.
- Our measures for sustainability are highly correlated with the WEC ETI measures. However, our measures for security are not, and the measures for accessibility are significantly negatively correlated. This may suggest that the amount of reporting about the two latter components does not simply reflect the actual progress on solving the issues.

References

Heffron, RJ, McCauley, D, Sovacool, BK. 2015. Resolving society's energy trilemma through the Energy Justice Metric, Energy Policy, Volume 87, Pages 168-176

Monaghan, P. and Roberts, S.G., 2019. Cognitive influences in language evolution: Psycholinguistic predictors of loan word borrowing. Cognition, 186, pp.147-158.