MA615 Final Project

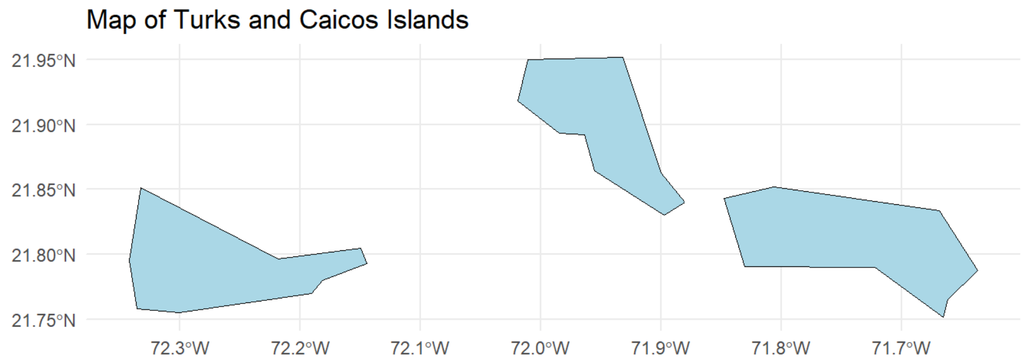
AUTHOR
Truc Minh Nguyen

The Purpose of this report will focus on EDA and modelling a dataset obtained regarding the Total capital stock for urban and rural areas in the Turks and Caicos. Most of the Key Facts about TCI EDA is shown in the Shiny App and the Presentation for other Key Facts about TCI.

```
Warning: package 'ggplot2' was built under R version 4.4.2

Warning: package 'dplyr' was built under R version 4.4.2

── Attaching core tidyverse packages ──────────────────────── tidyverse 2.0.0 ──
✔ dplyr     1.1.4     ✔ readr     2.1.5
✔ forcats   1.0.0     ✔ stringr   1.5.1
✔ ggplot2   3.5.1     ✔ tibble    3.2.1
✔ lubridate 1.9.3     ✔ tidyr     1.3.1
✔ purrr     1.0.2     
── Conflicts ────────────────────────────────────────── tidyverse_conflicts() ──
✖ dplyr::filter() masks stats::filter()
✖ dplyr::lag()    masks stats::lag()
ℹ Use the conflicted package (<http://conflicted.r-lib.org/>) to force all conflicts to become errors

Warning: package 'sf' was built under R version 4.4.2

Linking to GEOS 3.12.2, GDAL 3.9.3, PROJ 9.4.1; sf_use_s2() is TRUE

Warning: package 'rnaturalearth' was built under R version 4.4.2

Warning: package 'rnaturalearthdata' was built under R version 4.4.2


Attaching package: 'rnaturalearthdata'

The following object is masked from 'package:rnaturalearth':

    countries110

Warning: package 'tmap' was built under R version 4.4.2

Breaking News: tmap 3.x is retiring. Please test v4, e.g. with
remotes::install_github('r-tmap/tmap')
corrplot 0.95 loaded
```

Let’s retrieve spatial data for Turks and Caicos

```r
world <- ne_countries(scale = "medium", returnclass = "sf")
turks_caicos <- world[world$name == "Turks and Caicos Is.", ]

# Let's plot a simple map of the Turks and Caicos Islands using ggplot

ggplot(data = turks_caicos) +
  geom_sf(fill = "lightblue", color = "black") +
  labs(
    title = "Map of Turks and Caicos Islands",
    caption = "Source: Natural Earth"
  ) +
  theme_minimal()
```

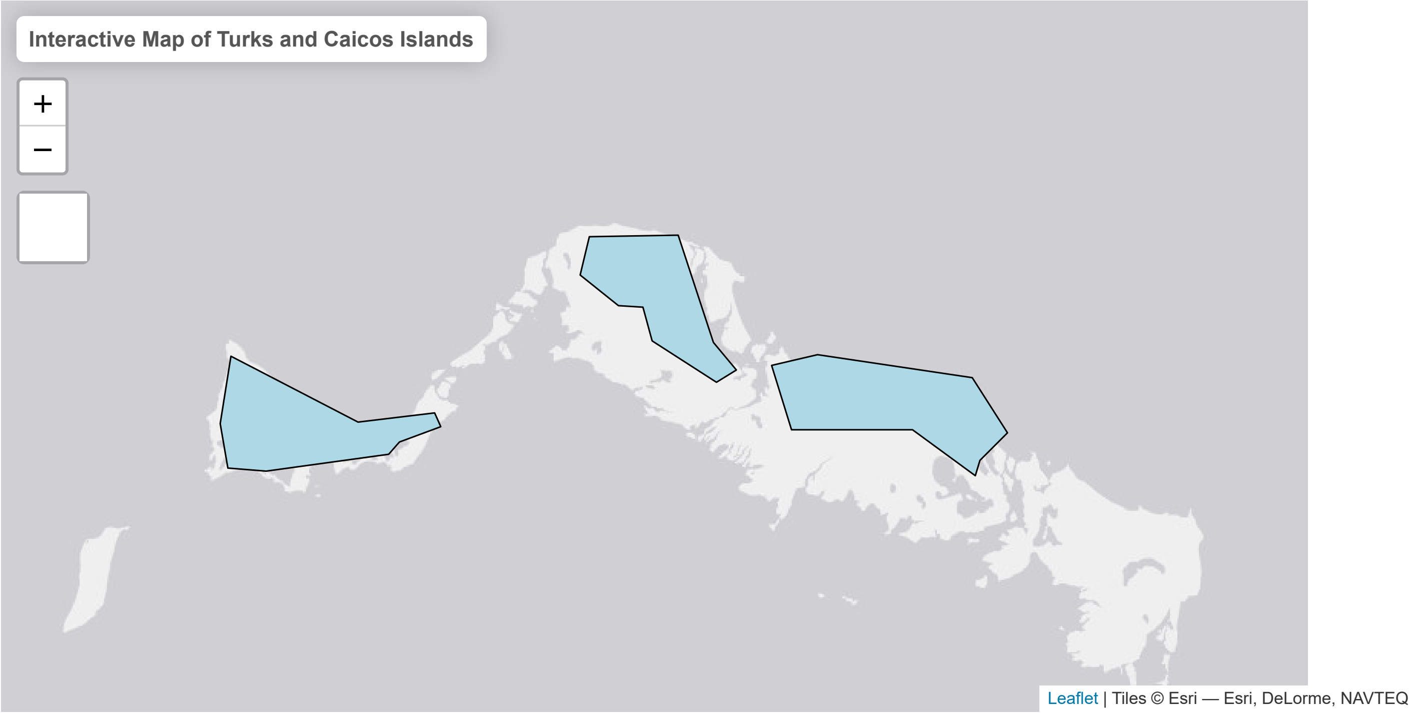


Source: Natural Earth

```
# Let's create and interactive map using tmap:

tmap_mode("view") # Set to interactive mode
```

```
tmap mode set to interactive viewing
```

```
tm_shape(turks_caicos) +
  tm_polygons(col = "lightblue", border.col = "black") +
  tm_layout(title = "Interactive Map of Turks and Caicos Islands")
```


Interactive Map of Turks and Caicos Islands
+
−
Leaflet | Tiles © Esri — Esri, DeLorme, NAVTEQ

GDP Data of the Turks and Caicos

```r
GDP <- read.csv("Turks_GDP.csv", header = TRUE)
# Convert character column to Date format
GDP$Date <- as.Date(GDP$Date, format = "%m/%d/%Y")

# Extract only the Year
GDP$Year <- format(GDP$Date, "%Y")

GDP <- GDP %>%
  rename(
    GDP_billions_USD = GDP..Billions.of.US...,
    Per_Capita = Per.Capita..US...
  )
GDP$Per_Capita_Scaled <- GDP$Per_Capita / 10000  # Scale down for visualization


# Plot with adjusted y-axis limits
# Rescale Per Capita to match the GDP scale
GDP$Per_Capita_Scaled <- GDP$Per_Capita / 10000  # Adjust scaling

GDP_long <- GDP %>%
  pivot_longer(cols = c(GDP_billions_USD, Per_Capita_Scaled),
               names_to = "Metric", values_to = "Value")

# Updated Plot
GDP_plot <- ggplot(GDP_long, aes(x = Year, y = Value, group = Metric)) +
  # Bars for GDP
  geom_bar(data = subset(GDP_long, Metric == "GDP_billions_USD"),
           aes(fill = "GDP (Billions USD)"),
           stat = "identity", alpha = 0.7) +
  # Line and points for Per Capita
  geom_line(data = subset(GDP_long, Metric == "Per_Capita_Scaled"),
            aes(color = "Per Capita (USD)"), size = 1) +
  geom_point(data = subset(GDP_long, Metric == "Per_Capita_Scaled"),
             aes(color = "Per Capita (USD)"), size = 2) +
  # Define the y-axis and secondary axis
  scale_y_continuous(
    name = "GDP (Billions USD)",
    limits = c(0, 3.5),
    sec.axis = sec_axis(~ . * 10000, name = "Per Capita (USD)")
  ) +
  # Single legend with manual color and fill labels
  scale_fill_manual(name = "Metric", values = c("GDP (Billions USD)" = "skyblue")) +
  scale_color_manual(name = "Metric", values = c("Per Capita (USD)" = "red")) +

  # Labels and theme
  labs(
    title = "GDP (Billions USD) and Per Capita (USD) Over the Years",
    x = "Year",
    y = "GDP (Billions USD)"
  ) +
  theme_minimal() +
  theme(
    axis.text.x = element_text(angle = 45, hjust = 1),
    legend.position = "top"  # Place legend at the top
  )
```

```
Warning: Using `size` aesthetic for lines was deprecated in ggplot2 3.4.0.
ℹ Please use `linewidth` instead.
```

```r
# Save the plot as a PNG image

# Save the plot with a white background
ggsave(
  filename = "GDP_plot_white_bg.png",
  plot = GDP_plot,
  width = 10,
  height = 6,
  units = "in",
  dpi = 300,
  bg = "white"  # Explicitly set background to white
)
```

Read in Capital Stock Data of TCI, create table of important variables and definitions

```
TCI_stock <- read.csv("turks_model_df.csv", header = TRUE)

variable_table <- data.frame(
  "Important_Variables" = c("tot_cu","bed_prv_cu", "bed_pub_cu", "edu_prv_cu",
                            "edu_pub_cu", "emp_agr_cu", "emp_gov_cu", "emp_ind_cu",
                            "emp_ser_cu", "ic_high_cu", "ic_low_cu", "ic_mhg_cu",
                            "ic_mlw_cu", "tot_cr","bed_prv_cr", "bed_pub_cr",
                            "edu_prv_cr","edu_pub_cr", "emp_agr_cr",
                            "emp_gov_cr","emp_ind_cr","emp_ser_cr", "ic_high_cr",
                            "ic_low_cr", "ic_mhg_cr","ic_mlw_cr"),
  "Definitions" = c(
    "Total capital stock urban (built environment) in million USD $",
    "Health-private sector-capital stock urban (built environment) in million USD $",
    "Health-public sector-capital stock urban (built environment) in million USD $",
    "Education-private sector-capital stock urban (built environment) in million USD $",
    "Education-public sector-capital stock urban (built environment) in million USD $",
    "Employment-agricol sector-capital stock urban (built environment) in million USD $",
    "Employment-government sector-capital stock urban (built environment) in million USD $",
    "Employment-industrial sector-capital stock urban (built environment) in million USD $",
    "Employment-service sector-capital stock urban (built environment) in million USD $",
    "Housing-high income group-capital stock urban (built environment) in million USD $",
    "Housing-low income group-capital stock urban (built environment) in million USD $",
    "Housing-upper middle income group-capital stock urban (built environment) in million USD $",
    "Housing-lower middle income group-capital stock urban (built environment) in million USD $",
    "Total capital stock rural (built environment) in million USD $",
    "Health-private sector-capital stock rural (built environment) in million USD $",
    "Health-public sector-capital stock rural (built environment) in million USD $",
    "Education-private sector-capital stock rural (built environment) in million USD $",
    "Education-public sector-capital stock rural (built environment) in million USD $",
    "Employment-agricol sector-capital stock rural (built environment) in million USD $",
    "Employment-government sector-capital stock rural (built environment) in million USD $",
    "Employment-industrial sector-capital stock rural (built environment) in million USD $",
    "Employment-service sector-capital stock rural (built environment) in million USD $",
    "Housing-high income group-capital stock rural (built environment) in million USD $",
    "Housing-low income group-capital stock rural (built environment) in million USD $",
    "Housing-upper middle income group-capital stock rural (built environment) in million USD $",
    "Housing-lower middle income group-capital stock rural (built environment) in million USD $"

  )
)

# Print the table
kable(variable_table, caption = "Important Variables and Definitions")
```

Important Variables and Definitions

Important_Variables	Definitions
tot_cu	Total capital stock urban (built environment) in million USD $
bed_prv_cu	Health-private sector-capital stock urban (built environment) in million USD $
bed_pub_cu	Health-public sector-capital stock urban (built environment) in million USD $
edu_prv_cu	Education-private sector-capital stock urban (built environment) in million USD $

Important_Variables	Definitions
edu_pub_cu	Education-public sector-capital stock urban (built environment) in million USD $
emp_agr_cu	Employment-agricol sector-capital stock urban (built environment) in million USD $
emp_gov_cu	Employment-government sector-capital stock urban (built environment) in million USD $
emp_ind_cu	Employment-industrial sector-capital stock urban (built environment) in million USD $
emp_ser_cu	Employment-service sector-capital stock urban (built environment) in million USD $
ic_high_cu	Housing-high income group-capital stock urban (built environment) in million USD $
ic_low_cu	Housing-low income group-capital stock urban (built environment) in million USD $
ic_mhg_cu	Housing-upper middle income group-capital stock urban (built environment) in million USD $
ic_mlw_cu	Housing-lower middle income group-capital stock urban (built environment) in million USD $
tot_cr	Total capital stock rural (built environment) in million USD $
bed_prv_cr	Health-private sector-capital stock rural (built environment) in million USD $
bed_pub_cr	Health-public sector-capital stock rural (built environment) in million USD $
edu_prv_cr	Education-private sector-capital stock rural (built environment) in million USD $
edu_pub_cr	Education-public sector-capital stock rural (built environment) in million USD $
emp_agr_cr	Employment-agricol sector-capital stock rural (built environment) in million USD $
emp_gov_cr	Employment-government sector-capital stock rural (built environment) in million USD $
emp_ind_cr	Employment-industrial sector-capital stock rural (built environment) in million USD $
emp_ser_cr	Employment-service sector-capital stock rural (built environment) in million USD $
ic_high_cr	Housing-high income group-capital stock rural (built environment) in million USD $
ic_low_cr	Housing-low income group-capital stock rural (built environment) in million USD $
ic_mhg_cr	Housing-upper middle income group-capital stock rural (built environment) in million USD $
ic_mlw_cr	Housing-lower middle income group-capital stock rural (built environment) in million USD $

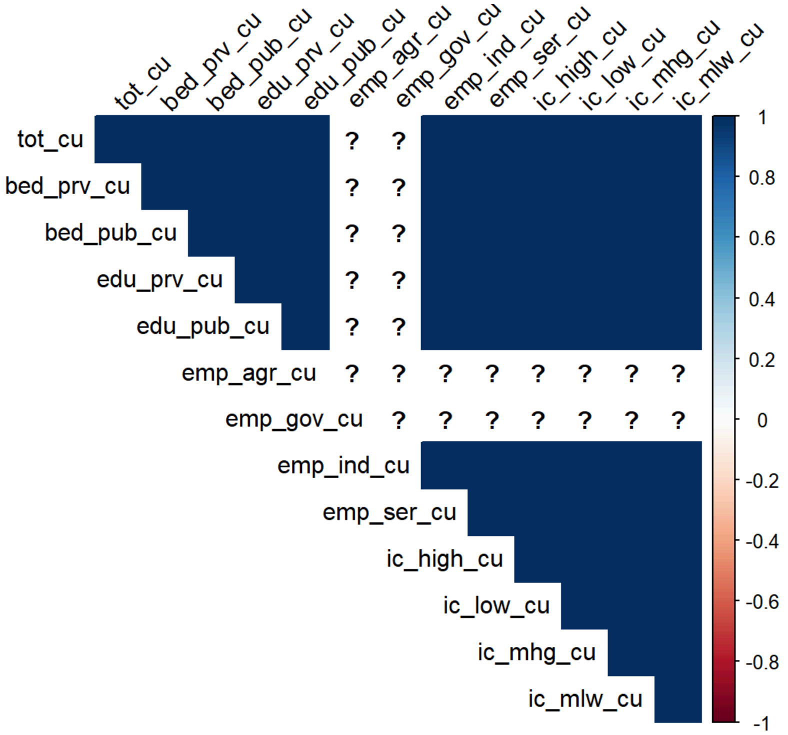
Read in Capital Stock Data of TCI, look at correlation matrix :

We are interested in doing a linear regression to see what predictors can accurately predict the Total Capital Stock for Urban and Rurul Locations in TCI. We will check assumptions to be able to fit a linear model.

```
urban_predictors <- TCI_stock[,c("tot_cu","bed_prv_cu", "bed_pub_cu", "edu_prv_cu",
                                 "edu_pub_cu", "emp_agr_cu", "emp_gov_cu", "emp_ind_cu",
                                 "emp_ser_cu", "ic_high_cu", "ic_low_cu", "ic_mhg_cu",
                                 "ic_mlw_cu")]
cor_matrix <- cor(urban_predictors, use = "pairwise.complete.obs")
```

```
Warning in cor(urban_predictors, use = "pairwise.complete.obs"): the standard
deviation is zero
```

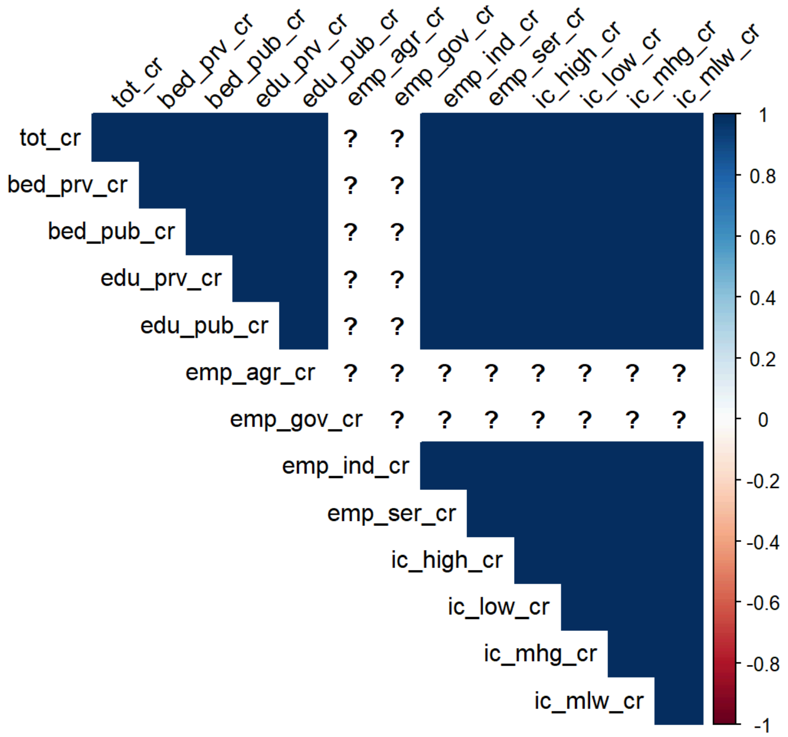
```
urban_corrplot <- corrplot(cor_matrix, method = "color", type = "upper", tl.col = "black", tl.srt = 45)
```



```
#let's repeat this step for rural predictors
rural_predictors <- TCI_stock[,c("tot_cr","bed_prv_cr", "bed_pub_cr", "edu_prv_cr",
                                 "edu_pub_cr", "emp_agr_cr", "emp_gov_cr", "emp_ind_cr",
                                 "emp_ser_cr", "ic_high_cr", "ic_low_cr", "ic_mhg_cr",
                                 "ic_mlw_cr")]
cor_matrix2 <- cor(rural_predictors, use = "pairwise.complete.obs")
```

```
Warning in cor(rural_predictors, use = "pairwise.complete.obs"): the standard
deviation is zero
```

```
urban_corrplot <- corrplot(cor_matrix2, method = "color", type = "upper", tl.col = "black", tl.srt = 45)
```



From this step, it seems like everything is highly correlated with each other and there are some missing values. This is likely violating collinearity. But for the sake, let’s entertain some models.

```r
# Let's start with all the private sector predictors, with high income on the urban stock
urban_private_fit <- lm(tot_cu ~ bed_prv_cu + edu_prv_cu + emp_ind_cu + ic_high_cu,
                        data = TCI_stock)
summary(urban_private_fit)
```

```
Warning in summary.lm(urban_private_fit): essentially perfect fit: summary may
be unreliable


Call:
lm(formula = tot_cu ~ bed_prv_cu + edu_prv_cu + emp_ind_cu +
    ic_high_cu, data = TCI_stock)

Residuals:
       Min         1Q     Median         3Q        Max
-5.737e-14  8.550e-16  8.550e-16  8.550e-16  2.623e-15

Coefficients: (3 not defined because of singularities)
              Estimate Std. Error    t value Pr(>|t|)
(Intercept) -1.302e-15  8.830e-16 -1.475e+00    0.145
bed_prv_cu   2.997e+03  1.183e-13  2.534e+16   <2e-16 ***
edu_prv_cu          NA         NA         NA       NA
emp_ind_cu          NA         NA         NA       NA
ic_high_cu          NA         NA         NA       NA
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 7.173e-15 on 65 degrees of freedom
Multiple R-squared:      1, Adjusted R-squared:      1
F-statistic: 6.421e+32 on 1 and 65 DF,  p-value: < 2.2e-16
```

```r
# Let's continue with all the private sector predictors, with low income on the urban stock
urban_public_fit <- lm(tot_cu ~ bed_pub_cu + edu_pub_cu + emp_ind_cu + ic_low_cu,
                        data = TCI_stock)
summary(urban_public_fit)
```

```
Warning in summary.lm(urban_public_fit): essentially perfect fit: summary may
be unreliable


Call:
lm(formula = tot_cu ~ bed_pub_cu + edu_pub_cu + emp_ind_cu +
    ic_low_cu, data = TCI_stock)

Residuals:
       Min         1Q     Median         3Q        Max
-9.487e-15 -7.250e-16 -7.250e-16 -7.250e-16  5.586e-14

Coefficients: (3 not defined because of singularities)
             Estimate Std. Error   t value Pr(>|t|)
(Intercept) 4.340e-16  8.696e-16 4.990e-01    0.619
bed_pub_cu  6.581e+02  2.558e-14 2.573e+16   <2e-16 ***
edu_pub_cu         NA         NA        NA       NA
emp_ind_cu         NA         NA        NA       NA
ic_low_cu          NA         NA        NA       NA
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 7.064e-15 on 65 degrees of freedom
Multiple R-squared:      1, Adjusted R-squared:      1
F-statistic: 6.62e+32 on 1 and 65 DF,  p-value: < 2.2e-16
```

```r
# Let's predict urban stocks using rural predictors, let's keep bed_prv_cu because
# significant predictor

urban_combine_fit2 <- lm(tot_cu ~ bed_prv_cu + bed_pub_cr + edu_pub_cr + emp_ind_cr
                        + ic_high_cr + ic_low_cr,
                        data = TCI_stock)
summary(urban_combine_fit2)
```

```
Warning in summary.lm(urban_combine_fit2): essentially perfect fit: summary may
be unreliable


Call:
lm(formula = tot_cu ~ bed_prv_cu + bed_pub_cr + edu_pub_cr + 
    emp_ind_cr + ic_high_cr + ic_low_cr, data = TCI_stock)

Residuals:
       Min         1Q     Median         3Q        Max 
-5.396e-14 -7.250e-16  3.300e-16  2.363e-15  4.253e-15 

Coefficients:
              Estimate Std. Error    t value Pr(>|t|)    
(Intercept) -1.736e-15  9.743e-16 -1.782e+00   0.0798 .  
bed_prv_cu   2.997e+03  1.303e-13  2.300e+16   <2e-16 ***
bed_pub_cr   3.846e-11  2.728e-11  1.410e+00   0.1638    
edu_pub_cr  -8.751e-13  1.630e-12 -5.370e-01   0.5932    
emp_ind_cr   3.503e-13  3.962e-13  8.840e-01   0.3801    
ic_high_cr   5.033e-14  6.755e-13  7.500e-02   0.9409    
ic_low_cr   -1.265e-12  2.483e-12 -5.100e-01   0.6122    
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 7.245e-15 on 60 degrees of freedom
Multiple R-squared:      1,	Adjusted R-squared:      1 
F-statistic: 1.049e+32 on 6 and 60 DF,  p-value: < 2.2e-16
```

It seems that the only significant predictors for the urban stock prediction model with low p-value is the bed_prv_cu variable (Health-private sector-capital stock urban (built environment) in million USD $).Interesting to note that using rural predictors to estimate urban stock price results in non NA results. This is probably due to collinearity issue of using urban predictors to predict urban stocks.

Let's do the Rural Modeling using Urban Predictors:

```r
rural_fit <- lm(tot_cr ~ bed_prv_cr + bed_pub_cu + edu_prv_cu + emp_ind_cu +
                  ic_high_cu + ic_low_cu,
                        data = TCI_stock)
summary(rural_fit)
```

```


Call:
lm(formula = tot_cr ~ bed_prv_cr + bed_pub_cu + edu_prv_cu + 
    emp_ind_cu + ic_high_cu + ic_low_cu, data = TCI_stock)

Residuals:
      Min        1Q    Median        3Q       Max 
-0.155136 -0.070513 -0.002824  0.083679  0.154560 

Coefficients: (4 not defined because of singularities)
              Estimate Std. Error  t value Pr(>|t|)    
(Intercept)  3.689e-03  1.232e-02    0.299    0.766    
bed_prv_cr   2.999e+03  1.189e+00 2522.634   <2e-16 ***
bed_pub_cu  -3.872e-01  3.563e-01   -1.087    0.281    
edu_prv_cu          NA         NA       NA       NA    
emp_ind_cu          NA         NA       NA       NA    
ic_high_cu          NA         NA       NA       NA    
ic_low_cu           NA         NA       NA       NA    
---
```

```
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.09278 on 64 degrees of freedom
Multiple R-squared:      1, Adjusted R-squared:      1 
F-statistic: 3.579e+06 on 2 and 64 DF,  p-value: < 2.2e-16
```

When using urban predictors to predict rural stock, there are some NAs in model, so it seems that there is more collinearity issue.

Conclusion:

Due to time constraints, EDA was not able to be performed thoroughly to choose the correct predictors and even the most appropriate model. Future works include spend more time on EDA, doing literature review.

References:

This section includes all citations for sources used in the report, shiny app, and presentation.

[1] Stanford University. (n.d.). [GAR15 Global Exposure Dataset for Turks and Caicos Islands]. Stanford Digital Repository. https://purl.stanford.edu/wb949hp4321 [2] Worldometer. (n.d.). Dominican Republic GDP. Worldometer. Retrieved June 17, 2024, from https://www.worldometers.info/gdp/dominican-republic-gdp/ [3] Macrotrends. (n.d.). Cuba GDP per capita 1960-2024. Macrotrends. Retrieved June 17, 2024, from https://www.macrotrends.net/global-metrics/countries/CUB/cuba/gdp-per-capita [4] Worldometer. (n.d.). Bahamas GDP. Worldometer. Retrieved June 17, 2024, from https://www.worldometers.info/gdp/bahamas-gdp/ [5] Government of Turks and Caicos Islands. (2023). National tourism development strategy and action plan 2023. Government of Turks and Caicos Islands. Retrieved June 17, 2024, from https://gov.tc/tourismregulations/images/docs/TCI%20National%20Tourism%20Development%20Strategy%20and%20Action%20Plan%202023.pdf [6] Government of Turks and Caicos Islands. (n.d.). Turks and Caicos Islands statistics department. Government of Turks and Caicos Islands. Retrieved June 17, 2024, from https://www.gov.tc/stats/ [7] Government of Turks and Caicos Islands. (n.d.). Cabinet. Government of Turks and Caicos Islands. Retrieved June 17, 2024, from https://www.gov.tc/premier/cabinet [8] Government of Turks and Caicos Islands. (n.d.). Tourism statistics. Government of Turks and Caicos Islands. Retrieved June 17, 2024, from https://www.gov.tc/stats/statistics/economic/41-tourism [9] Encyclopaedia Britannica. (n.d.). Caribbean Sea. Encyclopaedia Britannica. Retrieved June 17, 2024, from https://www.britannica.com/place/Caribbean-Sea [10] Central Intelligence Agency. (n.d.). Turks and Caicos Islands: Flag. The World Factbook. Retrieved June 17, 2024, from https://www.cia.gov/the-world-factbook/countries/turks-and-caicos-islands/flag/