PCA-on-Financial-Market-in-2020

August 2, 2021

1 Introduction

A hypothesis behind econometric analysis is that financial market is multivariate. However, this experiment intends to challenge this hypothesis, as COVID-19 influenced almost every part of our lives in 2020. Because one single factor (COVID-19) caused very powerful impact on global economy, price fluctuation of global stock market may largely be explained by COVID-19 spread rate. I do not intend to hypothesize that 100% of variance can be explained by the spread of COVID-19; however, I would like to assume that an analysis could explain approximately 80% of variance. Because I want to understand correlation between market indices and COVID-19 confirmed rate. I would like to combine a number of data and would like to calculate explained rate of variance in each principal component.

2 Methodology

2.1 Explained Variance of First Principal Component

In PCA, $\mathbf{W}, \mathbf{Z}$ can be found using either an eigenvalue decomposition or the SVD. Suppose the matrix $\mathbf{X}$ is centered so that

$$\frac{1}{n}\sum_{i=1}^{n}\mathbf{x}_i = \vec{0} \in \mathbb{R}^p$$

The covariance matrix is defined to be $\mathbf{C} = \mathbf{X}\mathbf{X}^T$. The eigen-decomposition of $\mathbf{C} = \mathbf{W}\,\mathbf{W}^T$ gives the matrices $\mathbf{W}$ and $\mathbf{Z} = \mathbf{W}^T$. Here

$$= \begin{bmatrix} \sigma_1^2 & & \\ & \ddots & \\ & & \sigma_p^2 \end{bmatrix}$$

is the diagonal matrix with eigenvalues σ_i^2. The proportion of explained variance by our low-dimensional projection is defined to be

$$\mathrm{PV}(q) := \frac{\sum_{i=1}^{q}\sigma_i^2}{\sum_{i=1}^{p}\sigma_i^2}$$

I suppose that 80% of variance could be explained by the first principal component. In other words, I suppose that 40 global stock indices and COVID-19 confirmed rate of corresponding country may move together by the degree of 80%.

3 Experiment

3.1 Import Libraries and Define Required Functions

[1]:
```
# Load Packages

import yfinance as yf
import csv
import pandas as pd
import numpy as np
from datetime import datetime, date, time, timedelta
from countryinfo import CountryInfo
from sklearn.decomposition import PCA
from datapackage import Package

today = datetime.today()
yesterday = str(today - timedelta(2))[:10]

# apply the z-score method in Pandas using the .mean() and .std() methods
def z_score(df):
    # copy the dataframe
    df_std = df.copy()
    # apply the z-score method
    for column in df_std.columns:
        df_std[column] = (df_std[column] - df_std[column].mean()) /␣
 ↪df_std[column].std()

    return df_std

# Convert Date
def date_convert(dates):
    dates_return = []

    for date in dates:
        date = date.split("/")
        year = '20' + str(date[2])
        month = str(date[0])
        day = str(date[1])

        if int(month) < 10:
            month = '0' + month

        if int(day) < 10:
```

```
            day = '0' + day

        date = year + "-" + month + "-" + day
        dates_return.append(date)

    return dates_return

start = "2020-01-22"
end = "2021-01-01"

# Matplotlib
import matplotlib.pyplot as plt
pd.set_option('max_rows', 500)
pd.set_option('max_columns', 500)
np.set_printoptions(suppress=True)

%matplotlib inline
plt.rcParams["figure.figsize"] = (16, 12)
plt.style.use('seaborn-pastel')
plt.rcParams['lines.linewidth'] = 1
plt.figure(dpi=300)
plt.rcParams['lines.color'] = 'b'
plt.rcParams['axes.grid'] = True
plt.tight_layout()
```

```
<Figure size 4800x3600 with 0 Axes>
```

3.2 Data Import

3.2.1 Import Stock Indices

This part of code imports **40 Market Indices** that represent major financial market in the globe.

[2]:
```
# Import 40 Market Indices

BUK100P = yf.download("^BUK100P", start, end)['Adj Close'].to_frame()
SPY = yf.download("SPY", start, end)['Adj Close'].to_frame()
Singapore = yf.download("^STI", start, end)['Adj Close'].to_frame()
Dow = yf.download("^DJI", start, end)['Adj Close'].to_frame()
Nasdaq = yf.download("^IXIC", start, end)['Adj Close'].to_frame()
FTSE100 = yf.download("^FTSE", start, end)['Adj Close'].to_frame()
FTSE250 = yf.download("^FTSE", start, end)['Adj Close'].to_frame()
FTSE350 = yf.download("^FTLC", start, end)['Adj Close'].to_frame()
FTAI = yf.download("^FTAI", start, end)['Adj Close'].to_frame()
N225 = yf.download("^N225", start, end)['Adj Close'].to_frame()
N500 = yf.download("^N500", start, end)['Adj Close'].to_frame()
N1000 = yf.download("^N1000", start, end)['Adj Close'].to_frame()
HSI = yf.download("^HSI", start, end)['Adj Close'].to_frame()
```

```
Taiwan = yf.download("^TWII", start, end)['Adj Close'].to_frame()
SSE = yf.download("000001.SS", start, end)['Adj Close'].to_frame()
Shenzhen = yf.download("399001.SZ", start, end)['Adj Close'].to_frame()
DAX = yf.download("^GDAXI", start, end)['Adj Close'].to_frame()
France = yf.download("^FCHI", start, end)['Adj Close'].to_frame()
Indonesia = yf.download("^JKSE", start, end)['Adj Close'].to_frame()
PSEI = yf.download("PSEI.PS", start, end)['Adj Close'].to_frame()
AORD = yf.download("^AORD", start, end)['Adj Close'].to_frame()
AXJO = yf.download("^AXJO", start, end)['Adj Close'].to_frame()
AXKO = yf.download("^AXKO", start, end)['Adj Close'].to_frame()
kospi = yf.download("^KS11", start, end)['Adj Close'].to_frame()
India = yf.download("^BSESN", start, end)['Adj Close'].to_frame()
NZ50 = yf.download("^NZ50", start, end)['Adj Close'].to_frame()
XAX = yf.download("^XAX", start, end)['Adj Close'].to_frame()
RUI = yf.download("^RUI", start, end)['Adj Close'].to_frame()
RUT = yf.download("^RUT", start, end)['Adj Close'].to_frame()
RUA = yf.download("^RUA", start, end)['Adj Close'].to_frame()
GSPTSE = yf.download("^GSPTSE", start, end)['Adj Close'].to_frame()
N100 = yf.download("^N100", start, end)['Adj Close'].to_frame()
N150 = yf.download("^N150", start, end)['Adj Close'].to_frame()
BFX = yf.download("^BFX", start, end)['Adj Close'].to_frame()
IMOEX = yf.download("IMOEX.ME", start, end)['Adj Close'].to_frame()
MERV = yf.download("^MERV", start, end)['Adj Close'].to_frame()
TA125 = yf.download("^TA125.TA", start, end)['Adj Close'].to_frame()
JNOU = yf.download("^JNOU.JO", start, end)['Adj Close'].to_frame()
AEX = yf.download("^AEX", start, end)['Adj Close'].to_frame()
ATOI = yf.download("^ATOI", start, end)['Adj Close'].to_frame()
BVSP = yf.download("^BVSP", start, end)['Adj Close'].to_frame()
MIB = yf.download("FTSEMIB.MI", start, end)['Adj Close'].to_frame()
ATX = yf.download("^ATX", start, end)['Adj Close'].to_frame()
ISEQ = yf.download("^ISEQ", start, end)['Adj Close'].to_frame()
NSEI = yf.download("^NSEI", start, end)['Adj Close'].to_frame()
MXX = yf.download("^MXX", start, end)['Adj Close'].to_frame()
SSMI = yf.download("^SSMI", start, end)['Adj Close'].to_frame()
STOXX50E = yf.download("^STOXX50E", start, end)['Adj Close'].to_frame()
MDAXI = yf.download("^MDAXI", start, end)['Adj Close'].to_frame()
SDAXI = yf.download("^SDAXI", start, end)['Adj Close'].to_frame()
HSCC = yf.download("^HSCC", start, end)['Adj Close'].to_frame()
HSCE = yf.download("^HSCE", start, end)['Adj Close'].to_frame()
KLSE = yf.download("^KLSE", start, end)['Adj Close'].to_frame()

# Transform into Dataframe
df = pd.concat([
    BUK100P, Dow, Nasdaq, FTSE100, FTSE250, FTAI, N225, SSE, Shenzhen,
    DAX, France, Indonesia, PSEI, AXKO, kospi, NZ50, RUI, RUT, RUA,
    GSPTSE, N100, N150, BFX, IMOEX, MERV, TA125, JNOU, SPY, Singapore,
    AEX, ATOI, BVSP, MIB, ATX, ISEQ, MXX, STOXX50E, MDAXI, SDAXI, KLSE],
```

```python
    axis=1
)

# Set Columns
# Columns include Country Code, so that I can match country to COVID-19␣
↪confirmed rate.
df.columns=[
    'US-Dow', 'US-Nasdaq', 'GB-FTSE100', 'GB-FTSE250', 'GB-FTAI',
    'GB-BUK100P', 'JP-N225', 'CN-SSE', 'CN-Shenzhen', 'DE-DAX',
    'FR-FCHI', 'ID-JKSE', 'PH-PSEI', 'AU-AXKO', 'KR-KSII', 'NZ-NZ50',
    'US-RUI', 'US-RUT', 'US-RUA', 'CA-GSPTSE', 'FR-N100', 'FR-N150',
    'BE-BFS', 'RU-IMOEX', 'AR-MERV', 'IL-TA125', 'ZA-JNOU', 'US-SPX',
    'SG-STI', 'NL-AEX', 'AU-ATOI', 'BR-BVSP', 'IT-MIB', 'AT-ATX', 'IE-ISEQ',
    'MX-MXX', 'DE-Stoxx50E', 'DE-MDAXI', 'DE-SDAXI', 'MY-KLSE']

# Eliminate Missing Values
daily_return = df.fillna(method='ffill').fillna(method='bfill')

# Normalize Data
daily_return = z_score(daily_return)

# Copy it for the future use
daily_return1 = daily_return
```

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3.2.2 COVID-19 Confirmed Data

This part of code imports **corresponding COVID-19 Confirmed Rate**.

[3]:
```
# COVID-19 Dataset

states_url = "https://covidtracking.com/api/states/daily"
us_url = "https://covidtracking.com/api/us/daily"
case_threshold = 100

cases = ["confirmed", "deaths", "recovered"]
sheet = "https://raw.githubusercontent.com/CSSEGISandData/COVID-19/master/
 ↪csse_covid_19_data/csse_covid_19_time_series/time_series_covid19_"
suffix = "_global.csv"
df_list = []

url_confirmed = sheet + "confirmed" + suffix
```

```
df_confirmed = pd.read_csv(url_confirmed, header=0, escapechar="\\")
df_confirmed1 = df_confirmed.drop(columns=["Lat", "Long"])
df_confirmed = df_confirmed.drop(columns=["Lat", "Long"])

df_confirmed = df_confirmed.groupby("Country/Region").agg("sum").T
df_confirmed1 = df_confirmed1.groupby("Province/State").agg("sum").T

# Preprocess Data
dates = df_confirmed.index.tolist()
dates = date_convert(dates)
US = df_confirmed["US"].tolist()
China = df_confirmed["China"].tolist()
Germany = df_confirmed["Germany"].tolist()
Japan = df_confirmed["Japan"].tolist()
UK = df_confirmed["United Kingdom"].tolist()
Korea = df_confirmed["Korea, South"].tolist()
Australia = df_confirmed["Australia"].tolist()
Austria = df_confirmed["Austria"].tolist()
Denmark = df_confirmed["Denmark"].tolist()
Greece = df_confirmed["Greece"].tolist()
Finland = df_confirmed["Finland"].tolist()
Ireland = df_confirmed["Ireland"].tolist()
Italy = df_confirmed["Italy"].tolist()
SouthAfrica = df_confirmed["South Africa"].tolist()
Spain = df_confirmed["Spain"].tolist()
Singapore = df_confirmed["Singapore"].tolist()
Russia = df_confirmed["Russia"].tolist()
NewZealand = df_confirmed["New Zealand"].tolist()
Canada = df_confirmed["Canada"].tolist()
France = df_confirmed["France"].tolist()
Netherlands = df_confirmed["Netherlands"].tolist()
Mexico = df_confirmed["Mexico"].tolist()
Brazil = df_confirmed["Brazil"].tolist()
Philippines = df_confirmed["Philippines"].tolist()
India = df_confirmed["India"].tolist()
Argentina = df_confirmed["Argentina"].tolist()
Indonesia = df_confirmed["Indonesia"].tolist()
Malaysia = df_confirmed["Malaysia"].tolist()
Israel = df_confirmed["Israel"].tolist()
Poland = df_confirmed["Poland"].tolist()
Afghanistan = df_confirmed["Afghanistan"].tolist()

data = [
    US, China, Japan,
    Korea, Australia, Austria,
    Germany, UK, Denmark,
    Greece, Italy, SouthAfrica,
```

```
    Spain, Singapore, Russia,
    NewZealand, Canada, France,
    Netherlands, Mexico, Philippines,
    India, Argentina, Indonesia,
    Malaysia, Israel, Poland,
    Brazil, Spain
]

# Country Codes
country_codes = [
    "US", "CN", "JP",
    "KR", "AU", "AT",
    "DE", "GB", "DK",
    "GR", "IT", "ZA",
    "ES", "SG", "RU",
    "NZ", "CA", "FR",
    "NL", "MX", "PH",
    "IN", "AR", "ID",
    "MY", "IL", "PL",
    "BR", "ES"
]

daily_confirmed = pd.DataFrame(data, index=country_codes, columns=dates).T
daily_confirmed = z_score(daily_confirmed)

for code in country_codes:
    population = CountryInfo(code).population()
    daily_confirmed[code] = daily_confirmed[code].div(population, axis=0)

daily_confirmed.index.name = 'Date'
daily_confirmed1 = daily_confirmed
```

3.3 Merge Dataframe

Because I need to **merge dataframe** to apply Principal Component Analysis as a means of calculating explained variance, I now merge two dataframes: **Daily Return** and **Daily Confirmed**.

[4]:
```
# List of Dates
confirmed = daily_confirmed.index.tolist()
returns = daily_return.index.tolist()

# Build a list to include dates in common
dates_common = []
for date in returns:
    date = (str(date)[:10])
    if date in confirmed:
        dates_common.append(date)
```

```
# Only leave dates in common from daily_confirmed
for date in daily_confirmed.index:
    if date not in dates_common:
        daily_confirmed = daily_confirmed.drop(date)

# Only leave dates in common from daily_return
daily_return_index = []
for var in daily_return.index.tolist():
    date = (str(var))[:10]
    if date not in dates_common:
        daily_return = daily_return.drop(var)

    else:
        daily_return_index.append(str(date))

daily_return.index = daily_return_index
daily_return.index.name = 'Date'

# Now, merge them in same index
df_merged = pd.concat([daily_return, daily_confirmed], axis=1)

# Normalize
df_merged = z_score(df_merged)
```

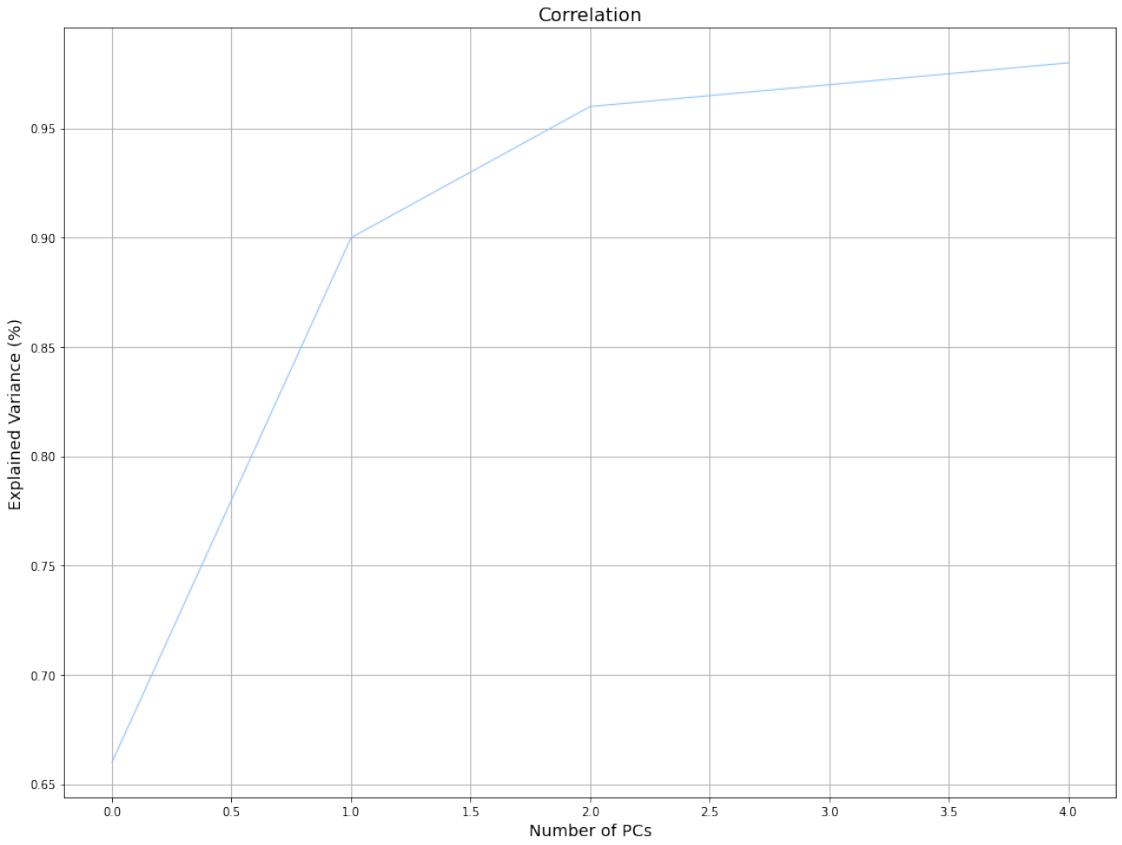
4 Principal Component Analysis

4.1 Extraction of Five Principal Components

I extract first 5 principal components. They represent how a limited number of principal components, which are orthogonal combinations of vectors, can explain total variance.

[5]:
```
pca = PCA(5).fit(df_merged)
daily_return_factors = pd.Series(index=df_merged.columns, data=pca.
 ↪components_[0])
print("TOP 5 Principal Components:", pca.explained_variance_ratio_.round(2))
variance_stock = pca.explained_variance_ratio_.cumsum().round(2)
plt.plot(variance_stock)
plt.title('Correlation', fontsize = 16)
plt.xlabel('Number of PCs', fontsize = 14)
plt.ylabel('Explained Variance (%)', fontsize = 14)
plt.show()
```

```
TOP 5 Principal Components: [0.66 0.24 0.06 0.01 0.01]
```



First principal component explains 66% of entire variance, which means H_0 is accepted. If we take second principal component into account, it combinedly explains 80% of variance. It appears that COVID-19 is powerful variable to explain financial market's fluctuation. However, it appears that it still does not explain 80% of entire variance, which means that its impact is still limited to challenge multivariate assumption.

5 Comparison of Eigenvalues

While explained variance methodology proves that COVID-19 Confirmed Rate is limited to explain financial fluctuation alone, I took further process to solidify this conclusion.

5.1 Eigenvalues

Principal Component Analysis is essentially about reducing complex dimensionality of data by taking **orthogonal transformation** of vectors. Each loading of principal component, which is `eigenvalue` whose sum of entire eigenvalues is equal to 1, as `unit vector`.

$$u := \min(\frac{1}{n}\sum_{i}^{n}(x_i^T x_i - (u_1^T x_i)^2))$$

Principal Component Analysis aims for minimizing total distance of a unit vector whose perpendicular distance is minimized as a result. And it is the eigenvector of the covariance matrix of X.

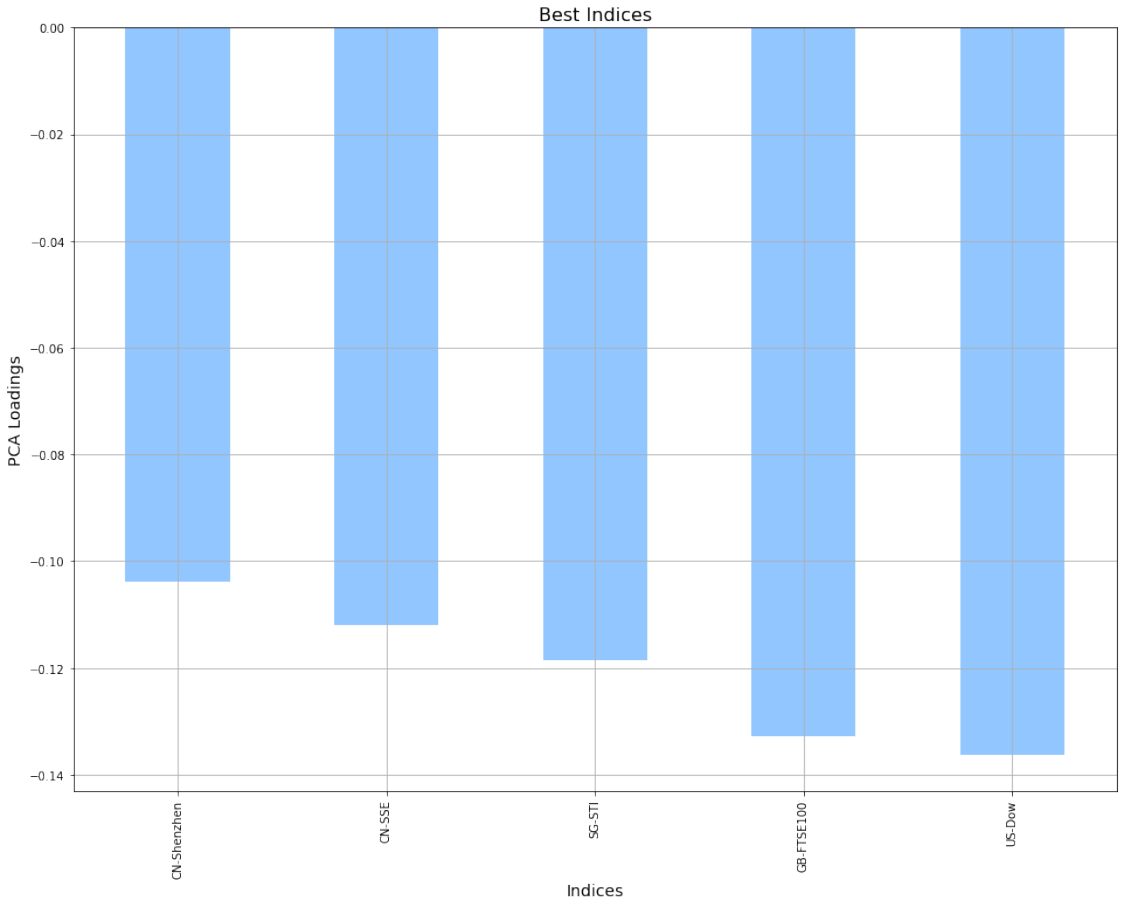
$$Av = \lambda v$$

5.2 PCA Loading: "Degree of Impact"

I will sorely concentrate on the first principal component, which explains roughly 70% of variance. I intend to check if it aligns with intuition that we experienced in 2020. From the first principal component, its vector includes eigenvalue, or factor loading, that represents coefficient. And therefore, larger eigenvalue could imply more influenced whereas smaller eigenvalue could imply less influenced. I suppose that COVID-19 should have played its role in negative direction. It does never make sense that COVID-19's heavy strike on labor market and global economy will result in positive impact. Therefore, comparing PCA loadings imply how big each country was harmed.

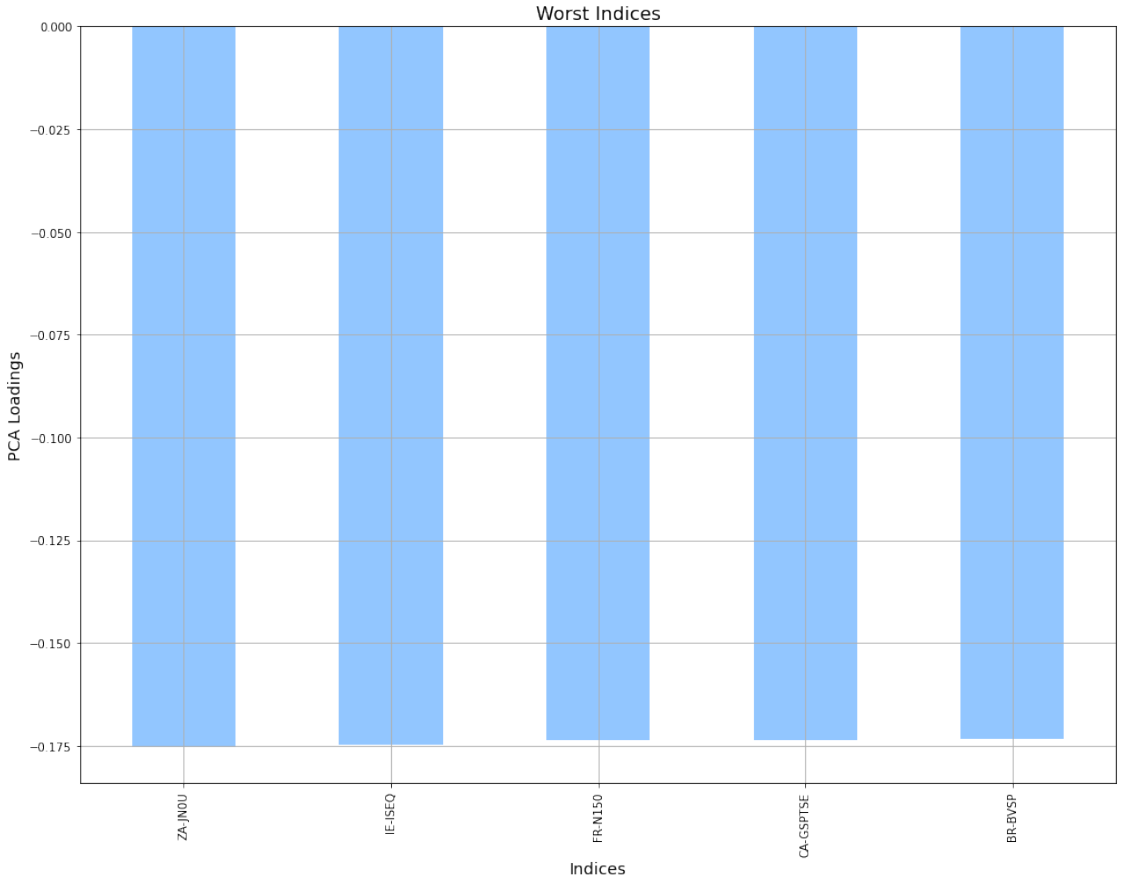
[6]:
```
pca_dr = PCA(1).fit(daily_return1)
daily_return_factors = pd.Series(index=daily_return1.columns, data=pca_dr.
↪components_[0])

daily_return_factors.nlargest(5).plot.bar()
plt.title('Best Indices', fontsize=16)
plt.xlabel('Indices', fontsize=14)
plt.ylabel('PCA Loadings', fontsize = 14)
# plt.savefig('Best Indices.png', dpi=300)
```

[6]:
```
Text(0, 0.5, 'PCA Loadings')
```



[7]:
```
daily_return_factors.nsmallest(5).plot.bar()
plt.title('Worst Indices', fontsize=16)
plt.xlabel('Indices', fontsize=14)
plt.ylabel('PCA Loadings', fontsize = 14)
```

[7]: Text(0, 0.5, 'PCA Loadings')



In the first Z, a linear combination of high-dimensional vectors, there is discrepancy between intuition and result. Great Britain and United States are on top of most of other countries, in terms of `COVID19's limited influence on market`. However, because COVID-19 has stroke U.S.A. and Great Britain hardest than any other, the linear relationship between COVID-19's impact and market fluctuation is quite limited. In other words, there should be `other factors`, supposedly monetary policy of western governments, that are to make the model be more accurate.

[8]:
```
print("Most Positively Influenced Indices Are:")
print(daily_return_factors.nlargest(5).index.tolist())
print("")
print("Degree of Impact is", daily_return_factors.nlargest(5).values.tolist())
print("")

print("Most Negatively Influenced Indices Are:")
print(daily_return_factors.nsmallest(5).index.tolist())
print("")
print("Degree of Impact is", daily_return_factors.nsmallest(5).values.tolist())
print("")
```

```
Most Positively Influenced Indices Are:
```

```
['CN-Shenzhen', 'CN-SSE', 'SG-STI', 'GB-FTSE100', 'US-Dow']

Degree of Impact is [-0.10386905041725426, -0.11185218241949893,
-0.11849356397466648, -0.13284897201600882, -0.13619868522005837]

Most Negatively Influenced Indices Are:
['ZA-JNOU', 'IE-ISEQ', 'FR-N150', 'CA-GSPTSE', 'BR-BVSP']

Degree of Impact is [-0.1751972802144581, -0.17478189737240282,
-0.1737130864090994, -0.17355907590772135, -0.17322922178860994]
```

It appears that understanding financial market is not still explained by COVID-19 alone; even if there is significant impact of COVID-19 on financial market, it is still on the assumption that financial market could only be understood in multivariate ground.