Historical analysis of the Forex market (USD/INR) using Python

The foreign exchange market has seen significant movement in recent years. The dollar has appreciated in value relative to other currencies, especially compared to the INR. In this article we will use historical data to analyze how the dollar has changed and whether there is a relationship between the dollar and INR and Indian interest rates. The analysis will be conducted using Python.

Throughout this article we will learn
1. How to get and analyze financial data
2. How Dollar-INR exchange rate have been changing
3. Relationship between the U.S.-India interest rate differential and the exchange rate

```python
import os
import re
import datetime as dt
import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
import pandas_datareader.data as web
from scipy import stats
import statsmodels.api as sm
import seaborn as sns
data_dir = "./data/forex_analysis"
os.makedirs(data_dir, exist_ok=True)

business_cycle = pd.read_html(
 "https://www.nber.org/research/data/us-business-cycle-expansions-
and-contractions")[0]
# save the data
business_cycle_file_path = f"{data_dir}/business_cycle.csv"
business_cycle.to_csv(business_cycle_file_path, index=False)
business_cycle = pd.read_csv(business_cycle_file_path, header=1)
business_cycle = business_cycle.iloc[1:].reset_index(drop=True)
business_cycle.head(3)
```

```
 Peak Month Peak Year Peak Quarter Trough Month Trough Year \
0 June 1857 2 December 1858
1 *October 1860 3 *June 1861
2 *April 1865 1 *December 1867

Trough Quarter Peak to Trough (Months) \
0 4 18
1 3 8
2 Trough occurred 1868Q1 32

    Previous Trough to this Peak (Months) Trough from Previous Trough
(Months) \
0 30
48
1 22
30
2 46
78

Peak from Previous Peak (Months) Unnamed: 10_level_1
```

0 - NaN
1 40 NaN
2 54 NaN

Let's check the business cycle by drawing a diagram showing periods of recession in gray and periods of expansion in white.

```
cycle_list = []
for i in range(len(business_cycle)):
 row = business_cycle.iloc[i]
 peak_month = re.sub(r"\*", "", row["Peak Month"])
 peak = dt.datetime.strptime(f"{row['Peak Year']}{peak_month}", "%Y %B")
 trough_month = re.sub(r"\*", "", row["Trough Month"])
 trough = dt.datetime.strptime(f"{row['Trough Year']} {trough_month}",
"%Y%B")
 cycle_list.append((peak, trough))
print(cycle_list[-3:])
fig, ax = plt.subplots(figsize=(20, 5))
for x in cycle_list:
 ax.axvspan(x[0], x[1], color="gray", alpha=0.3)
ax.get_yaxis().set_visible(False)
plt.show()
```

[(datetime.datetime(2001, 3, 1, 0, 0), datetime.datetime(2001, 11, 1, 0, 0)), (datetime.datetime(2007, 12, 1, 0, 0), datetime.datetime(2009, 6, 1, 0, 0)), (datetime.datetime(2020, 2, 1, 0, 0), datetime.datetime(2020, 4, 1, 0, 0))]
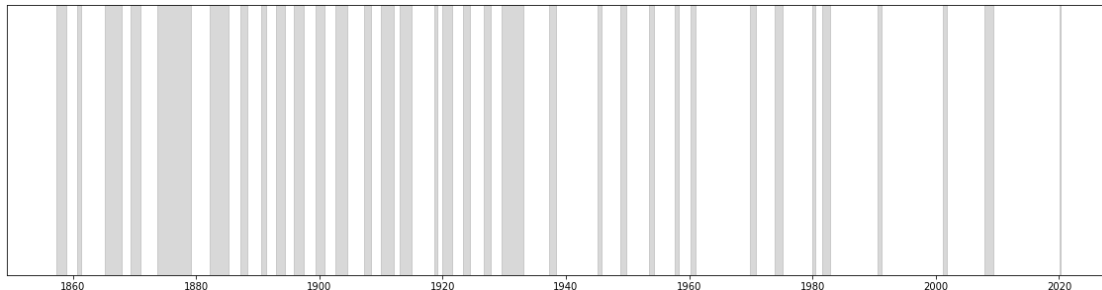


```
start = dt.datetime(1950, 1, 1)
end = dt.datetime(2022, 9, 30)
inr_to_usd = web.DataReader('DEXINUS', 'fred', start, end) #
save the data
file_path = f"{data_dir}/DEXINUS.csv"
inr_to_usd.to_csv(file_path)
inr_to_usd = pd.read_csv(file_path, index_col="DATE",
parse_dates=True)
print(inr_to_usd.shape)
inr_to_usd
```

(12974, 1)

```
 DEXINUS
DATE
1973-01-02 8.02
1973-01-03 8.02
1973-01-04 8.00
1973-01-05 8.01
1973-01-08 8.00

... ...
2022-09-19 79.71
2022-09-20 79.72
2022-09-21 79.96
2022-09-22 81.00
2022-09-23 81.11

[12974 rows x 1 columns]
```

```python
plt.figure(figsize=(10, 6))
plt.plot(inr_to_usd)
plt.hlines(
 inr_to_usd.tail(1),
 inr_to_usd.index[0],
 inr_to_usd.index[-1],
 linestyles="dashed",
 colors="red",
 alpha=0.5,)
for x in cycle_list:
 plt.axvspan(x[0], x[1], color="gray", alpha=0.3)
plt.grid(axis="y")
plt.xlabel("Date")
plt.ylabel("Indian INR to 1 USD (INR/$)")
plt.xlim(inr_to_usd.index[0], inr_to_usd.index[-1])
plt.show()
```
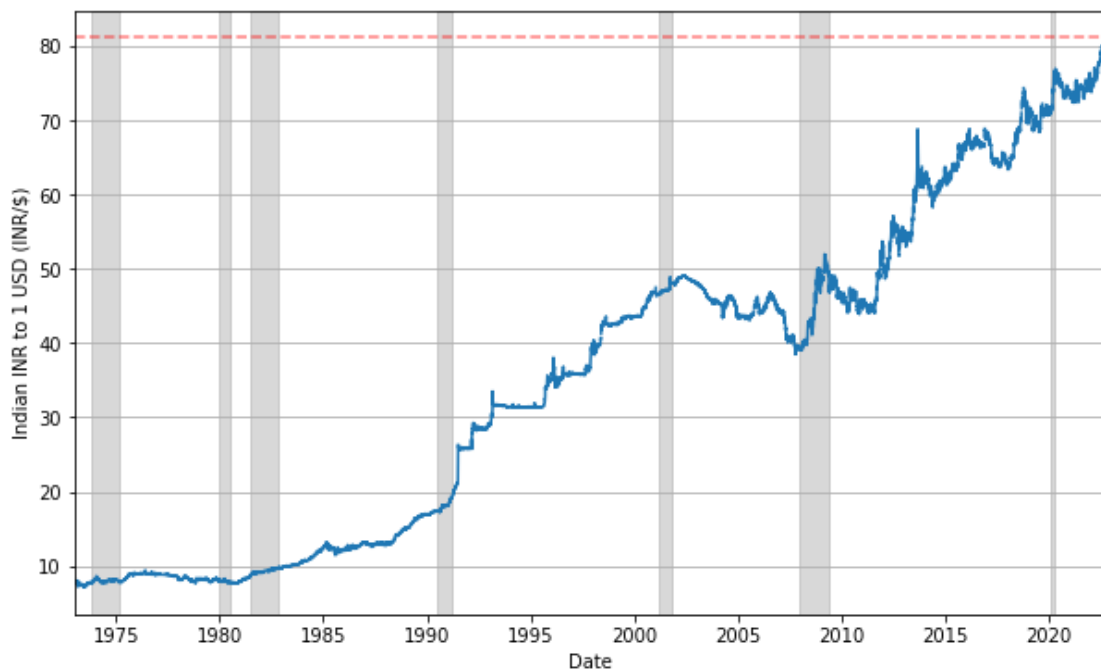
US 10Y Bond Yield

```python
treasury = web.DataReader('GS10', 'fred', start, end)
# save the data
file_path = f"{data_dir}/GS10.csv"
treasury.to_csv(file_path)
treasury = pd.read_csv(file_path, index_col="DATE", parse_dates=True)
print(treasury.shape)
treasury = treasury.interpolate()
treasury
```

```
(833, 1)

          GS10
DATE
1953-04-01 2.83
1953-05-01 3.05
1953-06-01 3.11
1953-07-01 2.93
1953-08-01 2.95

... ...
2022-04-01 2.75
2022-05-01 2.90
2022-06-01 3.14
2022-07-01 2.90
2022-08-01 2.90

[833 rows x 1 columns]
```

```python
plt.figure(figsize=(10, 6))
plt.plot(treasury)
plt.hlines(
 treasury.tail(1),
 treasury.index[0],
 treasury.index[-1],
 linestyles="dashed",
 colors="red",
 alpha=0.5,)
for x in cycle_list:
    plt.axvspan(x[0],  x[1],  color="gray",  alpha=0.3)
plt.grid(axis="y")
plt.xlabel("Date")
plt.ylabel("Yield(%)")
plt.xlim(treasury.index[0], treasury.index[-1]) plt.show()
```

India 10-year Bond Yield

```
in_bond = web.DataReader('INDIRLTLT01STM', 'fred', start, end)
# save the data
file_path = f"{data_dir}/INDIRLTLT01STM.csv"
in_bond.to_csv(file_path)
in_bond = pd.read_csv(file_path, index_col="DATE", parse_dates=True)
print(in_bond.shape)
in_bond = in_bond.interpolate()
in_bond
```

(128, 1)

To analyze the interest rate differential, we use data for Japanese government bonds, with the same maturities as the U.S. Treasury bonds we downloaded earlier.
& Drawing a time series plot.

```
        INDIRLTLT01STM
DATE
2011-12-01 8.5600
2012-01-01 8.2350
2012-02-01 8.1925
2012-03-01 8.3740
2012-04-01 8.5875
... ...
2022-03-01 6.8200
2022-04-01 7.1100
2022-05-01 7.3900
2022-06-01 7.5300
2022-07-01 7.4000

[128 rows x 1 columns]
```

```python
plt.figure(figsize=(10, 6))
plt.plot(in_bond)
plt.hlines(
 in_bond.tail(1),
 in_bond.index[0],
 in_bond.index[-1],
 linestyles="dashed",
 colors="red",
 alpha=0.5,)
plt.grid(axis="y")
plt.xlabel("Date")
plt.ylabel("Yield(%)")
plt.show()
```

```
plt.figure(figsize=(10, 6))
plt.plot(treasury, label="US")
plt.plot(in_bond, label="India")
plt.grid(axis="y")
plt.xlabel("Date")
plt.ylabel("Yield(%)")
plt.xlim(in_bond.index[0], in_bond.index[-1])
plt.legend()
plt.show()
```
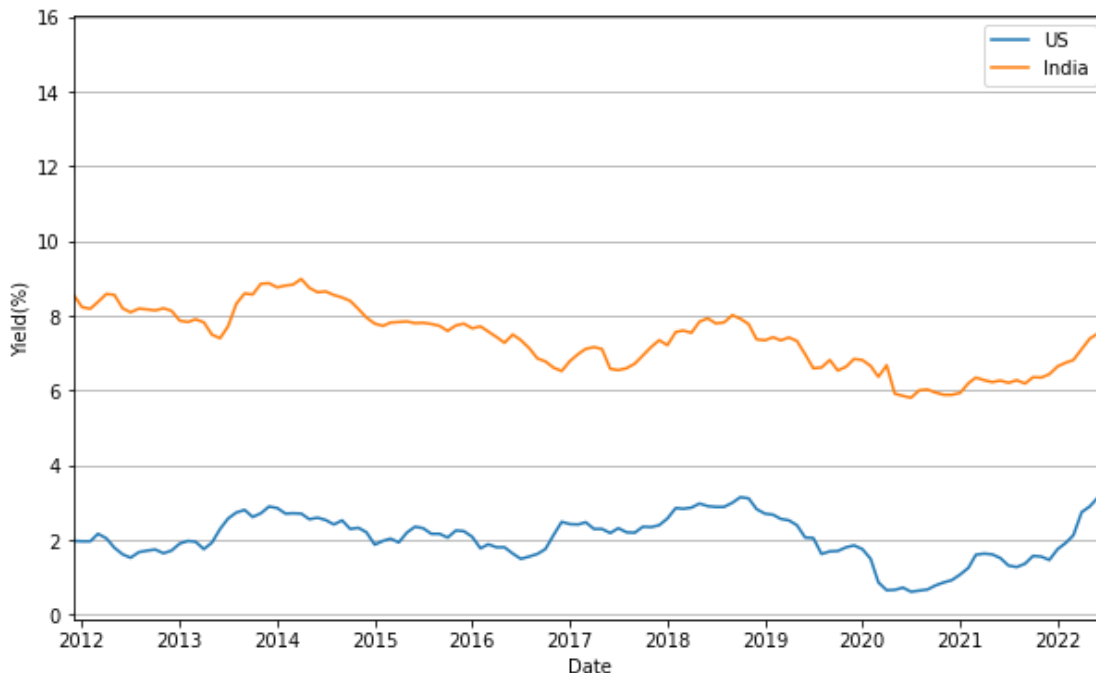

The relationship between the U.S.-India interest rate differential and the exchange rate

We will analyze how interest rates in India and the U.S. relate to the exchange rate. First, we will compare bond yields in both countries.

```
df = in_bond.join(treasury)
df["Treasury-IndBond"] = df["GS10"] - df["INDIRLTLT01STM"]
plt.figure(figsize=(10, 6))
plt.plot(df[["Treasury-IndBond"]])
for x in cycle_list:
 plt.axvspan(x[0], x[1], color="gray", alpha=0.3)
plt.grid(axis="y")
plt.xlabel("Date")
plt.ylabel("10-year Bond Yield Spread(%)")
plt.xlim(in_bond.index[0], in_bond.index[-1])
plt.show()
```
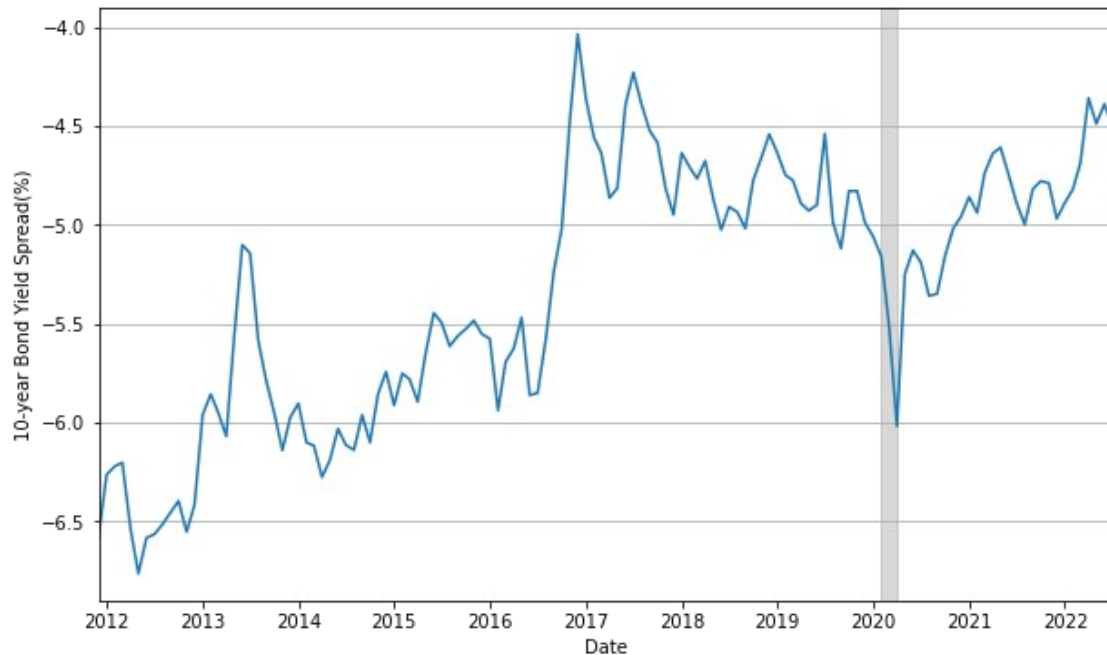
```python
fig, ax1 = plt.subplots(figsize=(15, 8))
ax2 = ax1.twinx()
ax1.plot(df[["Treasury-IndBond"]],
 color="green", label="10-year Bond Yield Spread(%)")
ax2.plot(inr_to_usd, color="red", alpha=0.5, label="Indian INR to 1
USD (INR/$)")
for x in cycle_list:
 ax1.axvspan(x[0], x[1], color="gray", alpha=0.3)
plt.tick_params(labelsize=10) # font size of tick labels
plt.title("CPI vs. S&P 500 Monthly Returns", fontsize=15)
handler1, label1 = ax1.get_legend_handles_labels()
handler2, label2 = ax2.get_legend_handles_labels()
ax1.legend(handler1 + handler2, label1 + label2, loc=1,
borderaxespad=0.)
ax1.set_xlabel("Date")
ax1.set_ylabel("10-year Bond Yield Spread(%)")
ax2.set_ylabel("Indian INR to 1 USD (INR/$)")
ax1.set_ylim([-10, 3])
ax2.set_ylim([10, 90])
ax1.set_xlim(in_bond.index[0], in_bond.index[-1])
plt.show()
```

CPI vs. S&P 500 Monthly Returns
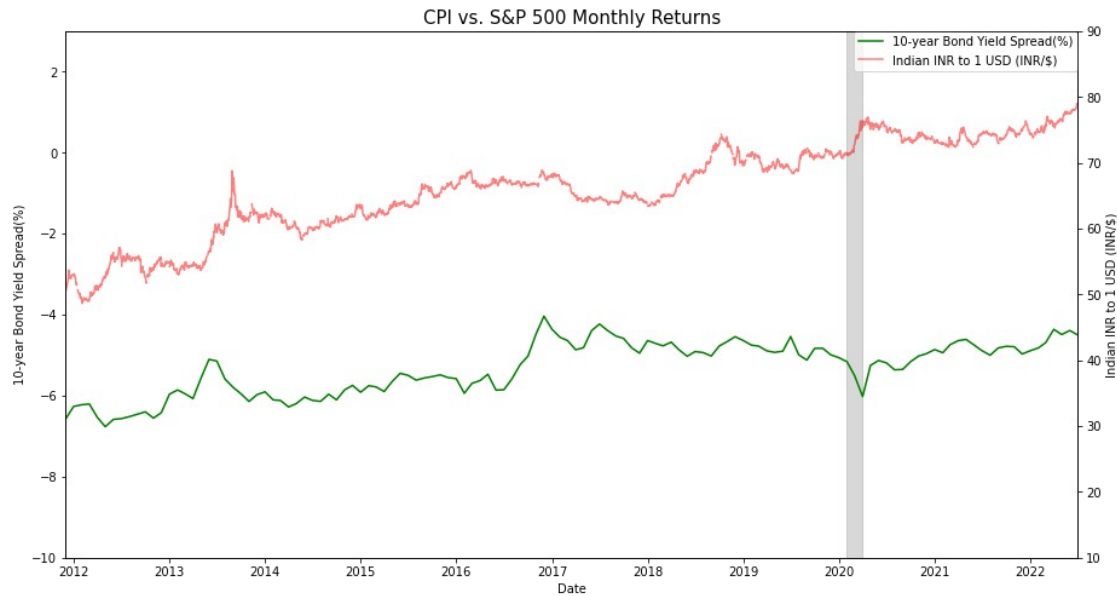
Excellent! We can see that when the interest rate differential increases, that is, when the outlook for the U.S. economy is good, the dollar basically appreciates. Conversely, the INR appreciates when the U.S. is in boom or when the economic outlook is good.

```python
T10Y_minus_T2Y = web.DataReader('T10Y2Y', 'fred', start, end) # save the data
file_path = f"{data_dir}/T10Y2Y.csv"
T10Y_minus_T2Y.to_csv(file_path)
T10Y_minus_T2Y = pd.read_csv(file_path, index_col="DATE", parse_dates=True)
print(T10Y_minus_T2Y.shape)
plt.figure(figsize=(10, 6))
plt.plot(T10Y_minus_T2Y)
for x in cycle_list:
 plt.axvspan(x[0], x[1], color="gray", alpha=0.3) plt.grid(axis="y")
plt.xlabel("Date")
plt.ylabel("T10Y_minus_T2Y(%)")
plt.xlim(T10Y_minus_T2Y.index[0], T10Y_minus_T2Y.index[-1])
plt.show()
```

(12089, 1)

When Will the Next Recession Come?

Currently, the U.S. economy is strong, the interest rate differential is expanding, and the dollar is appreciating. However, there is a possibility that the yen will depreciate if the U.S. enters a recession. So when will the U.S. enter a recession?

One indicator to find out is the difference between short- and long-term interest rates. We

will download and plot the data for the yield on the U.S. 10-year Treasury note minus the yield on the U.S. 2-year Treasury note.

Amit Kumar Jha
Ph.D. Financial Economics
IIT Madras, Chennai, india