FIN3524 - Int. Financial Management Problem Set 1

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1 Real-exchange-rate volatility

1.1 (a) What are nominal exchange rates and what are real exchange rates?

When discussing nominal exchange rates and real exchange rates you can think of the nominal exchange rate (S) as the price of one currency in terms of another, it is the rate you see quoted in the FX market. On the other hand, the real exchange rate (Q) takes that nominal rate and adjusts it for differences in price levels (or inflation) across the two countries, thereby measuring how many goods in one country can be exchanged for goods in another.

1. Nominal Exchange Rate (S) - The straightforward "market" rate: how many units of domestic currency it takes to purchase one unit of foreign currency (or vice versa). If 1 USD = 10 NOK, the nominal exchange rate is 10 NOK per USD.

2. Real Exchange Rate (Q): Adjusts the nominal rate by the ratio of price levels (or by inflation differentials) across countries. Conceptually, it answers: "How many basket of goods in the domestic country are needed to buy the same basket abroad?". A common formula for the real FX rate is $Q = S \times \frac{P^*}{P}$ where S is the spot for the nominal exchange rate and P^* is the foreign price level, and P is the domestic price level.

3. It could also be important to mention that if $Q = 1$, the currencies have the same purchasing power (i.e., PPP "holds"). If $Q < 1$, the domestic currency is considered "undervalued" (domestic goods relatively cheap), and if $Q > 1$, the domestic currency is "overvalued" (domestic goods relatively expensive).

The nominal exchange rate is what you observe directly in the FX market, while the real FX rate is an economic concept that incorporates price-level differences and thus tells you more about competitiveness and purchasing power.

1.2 (b)

If we are employed by a corporation that has production facilities abroad, has trading partners abroad, or for some othe reason is making transactions in foreign currencies, what are we primarily concerned about: nominal or real exchange rate fluctuations? Why?

We focus on the real exchange rate because it tells us how many goods we can actually purchase for our currency once price levels are factored in. A purely nominal exchange rate, S, just shows how many units of foreign currency we get for each home unit, but it doesn't reveal whether inflation at home or abroad is eating into that "better" or "worse" rate. If one country's prices are rising faster, then even a favorable move in S might not help us in real terms. That's why define the real exchange rate $Q = S \times \frac{P^*}{P}$, so we can see if we're genuinely getting more (or fewer) goods and services compared to before.

For MNCs with production facilities or sales in foreign markets, these real fluctuations matter most because they determine competitiveness and profitability. If Q goes down, we might end up paying higher real costs for inputs or receiving lower real revenue abroad - even if the nominal rate looks stable. On the other hand, if Q rises, our goods become relatively cheaper to produce or sell, improving our margins. In practice, we might hedge nominal exchange rate movements to manage short-term currency risk, but real exchange rate changes are what drive strategic decisions and reveal whether we're truly paying a premium or enjoying a discount in foreign markets.

1.3 (c)

We would like to study the relationship between changes in price and cost levels and changes in the nominal exchange rate - ie. to study whether the real exchange rate is stable over time.

1.3.1 Briefly document the steps you make to download the data from FRED

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We first set up the required packages (httr, jsonlite, and tidyverse), followed by my API key from the FRED account registration, and then lastly endpoint construction to retrieve NOK/USD [4] exchange rate series from FRED in JSON format. The API request is made using the GET function, and the JSON response is parsed using fromJSON(), extracting the relevant time series observations. The extracted data is then converted into a dataframe, where the FX rate values are converted into numeric format.The same approach follows for CPIAUCSL [1] and CPILFESL [2].

For the Norwegian monthly inflation [3] is imported. The CSV file does not seem correctly formatted for importation, and therefore corrections needs to be applied, including column renaming, removal for extra rows, and type conversion for numerical values. The script extracts the year and month information from the date field and constructs a proper Date column to standardize the time series format. After cleaning, only the relevant columns, Date and CPI, are retained.

This ensures that all the datasets [1] [2] [3] [4], whether sourced via API or imported locally, are structured consistently with proper numeric formatting and date representation.

1.3.2 Compute year-on-year changes in the NOK/USD exchange rate for each month from January 1971 to December last year

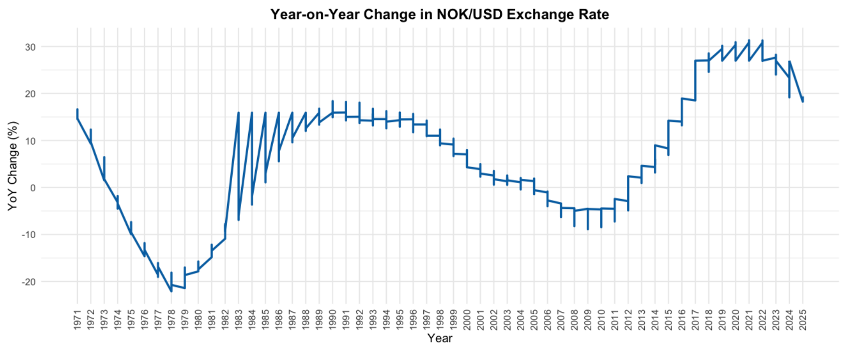


Figure 1: The year-on-year changes for the NOKUSD since 1971 until December last year.

The given code processes the NOK/USD [4] exchange rate data to compute the year-on-year (YoY) percentage change and then smooths the results using a rolling average. The first step removes NA values to ensure the dataset is ready for computation. Next, the date column is converted into a date format, and year and month are extracted separately. To reduce fluctuations, the data is aggregated at the monthly level by computing the mean FX ratefor each month. The year and month columns are converted into numeric format. This how the YoY percentage change is calculated:

$$\text{NOKUSD\_monthly\$YoY\_Change} = \left(\frac{\text{value}_t - \text{value}_{t-12}}{\text{value}_{t-12}} \right)$$

The computed YoY change values include missing entries for the first 12 months since there is no prior year data for comparison. These missing values are removed from the dataset, to futher smooth fluctuations in the YoY changes, a rolling mean is applied using a window size of 15 months with an extended fill and centered alignment. This rolling average helps in identifying long-term trends while reducing short-term volatility in the FX change.

1.3.3 Compute year-on-year changes in the price levels for each month from January 1971 to December last year.

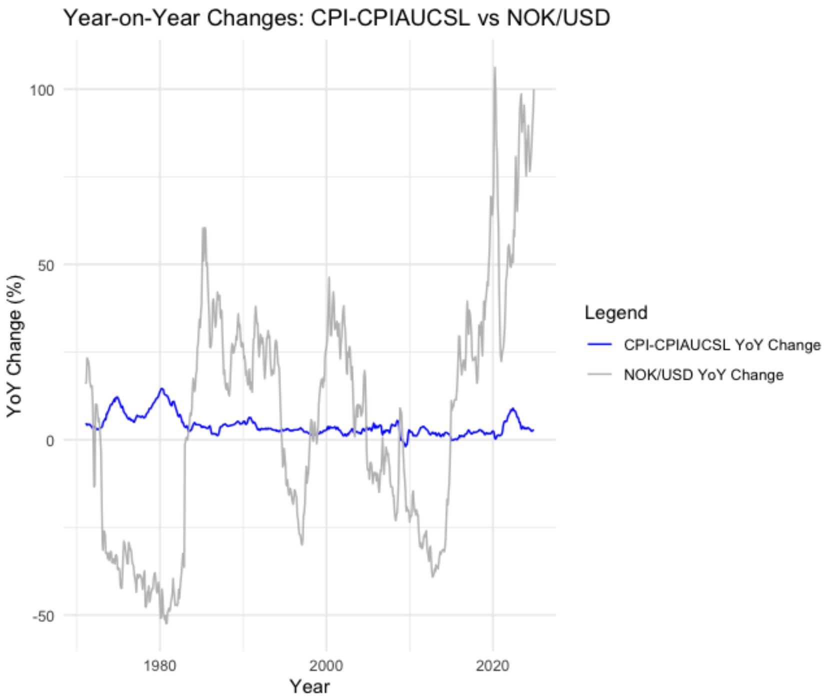


Figure 2: YoY NOKUSD Change against CPIAUCSL YoY Change

We load in CPIAUCSL [1] (Consumer Price Index for All Urban Consumers) and NOKUSD [4] from the .csv files. We ensure that the Year and Month columns are correctly converted into a date format using make_date(). This transformation helps in aligning two datasets by month and year. The next step performs an inner_join() on the date column, merging the two datasets and keeping only the overlapping time period for analysis. The suffixes _CPI and _NOKUSD ensure that similarly named columns from both datasets remain distinguishable.

The NOKUSD [4] YoY change, shows high volatility compared to the CPIAUCSL [1]. This reflects the currency's sensitivity to macroeconomic factors, such as oil prices, interest rate changes, or geopolitical events. Unlike the CPIAUCSL, which shows a more stable and gradual trend, NOK/USD experiences extreme fluctuations, including significant depreciation and appreciation periods.

1.3.4 Compute the regression

For the regression computation I decided that it would be interesting to predict the NOKUSD-YoY change based on the CPIAUCSL-YoY change. Essentially NOKUSD-YoY $\equiv Y$ and CPIAUCSL-YoY $\equiv X$, therefore we have:

$$Y = \beta_0 + \beta_1 X$$

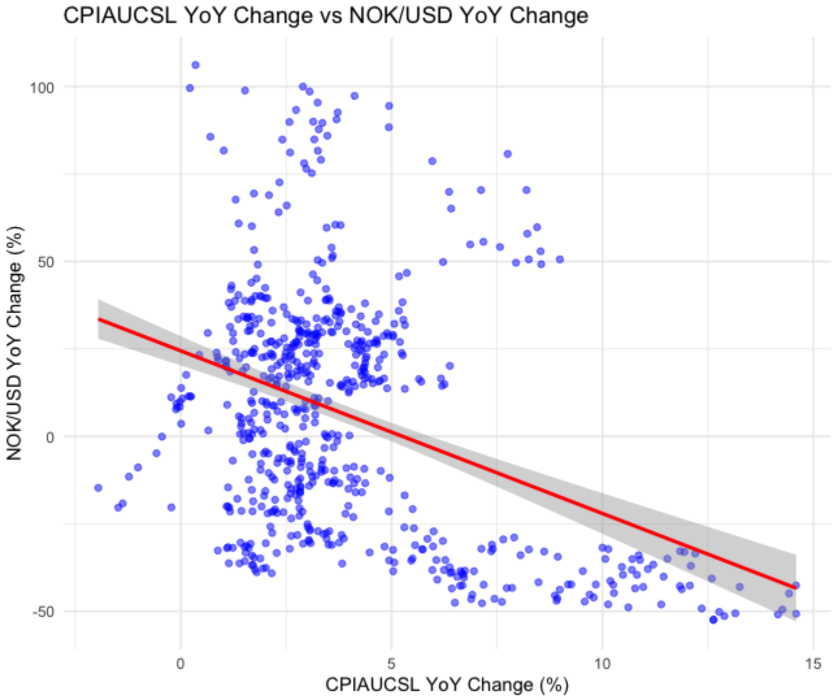


Figure 3: NOKUSD-YoY against CPIAUCSL-YoY

The negative slope suggests an inverse relationship between CPIAUCSL and the NOKUSD FX rate, meaning that CPIAUCSL increases, the NOKUSD YoY change tends to decrease. However, the dispersion of points around the regression line indicates high variability, suggesting that while inflation changes may influence FX movements, other factors contribute significantly to the fluctuations in NOKUSD. The shaded gray region represents the confidence interval, reinforcing the uncertainty in predicting NOKUSD solely based on CPIAUCSL changes.

1.3.5 Redoing 1.3.3 and 1.3.4 for CPILFESL [2]

Figure 4: Entire plot for the CPILFESL [2]

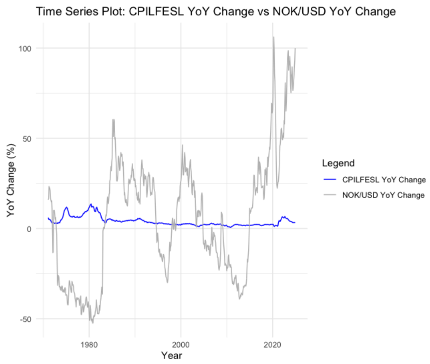


Figure 5: Showing the performance of CPILFESL YoY Changes against NOKUSD YoY Changes over time.

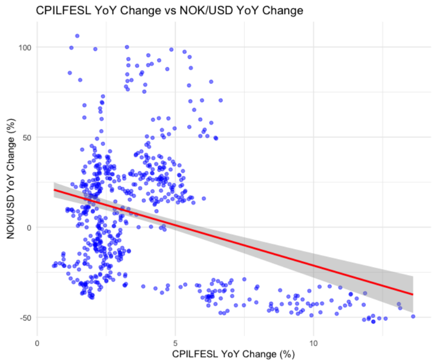


Figure 6: The regression line where NOKUSD YoY is Y and CPILFESL YoY is X

From the time-series and scatterplots, the main difference is that core inflation (CPILFESL, which excludes food and energy) is notably smoother than the headline measure (CPIAUCSL), and therefore shows narrower swings in its year-on-year changes. In the scatterplots against NOK/USD changes, the overall negative relationship remains, but CPILFESL's milder fluctuations yield a tighter clustering of point around the regression line. By contrast, CPIAUCSL's broader spikes - particularly when energy prices jump - produce a slightly looser fit, reflecting its greater sensitivity to volatile components

1.4 (d) What is the relevance for these results for whether we should hedge exchange rate risk or not?

The plots and regression lines shows that there does exist some inverse relationship between inflation and the NOK/USD rate, a large portion of FX rate fluctuations remain unexplained by inflation alone. The FX movements are volatile and subject to numerous other factors (e.g., oil prices, inerest-rate changes, geopolitical events), which means predicting them purely on the basis of inflation is highly uncertain. From a risk-management perspective, this high variability supports the idea of hedging FX exposure, since relying on solely inflation indicators to anticipate FX movements would leave firms or investors vulnerable to unpredictable swings in the currency.

2 Chief economists sometimes attribute exchange rate movements to changes in risk premia. We will be investigating this hypothesis by using NOK/USD [4], SP500 from Yahoo using quantmod in R and Brent Blend [5]

In this R script we'll perform a time series analysis by collecting, transforming, and analyzing three datasets: NOKUSD [4] FX rates, SP500 closing prices, and Brent blend prices. I extracted NOKUSD from the previous dataset used, and then I retrieved the SP500 data from Yahoo using the quantmod package and renamed the index column. Brent crude oil prices are fetched via an API request to the FRED database, with JSON parsing and a conversion into a dataframe.

Once ready, the data is aggregated to a quarterly frequency using a function that computes quarterly averages. The three datasets are then merged into a single dataframe, ensuring alignment by quarter. Afterward, ln changes are calculated for each variable to analyze percentage changes over time.

Finally I ran multiple linear regressions to examine the relationship between the NOKUSD FX rate to the SP500 and then Brent Crude. I also computed an actual MLR model where SP500$\equiv X_1$ and Brent Crude$\equiv X_2$ to see how the relationship changes if we include both at the same time.

```
Call:
lm(formula = ln_change_NOKUSD_Exchange ~ ln_change_SP500_Close,
    data = combined_quarterly_ln_changes)

Residuals:
      Min        1Q    Median        3Q       Max
-0.113388 -0.031979  0.003903  0.024707  0.192490

Coefficients:
                       Estimate Std. Error t value Pr(>|t|)
(Intercept)            0.005876   0.003843   1.529    0.128
ln_change_SP500_Close -0.119774   0.060342  -1.985    0.049 *
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.04484 on 149 degrees of freedom
Multiple R-squared:  0.02576,   Adjusted R-squared:  0.01922
F-statistic:  3.94 on 1 and 149 DF,  p-value: 0.04899
```

Figure 7: Regression model for LN NOKUSD against LN SP500

The estimated coefficient for ln change in SP500 is -0.1198, meaning that a 1% increase in the SP500 is associated with an approximate 0.12% depreciation in NOK/USD, holding other factors constant. This negative relationship suggests that when the SP500 rises, the NOK tends to weaken relative to the USD. The coefficient is statistically significant at the 5% level ($p = 0.049$), indicating moderate evidence against the null hypothesis that there is no relationship. The model has a low explanatory power, with an R-squared of only 0.0258, meaning that only about 2.58% of the variance in NOK/USD log changes is explained by changes in the SP500. This means that while there is statistically significant effect, others factors likely play a more substantial role in driving NOK/USD fluctuations.

```
Call:
lm(formula = ln_change_NOKUSD_Exchange ~ ln_change_Brent_Crude,
    data = combined_quarterly_ln_changes)

Residuals:
      Min        1Q    Median        3Q       Max
-0.089738 -0.026131  0.000269  0.024225  0.113360

Coefficients:
                       Estimate Std. Error t value Pr(>|t|)
(Intercept)            0.005002   0.003075   1.627    0.106
ln_change_Brent_Crude -0.159721   0.019497  -8.192 1.07e-13 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.03772 on 149 degrees of freedom
Multiple R-squared:  0.3105,    Adjusted R-squared:  0.3059
F-statistic: 67.11 on 1 and 149 DF,  p-value: 1.074e-13
```

Figure 8: Regression model for LN NOKUSD against LN Brent crude oil prices

The coefficient for ln change in brent crude is -0.1597, indicating that a 1% increase in Brent crude oil prices is associated with an approximate 0.16% depreciation in the NOK/USD exchange rate, holding other factors constant. This negative and statistically significant relationship (p-value$\approx$ $1.07e-13$) suggests that higher oil prices are linked to a weaker NOK against the USD, which aligns with Norway's status as a major oil exporter - where rising oil prices might reduce the need for USD, weakening the exchange rate. The model explains about 31.05% of the variation in NOK/USD log changes (R-squared = 0.3105), meaning that oil price fluctuations have a stronger explanatory power on NOK/USD movements compared to the SP500.

```
Call:
lm(formula = ln_change_NOKUSD_Exchange ~ ln_change_SP500_Close +
    ln_change_Brent_Crude, data = combined_quarterly_ln_changes)

Residuals:
      Min        1Q    Median        3Q       Max
-0.089754 -0.026352  0.000245  0.024216  0.111630

Coefficients:
                       Estimate Std. Error t value Pr(>|t|)
(Intercept)            0.005129   0.003245   1.581    0.116
ln_change_SP500_Close -0.006698   0.052943  -0.127    0.900
ln_change_Brent_Crude -0.159018   0.020334  -7.820 9.14e-13 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.03785 on 148 degrees of freedom
Multiple R-squared:  0.3106,    Adjusted R-squared:  0.3013
F-statistic: 33.34 on 2 and 148 DF,  p-value: 1.112e-12
```

Figure 9: A MLR with $Y \equiv$ NOKUSD ln change, and $X_1 \equiv$ SP500 ln change and $X_2 \equiv$ Brent Crude ln change

The coefficient for change in SP500 is -0.0067, which is statistically insignificant ($p = 0.900$), indicating that SP500 movements do not have a meaningful effect on NOK/USD exchange rate changes when accounting for Brent crude prices. In contrast, the coefficient for brent crude is -0.1590 and highly significant ($p = 9.14e - 13$), reinforcing that a 1% increase in Brent crude oil prices is associated with an approximate 0.16% depreciation in NOK/USD. The R-squared value of 0.3106 suggests that 31.06% of the variation in NOK/USD log changes is explained by the two predictors, but since the SP500 variable is not significant, Brent crude appears to be the main driver. This result implies that NOK/USD is more sensitive to oil price fluctuations than equity market movements.

3 Synthetic Forwards

3.1 (a) What are the three-month synthetic-forward USD/NZD bid-ask rates?

```
####### (a) what are the three-month synthetic forward USD/NZD bid-ask rates
## Spot USD/NZD
spot_USDNZD <- c(0.5791, 0.5835)
forward3MonthContract_USDNZD <- c(0.5821, 0.5867)
## Annualized 3-month interest rates
interestRates_NZD <- c(0.0565, 0.0590)
interestRates_USD <- c(0.0363, 0.0388)

# Synthetic forward ask
s_ask <- spot_USDNZD[2]
i_nzd_ask <- interestRates_NZD[2]*(3/12)
i_usd_bid <- interestRates_USD[1]*(3/12)

synthetic_forward_ask <- s_ask * ((1 + i_nzd_ask) / (1 + i_usd_bid))

# Synthetic forward bid
s_bid <- spot_USDNZD[1]
i_nzd_bid <- interestRates_NZD[1]*(3/12)
i_usd_ask <- interestRates_USD[2]*(3/12)

synthetic_forwad_bid <- s_bid * ((1 + i_nzd_bid) / (1 + i_usd_ask))

USDNZD_SYNTH_FORWARD = c(synthetic_forwad_bid, synthetic_forward_ask)
head(USDNZD_SYNTH_FORWARD)
```

Synthetic USD/NZD Forward Rate $= 0.5816379 - 0.5867816$

3.2 (b) What are the six-month synthetic-forward EUR/NZD bid-ask rates?

```r
####### (b) What are the six-month synthetic-forward EUR/NZD bid-ask rates?
spot_EURNZD <- c(0.5120, 0.5159)
forward6MonthContract <- c(0.5101-0.5146)
## Annualized 6-month interest rates
interestRates_NZD <- c(0.0547, 0.0582)
interestRates_EUR <- c(0.056, 0.0625)

# Synthetic forward ask
s_ask <- spot_EURNZD[2]
i_nzd_ask <- interestRates_NZD[2]*(6/12)
i_eur_bid <- interestRates_EUR[1]*(6/12)

synthetic_forwad_ask <- s_ask * ((1 + i_nzd_ask) / (1 + i_eur_bid))

# Synthetic forward bid
s_bid <- spot_EURNZD[1]
i_nzd_bid <- interestRates_NZD[1]*(6/12)
i_eur_ask <- interestRates_EUR[2]*(6/12)

synthetic_forwad_bid <- s_bid * ((1 + i_nzd_bid) / (1 + i_eur_ask))

EURNZD_SYNTH_FORWARD <- c(synthetic_forwad_bid, synthetic_forwad_ask)
```

Synthetic EUR/NZD Forward Rate $= 0.5100637 - 0.5164520$

3.3 (c) What are the six-month synthetic-forward DKK/NZD bid-ask rates?

```r
####### (c) What are the six-month synthetic-forward DKK/NZD bid-ask rates?
spot_DKKNZD <- c(3.3890, 3.4150)
forward6MonthContract <- c(3.3720, 3.4110)
## Annualized 6-month interest rates
interestRates_NZD
interestRates_DKK <- c(0.0593, 0.0618)

# synthetic forward ask
s_ask <- spot_DKKNZD[2]
i_nzd_ask <- interestRates_NZD[2]*(6/12)
i_dkk_bid <- interestRates_DKK[1]*(6/12)

synthetic_forwad_ask_dkk <- s_ask * ((1 + i_nzd_ask) / (1 + i_dkk_bid))

# Synthetic forward bid
s_bid <- spot_DKKNZD[1]
i_nzd_bid <- interestRates_NZD[1]*(6/12)
i_dkk_ask <- interestRates_DKK[2]*(6/12)

synthetic_forward_bid_dkk <- s_bid * ((1 + i_nzd_bid) / (1 + i_dkk_ask))

DKKNZD_SYNTH_FORWARD <- c(synthetic_forward_bid_dkk, synthetic_forwad_ask_dkk)
```

Synthetic DKK/NZD Forward Rate $= 3.377330 - 3.413176$

3.4 (d) What are the three-month synthetic-forward CAD/NZD bid-ask rates?

```r
####### (d) What are the three-month synthetic-forward CAD/NZD bid-ask rates?
spot_CADNZD <- c(0.5973, 0.6033)
forward3MonthContract <- c(0.5987, 0.6025)
## Annualized 3-month interest rates
interestRates_NZD <- c(0.0565, 0.0590)
interestRates_CAD <- c(0.0171, 0.0196)

# synthetic forward ask
s_ask <- spot_CADNZD[2]
i_nzd_ask <- interestRates_NZD[2]*(3/12)
i_cad_bid <- interestRates_CAD[1]*(3/12)

synthetic_forward_ask_cad <- s_ask * ((1 + i_nzd_ask) / (1 + i_cad_bid))

# Synthetic forward bid

s_bid <- spot_CADNZD[1]
i_nzd_bid <- interestRates_NZD[1]*(3/12)
i_cad_ask <- interestRates_CAD[2]*(3/12)

synthetic_forward_bid_cad <- s_bid * ((1 + i_nzd_bid) / (1 + i_cad_ask))

CADNZD_SYNTH_FORWARD <- c(synthetic_forward_bid_cad, synthetic_forward_ask_cad)
CADNZD_SYNTH_FORWARD
```

Synthetic CAD/NZD Forward Rate $= 0.6027832 - 0.6095927$

3.5 In a-d, are there any arbitrage opportunities?

	Currency	Spot_Bid	Spot_Ask	Forward_Bid	Forward_Ask	Synthetic_Forward_Bid	Synthetic_Forward_ask	Arbitrage_Opportunity_Buy_Synthetic	Arbitrage_Opportunity_Sell_Synthetic
1	USDNZD	0.5791	0.5835	0.5821	0.5867	0.5816379	0.5867816	FALSE	FALSE
2	EURNZD	0.5120	0.5159	0.5101	0.5146	0.5100637	0.5164520	FALSE	FALSE
3	DKKNZD	3.3890	3.4150	3.3720	3.4110	3.3773297	3.4131758	FALSE	FALSE
4	CADNZD	0.5973	0.6033	0.5987	0.6025	0.6027832	0.6095927	TRUE	FALSE

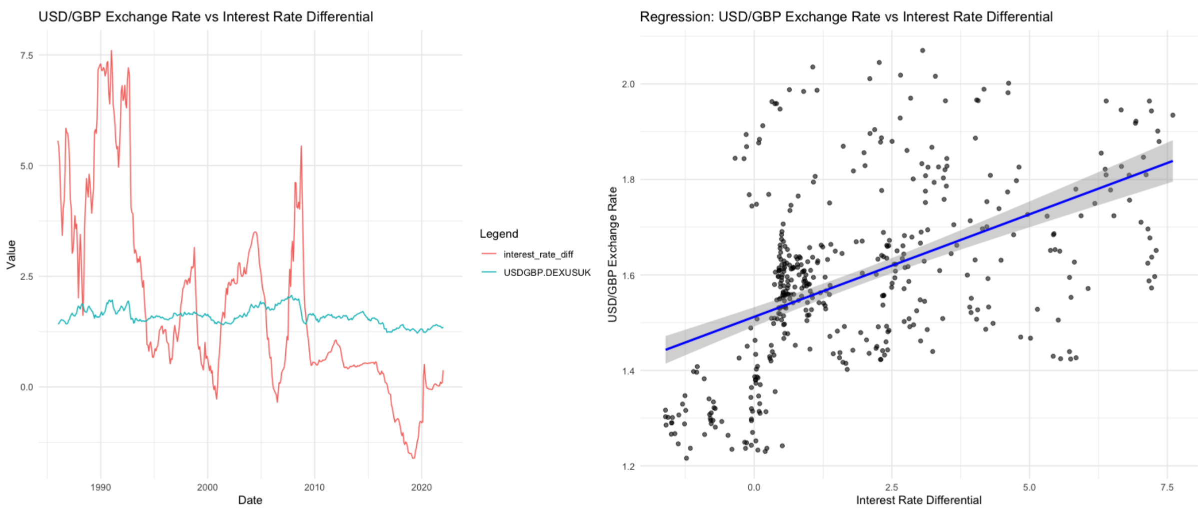
An arbitrage opportunity exists in the CADNZD currency pair because the Synthetic Forward Bid (0.6027832) is higher than the Forward Ask (0.6025). This means an arbitrageur can buy the forward contract at the market's lower aask price (0.6025) and simultaneously sell the synthetic forward at a higher bid price (0.6027832), locking in a risk-free profit. No arbitrage opportunities exist for the other currency pairs, as their synthetic forward rates do not create a profitable spread against the market forward rates.

4 Uncovered interest rate parity

4.1 Briefly document the steps you make to download the data

For this part I simply just downloaded the .csv files, because I did not want to bother with the API for this part of the document.

4.2 Plot and Regression Line



We can see from the graph on the left that the interest rate differential between the US and the UK has experienced significant swings over the last few decades, while the USD/GBP FX rate has fluctuated in narrower band. In the early 1990s the differential spiked to high levels, whereas post-2008 it turned notably negative, suggesting that at times the UK's interest rates were higher than the US's, and at other times they were lower. Meanwhile, the USD/GBP rate generally hovered between 1.3 and 2.0 but trended down slightly over the long run, indicating that the dollar strengthened against the pound for extended periods but also saw reverals in sync with macroeconomic shifts.

For our graph at the right, the scatter plot is a fitted regression line tells us a direct story of how the two variables move together. There appears to be a positive, upward-sloping relationship, indicating that when the US interest rate exceeds the UK interest rate by a great margin, the USD/GDP exchange rate also tends to be higher. While many other factors can certainly influence exchange rates, this finding is consistent with interest rate parity, higher returns in one currency often draw in capital flows that bid up that currency's value.

4.3 Plot and Regression Line

```
Call:
lm(formula = USDGBP.DEXUSUK ~ interest_rate_diff, data = problem_4_dataframe)

Residuals:
     Min       1Q   Median       3Q      Max 
-0.33682 -0.13048 -0.00022  0.07712  0.47762 

Coefficients:
                   Estimate Std. Error t value Pr(>|t|)    
(Intercept)        1.512183   0.010235  147.74   <2e-16 ***
interest_rate_diff 0.042954   0.003603   11.92   <2e-16 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.1611 on 431 degrees of freedom
Multiple R-squared:  0.248,	Adjusted R-squared:  0.2463 
F-statistic: 142.1 on 1 and 431 DF,  p-value: < 2.2e-16
```

When the US-UK interest rate differential is zero, the model predicts a USD/GBP exchange rate of about 1.51. For every 1 percentage-point increase in the interest rate differential, the exchange rate is expected to rise about 0.043, which implies a stronger dollar relative to the pound when US rates are higher than UK rates. Both the intercept and slope are highly statistically significant $p < 2.2 \times 10^{-16}$. The R^2 value of 0.248 indicates that around 25% of the variation in USD/GBP is explained by interest rate differential alone.

References

[1] Federal Reserve Bank of St. Louis, *Consumer Price Index for All Urban Consumers (CPIAUCSL)*, https://fred.stlouisfed.org/series/CPIAUCSL.

[2] Federal Reserve Bank of St. Louis, *Consumer Price Index for All Urban Consumers: All Items Less Food and Energy (CPILFESL)*, https://fred.stlouisfed.org/series/CPILFESL.

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[7] Federal Reserve Bank of St. Louis, *Interest Rates: 3-Month or 90-Day and Yields: Interbank Rates: Total for United Kingdom* https://fred.stlouisfed.org/series/IR3TIB01GBM156N

[8] Federal Reserve Bank of St. Louis, *Market Yield on U.S. Treasury Securities at 3-Month Constant Maturity, Quoted on an Investment Basis* https://fred.stlouisfed.org/series/DGS3MO