Does the Uncovered Interest Rate Parity hold for USD/GBP, EUR/GBP and JPY/GBP as interest rates move closer to Zero Lower Bound?

Mihai Leolea

BSc (Hons) Economics with a Year in Industry

School of Economics,

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Abstract

This research paper investigates the effects of the interest rates in the United Kingdom approaching zero lower bound on the uncovered interest rate parity. To conduct this empirical research, three currency pairs were analysed: USD/GBP, EUR/GBP, JPY/GBP. Daily frequency data was used, and the methodology was based on the original regression by Fama (1984). A dummy variable was implemented to indicate the threshold for the zero lower bound. Given that interest rates are quite dynamic, four different thresholds were utilised. The results were very much in favour of the standard literature – the uncovered interest rate parity fails to hold empirically. Furthermore, decreasing interest rates in the United Kingdom did not appear to have a significant impact on the uncovered interest rate parity.

1. Introduction

Consumers, investors and businesses across the globe are becoming increasingly interconnected, and this has led to a massive increase in international trade. Money is the main facilitator of trade, but with so many different countries involved, it becomes apparent that an efficient exchange rate system is required which allows agents to convert currency and purchase goods. The exchange rate between a currency pair is the rate at which one currency will be traded for the other (Kallianiotis, 2013). In other words, it is the price of one specific currency in terms of another specific currency.

There are a number of different exchange rate regimes as classified by the International Monetary Fund (IMF) (International Monetary Fund, 2003). Some countries may choose to circulate the currency of another country as the only legal tender, or a member country may belong to a currency union where the same legal tender is now shared with members of the union. The latter is seen in the European Union (EU), where the euro acts as the official currency for 19 of the 27 EU member countries (Countries using the Euro, 2022). In both cases, authorities no longer have independent control over their respective domestic monetary policy. Governments may also choose to peg or fix its currency at a fixed rate to another currency, allowing for some fluctuations within a very narrow band. On the other side of the spectrum, governments will allow the market to determine its exchange rate, and any intervention will only attempt to moderate the exchange rate rather than maintain it at a certain level.

The central bank in a respective country will hold foreign exchange reserves- these are assets held on reserve in a foreign currency (Foreign Exchange Reserves Definition, 2022). These can be used to cover any liabilities and control monetary policy. Monetary policy refers to any action taken by a country's central bank or government to control the amount of money in an economy or the cost to borrow (Monetary policy, 2022). The Bank of England, the UK's central bank, will set the 'Bank Rate'- this is the interest rate that they charge banks to borrow money. A brief look into history reveals that since 1450, there have been six countries issuing currency that dominated the world reserve currencies, each spanning roughly over a century: Portugal (1450–1530), Spain (1530–1640), Netherlands (1640–1720), France (1720–1815), Great Britain (1815–1920), and the United States (U.S.) from 1921 to present day (World Reserve Currencies Since 1450, 2022).

As of 2021, the IMF reported that the share of U.S. dollars reserves held by central banks is 58.81 percent, by far the most popular, with the share of the Euro coming in second at 20.64 percent (Currency Composition of Official Foreign Exchange Reserves, 2022). The Japanese yen has a reported share of 5.57 percent and the pound sterling 4.78 percent, making them the third and fourth most popular held foreign currencies. These four currencies also serve as the focus of this paper.

This paper will conduct an empirical investigation to verify whether the uncovered interest rate parity condition holds for three different exchange rates as the interest rates in the United Kingdom move closer to zero lower bounds. The exchange rates included are the U.S. dollar/Pound sterling (USD/GBP), Euro/Pound sterling (EUR/GBP) and Japanese Yen/Pound sterling (JPY/GBP).

1.1. Interest Rates

The interest rate indicates what the cost of borrowing is or what the reward for saving is. This is a percentage value of the total amount of money being loaned out or placed into a savings account. The Bank of England sets the 'Bank Rate,' but central banks all over the world set their own respective interest rates which they then use to charge commercial banks (Lien, 2021). In the United States, the Federal Reserve is responsible for this. In Japan, it is the Bank of Japan and in the Eurozone, it is the European Central Bank.

Traditionally, central banks around the world have undertaken a wide range of responsibilities as they work closely with, but independent from the government to support the economy (Dow, 2017). Their responsibilities include producing and distributing money, regulating banks, supervising and monitoring the banking system, managing payment systems and the exchange rate, managing debt and lending money to the government as needed. Most importantly, there has been a major shift over the last few decades in the way central banks operate as they conduct monetary policy to stabilise prices.

The rate at which prices increase of a set period of time is defined as inflation (Oner, 2017). When the nominal income fails to increase in line with prices, households become worse off as their real income decreases. This is directly correlated to the standard of living, which increases as real income increases. High inflation is bad for the economy, but so is deflation-consumers will postpone purchases when prices are falling, and this will decrease economic activity. When a government lowers their interest rate, this will create a temporary increase in demand and economic growth. Alternatively, central banks can make use of disinflationary policies by raising interest rates when the economy has overheated to reduce aggregate demand and in turn, inflation. The Fisher (1930) equation expresses the relationship between interest rates and inflation. The hypothesis states that the sum of the constant real interest rate and the expected decline in the purchasing power of money is the nominal interest rate (Crowder and Hoffman, 1996). However, this hypothesis has not managed to find substantial support from an empirical standpoint.

There are various models used to determine the exchange rate in a particular economy, and the monetary model is the simplest one (Copeland, 2014). The monetary model assumes that prices are entirely flexible and that thus the purchasing power parity (PPP) always holds. Whilst it may not be the most useful in explaining short-term trends and deviations, it helps paint a clear picture of the long-term economic landscape. Furthermore, it acts as an excellent benchmark for the comparison of other models of exchange rate determination as many are based on the monetary model. The monetary model can be applied to both floating and fixed exchange rates, although for the purpose of this paper only the floating exchange rate will be considered.

The monetary model can provide a great link between the central bank decisions on the interest rate and the role it plays in the monetary policy. Interest rates can be used as an indication of the opportunity cost of holding money, and thus influence the demand for money in an economy. When interest rates are high, the demand for real balances will be lower regardless of income. In the monetary model, the nominal demand will decrease as interest rates rise at any price level. Thus, with set nominal money stocks and real incomes, an increase in domestic interest rates compared to those in the foreign country will lead to a depreciation in the domestic currency.

1.2. Zero Lower Bound

The Zero Lower Bound (ZLB) effectively refers to the idea that interest rates cannot be reduced to a value below zero (Zero-Bound, 2022). Central banks will often use this to as an expansionary monetary policy tool by lowering short-term interest rates to zero if there is a need to stimulate the economy. This can be used if the economy is either stagnating or expanding at a pace that is unsustainable. The ZLB acts as a barrier or a limit to where nominal interest rates can be lowered to- once this limit is reached, the central bank can no longer manipulate the interest rates even if the economy is continuing to underperform. This scenario is described as a liquidity trap by economists, and the traditional school of thought was that interest rates could not be lowered into negative territory. However, this has not always been the case.

Alternative tools for monetary policy are required when central banks are faced with a liquidity trap. The most popular alternative tool is quantitative easing, in which a central bank will aim to increase the money supply by purchasing government bonds. This will maintain short-term rates low but also lower longer-term rates, thus encouraging borrowing.

Central banks around the world have been steadily lowering interest rates over the last 40 years. A historic record of these interest rates can be found on the next pages, with the monthly data series sourced from the Bank for International Statements (Central bank policy rates, 2022).

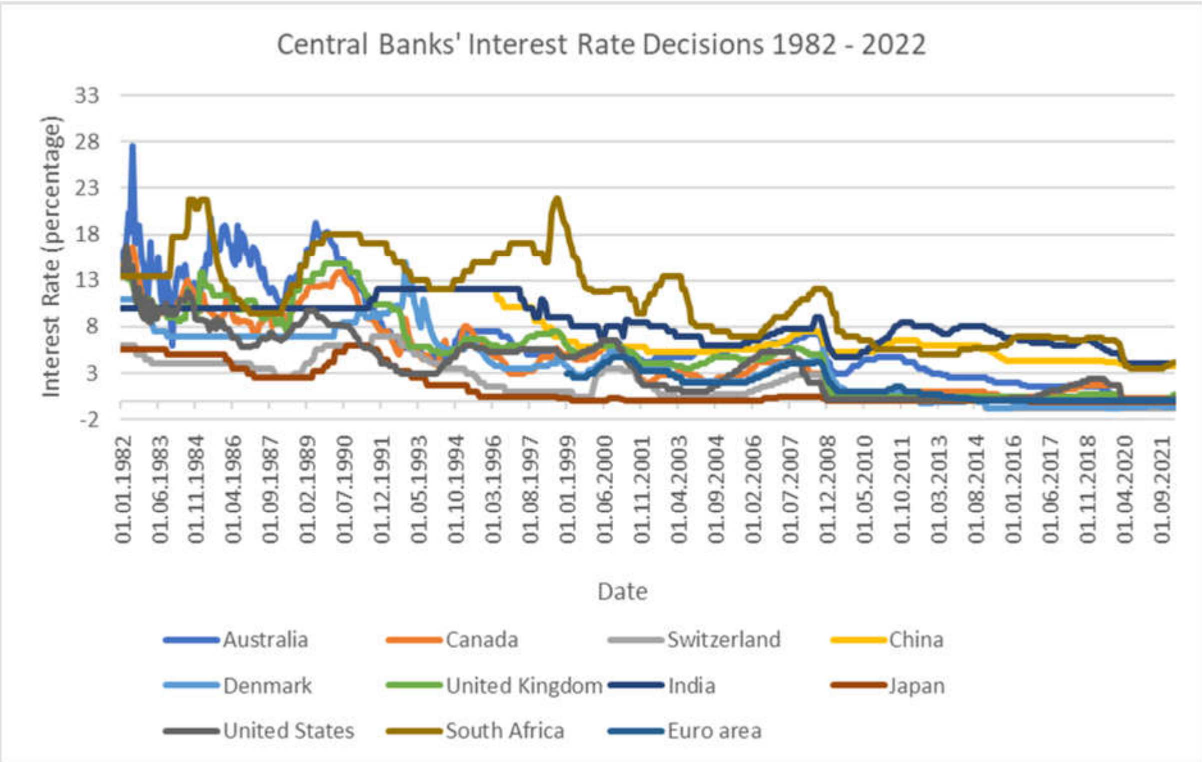

Figure 1.2.1 Interest rates set by 11 different central banks for their respective territory from 1982 to 2022 (Central bank policy rates, 2022)

The graph above represents the interest rate set by the central banks of ten countries and the Eurozone over the last 40 years. This paints an interesting picture- countries like Japan and Switzerland have always maintained a relatively lower interest rate but overall, there has been a downward trend. The drop after the financial crisis is the most notable, as it pushed many interest rates towards the ZLB. On the next page, the first graph represents the interest rate set by the central banks of the countries and currencies relevant to this paper, and the second graph focuses on the period after 2010 - this followed the financial crisis and is most relevant to this research. Japan has since set negative interest rates, whilst the Eurozone has also seen a gradual drop. The UK has managed to maintain a somewhat consistent level and the US even increased their rates after 2016. In the first quarter of 2020, the UK and the US decreased their interest rates in response to the pandemic.

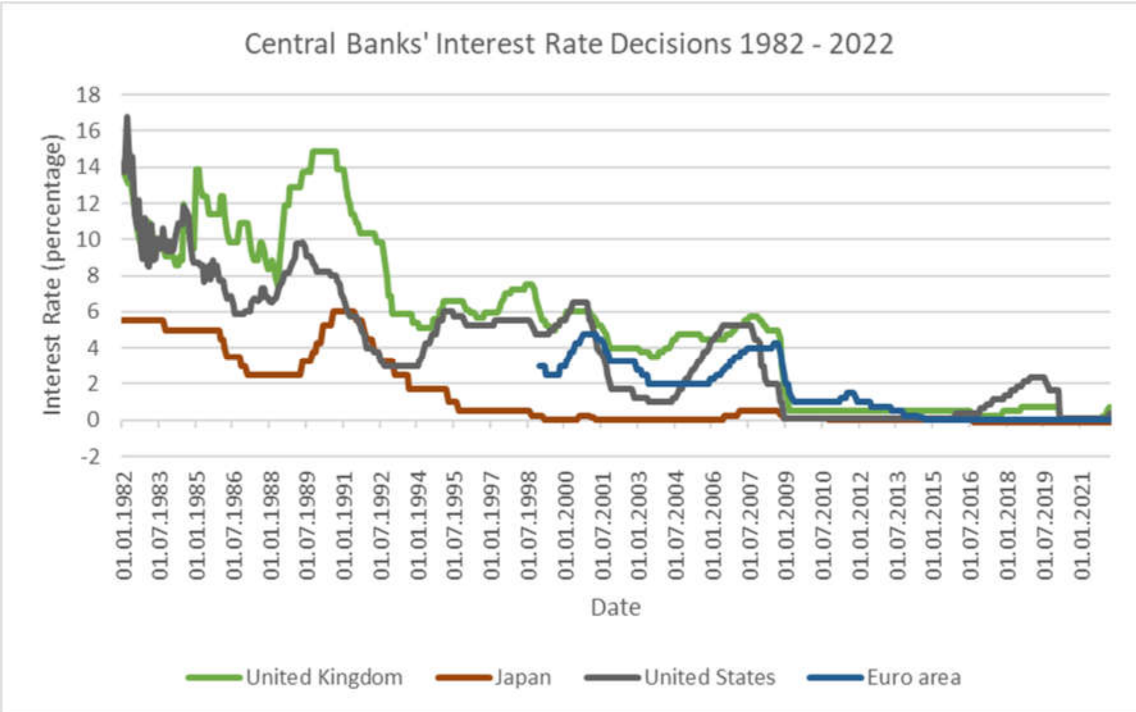

Figure 1.2.2. Interest rates set by the four central banks relevant to this paper for their respective territory from 1982 to 2022 (Central bank policy rates, 2022)

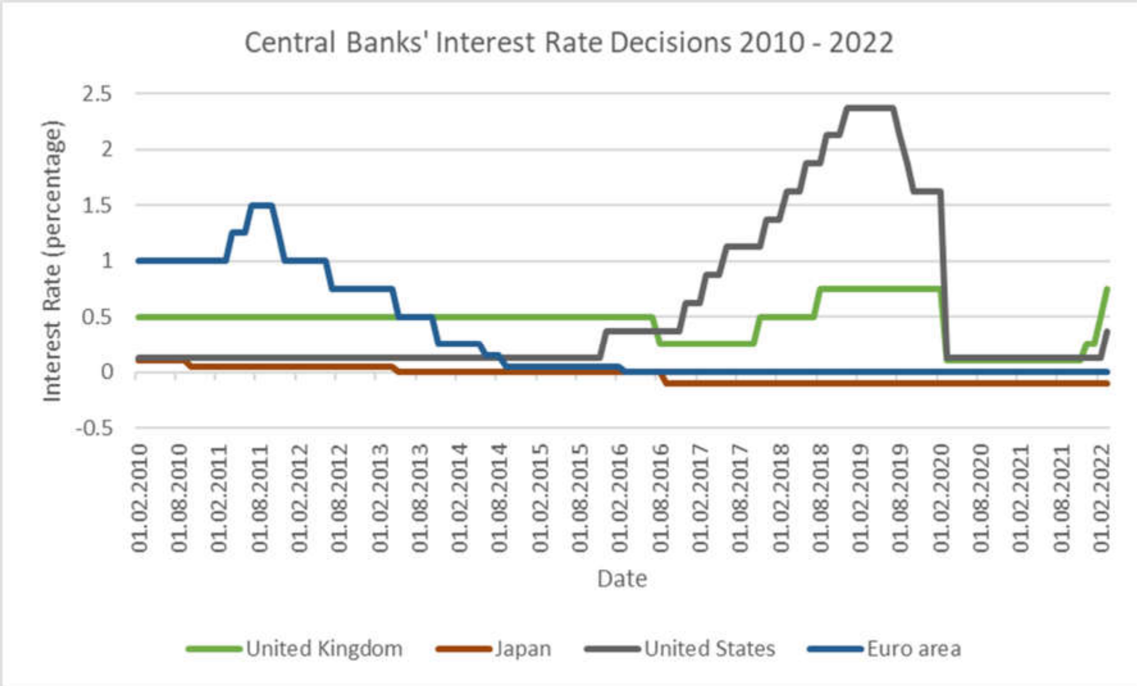

Figure 1.2.3. Interest rates set by the four central banks relevant to this paper for their respective territory from 2010 to 2022 (Central bank policy rates, 2022)

1.3. Covered and Uncovered Interest Rate Parity

Knowing that different countries offer different interest rates, what stops an investor in the United Kingdom from purchasing bonds abroad, where the rate of interest is higher than at home? In theory, the answer should be the exchange rate!

The covered interest rate parity (CIP) is used to describe the theoretical equilibrium condition between interest rates and the spot and forward exchange rates of two countries (Understanding Covered Interest Rate Parity, 2022). This implies that there is no arbitrage opportunity by making use of forward contracts when countries have different interest rates. The forward exchange rate refers to the exchange rate agreed today for a transaction set to take place at a specified date in the future (Forward Exchange Rate, 2022). When conducting international trade, it is quite common for an importer to pay for the product only after delivery. Sometimes, another 30 to 90 days may elapse after the product is received before payment is made. Between the date the decision of purchase was made, and the payment received, the exchange rate could have fluctuated and the cost of the transaction would have changed. The forward exchange rate is used when individuals and firms want to transfer the risk of a fluctuating exchange rate to a different party- a party that has agreed to the forward exchange rates. Forward exchange rates are calculated by taking into account the spot exchange rate and interest rates between the two currencies (Parity, 2022):

$$F = S\,x\,(1 + r_d \;/ 1 + r_f\,) \tag{1}$$

Where 'F' is the forward exchange rate, 'S' is the spot exchange rate, 'r_d' is the domestic interest rate and 'r_f' is the foreign interest rate.

The uncovered interest rate parity (UIP) expresses that over an identical period of time, any difference in the interest rates between two countries will be equal to the relative change in the foreign exchange rates (Understanding Uncovered Interest Rate Parity – UIP, 2022). This lays the foundation for the law of one price, which states that the price of identical goods should be the same globally after the currency exchange rates and interest rates are taken into account. Furthermore, when the UIP relationship fails to hold, the opportunity to make a risk-free profit arises.

Swap points are used to describe the difference between forward and spot exchange rates. If there is a positive difference, there is a forward premium; a negative difference is referred to as a forward discount. This is also what makes the UIP different from the CIP, as UIP makes use of spot exchange rates which have been forecasted for a specific time period- thus exposing it to foreign exchange risk. If the forecasted spot exchange rates are equal to the forward exchange rates, then there is no difference between the UIP and CIP in theory.

2. Literature Review

The following review aims to provide context around the research question by referencing various research papers that have previously dwelled on the areas of interest relevant to this paper; the failure of the uncovered interest rate parity (UIP) condition, the zero lower bound (ZLB) and the United Kingdom (UK).

Fama (1984) conducted research to add to the consensus that forward exchange rates are not efficient at predicting future spot exchange rates. He found that the majority of variations in forward exchange rates can be attributed to premiums, and that there is a negative correlation between the premium and the expected future spot rate components of forward rates. The key aspect of his research was the regression used to conduct the research, which has laid the foundation for future research. Valchev (2014) analysed the uncovered interest rate parity (UIP) by employing a different variation of the regression used by Fama (1984). He found that not only does the condition fail to hold, but that the complexity of the issue arises from the behaviour of the condition at different horizons. He found evidence that in the short-run, high interest rate currencies depreciate less than forecasted by the interest rate differential. However, these currencies happen to depreciate too much in the long-run (four to seven years). Over the long-run, this long-horizon surplus depreciation ultimately guides the exchange rates to return to the UIP benchmark.

Alexius (2001) also investigated the standard empirical findings that despite the UIP, countries with a high nominal interest rate find their currencies appreciating. The research made use of long-term government bond yields as opposed to the short-term interest rates which have been predominantly used to test the UIP condition. Surprisingly, the results claimed to provide some support for the UIP. This was due to the treatment of coupon payments, which traditionally have caused an error in measurement between the observed data and realized returns. Kiley (2013) also managed to find evidence in support of the UIP at long horizons for the USD/EUR and USD/JPY exchange rates. This was conditional on the monetary policy decisions, where many actions were revealed in part by statements from the FOMC and ultimately led to changes in exchange rates and long-term interest rates in line with the UIP. It was also found that the overshooting prediction of Dornbusch (1976) was in line with the short-run changes in exchange rates after an unexpected monetary policy decision. Most relevant to this research however, it was found that the impact of monetary policy statements on long-term interest rates and exchange rates has not changed significantly after short-term interest rates have approached zero-lower bound (ZLB).

A very recent study looked at the failure of the UIP for the U.S. dollar against major currencies at three different horizons: short, medium and long (Engel, et al., 2022). The key takeaway from this study was that there is instability regarding the evidence that interest rate differentials can forecast foreign exchange returns, but this completely disappears when interest rates approach ZLB. The study found that inflation rate differentials (year-on-year) were better at predicting excess returns. A link between relatively high year-on-year U.S. inflation rates and returns on U.S. deposits was found. The efficacy of inflation rates as a tool for predictions starts when the central banks began consistently targeting inflation (mid-1980s), however this continued after the interest rates approached ZLB and lost their superiority as a policy instrument. In the process, the study also attempted to fix some econometric issues which could induce bias in the conventional test set out by Fama (1984).

Guy Meredith and Menzie Chinn (1998) argued that when studying exchange rate movements, the uncovered interest rate parity has always been rejected, despite the inability to reach an agreement as to why. Contrary to previous studies, they made use of short-horizon data, testing the UIP by making use of the interest rates on long-maturity bonds for G-7 countries. They found that an endogenous monetary policy creates a risk premium shock, as opposed to the fundamentals that influence the exchange rate movements in the long run. A very interesting study by Richard Baillie and William Osterberg (2000) analysed the link between daily deviations from UIP and the US and German central bank intervention. Results supported the theoretical notion that the risk premium was affected by the intervention variables. Thomas McCurdy and Ieuan Morgan (1991) tested for the presence of a systematic risk component in deviations from the UIP. By using weekly sport currency prices and interest rates for the Eurocurrency, they were able to detect risk premia in deviations. This was conducted using a conditional capital asset pricing model, benchmarked against a world equity index that represents total wealth.

Adilzhan Ismailov and Barbara Rossi (2018), partially sponsored by the Spanish Ministry of Economy and Competitiveness, explored the effects of uncertainty on the UIP in detail. Their research acknowledges that during the short-term, it is well known that the UIP does not hold from an empirical standpoint. A link is found between uncertainty in the economic environment and the effect on the UIP, ultimately providing a new exchange rate uncertainty index. The UIP is more likely to hold in low uncertainty economic environments relative to high uncertainty ones. In a highly unpredictable environment, arbitrage opportunity gains become more uncertain, therefore distorting the link between exchange rates and interest rate differentials. The new measure of uncertainty was then used to produce empirical evidence which supports the claims above. The data on exchange rates, three-month Euro LIBOR rates and the uncertainty measure were collated from November 1993 until January 2015, with uncertainty measure data on the Euro only beginning in July 2001. The exchange rates for five currencies: Swiss franc, Canadian dollar, British pound, the Japanese yen, and the Euro against the US dollar were used to conduct the analysis and build the new uncertainty index.

Lothian and Wu (2011) have researched the UIP over the past two centuries and made some very interesting discoveries. When the interest-rate differentials are large, they are significantly better indicators of future performance than small interest-rate differentials. Whilst it was found that the UIP holds over long periods of time, deviations do occur as a result of ex post-expectation errors. Aggarwal (2013) explored the UIP puzzle in the foreign exchange market, analysing the effects of interest-rate differentials on depreciation of a currency. He mentioned that existing literature has made use of empirical data to reject the idea that currencies with a higher interest rate have appreciated relative to the lower interest rate currencies. This was of particular interest because it made use of data from 1992 to 2005, and the UIP examined for three currency pairs; Pound sterling-US dollar, Pound sterling-Japanese yen and Pound sterling-Australian dollar. The model used supported the theory of UIP and a depreciating relationship, whilst also finding that large interest-rate differentials have a greater impact on the movements of a currency pair than small differentials. One paper took a slightly different approach and conducted an empirical investigation into the GBP/USD and SEK (Swedish Krona)/USD exchange rates under covered interest rate parity (CIP) – the international finance relationship between forward premium and interest rate differential (Papadamou and Theodosiou, 2019). The analysis looked at 15 years' worth of monthly data and Euro rates. Interestingly enough, the results validated the CIP in the case of GBP/USD for both the three-month and six-month maturities. Systematic, small-scale deviations from parity where found and this was attributed to the modelling of transaction costs.

Building on the impact of interest rates on the UIP, a detailed review was conducted for the UIP puzzle to show that high interest rate currencies tend to appreciate (Backus, et al., 2010). The review made use of short-term interest rates and their relationship to the exchange rates, stating that the monetary policy in place had a strong impact on the short-term interest rates. In order to solve the UIP puzzle efficiently, different specifications for the Taylor rule were employed and evidence was found supporting a particular asymmetry. The model performed better when the foreign Taylor rule responds to exchange rate variation but the domestic Taylor rule does not. A nonlinear DSGE model was estimated using Bayesian methods in which the interest-rate lower bound is occasionally binding. Quantitative and qualitative analysis was conducted to observe the US economy move to the lower bound during the financial crisis in 2008 (Gust et al, 2017). It was found that the lower bound was a significant constraint on monetary policy, which amplified the recession and harmed recovery- the analysis implied that about 30% of the US GDP contraction in 2009 was due to the zero lower bound. This impact was also felt in the sluggish recovery that followed. When studying the impact of the financial crisis, Stefan Gerlach and John Lewis looked at the changes in the ECB interest rate setting behaviour as a result of Lehman brothers collapsing (Gerlach and Lewis, 2013). They found that the ECB was more aggressive than expected in cutting rates due to the negative macroeconomic conditions at the time, in line with research on the optimal monetary policy in the vicinity of the zero bound.

The zero lower bound also has major implications for the exchange rates, as seen in the research by David Cook and Michael Devereux (2016). When reacting to a macroeconomic shock, governments make use of the monetary policy and a flexible exchange rate. Recently however, countries have witnessed interest rates falling close to the lower bound, and this makes it difficult for policy-makers to deal with shocks. They found that the flexible exchange rate is less desirable than a single currency area when there is a binding lower zero bound constraint on nominal interest rates, and the policy provides an unsatisfactory 'forward guidance' mechanism. Swanson and Williams (2014) measured the effect of the zero lower bound on yields and exchange rates in the UK and Germany. They compared the sensitivity of exchange rates to the macroeconomic news during periods of time when the short-term interest rates were lower than normal, only to find that the USD/GBP and USD/EUR exchange rates were practically unaffected by the zero lower bound. Research on the foreign exchange markets investigated the anomalous appreciation of high interest rate currencies against low interest rate currencies under UIP. Boschen and Smith (2012) looked at six major currency pairs from 1995-2010 and found that these UIP anomalies have diminished over time. A link between the substantially higher transaction volume over time and the observed decline in deviations from the UIP was found; consistent with the idea that as the foreign exchange markets become more efficient the UIP anomaly dissipates.

One study analysed the effectiveness of unconventional monetary policy at the zero lower bound for eight different advanced economies (Gambacorta, Hofmann and Peersman, 2014). This was interesting because it focused on the period of time since the beginning of the world financial crisis, making use of monthly data to estimate a panel vector autoregression (VAR). The results found that there is a temporary increase in economic activity and consumer prices when there is an exogenous rise in the central bank balance sheets at the zero lower bound. Qualitatively speaking, their estimated output effects are homogenous to those of conventional monetary policy although the impact on the price level is weaker and less tenacious. Additionally, no major differences were found across countries regarding the macroeconomic effects of the unconventional monetary policies.

3. Methodology

This section will make use of the methodology employed in the research by Valchev (2014), with some adjustments made to fit the purpose of this paper; interest rates approaching zero lower bound (ZLB). Following this, description of the data used in this empirical research will be provided before the results are discussed in the next chapter.

The exchange rates mentioned below will be noted as S_t, representing the value of the domestic currency for every one unit of foreign currency. The domestic and foreign nominal interest rates on the default-free bonds will be noted as i_t and i^*_t respectively. As previously established, the domestic currency is the GBP and the foreign currencies are the JPY, EUR and USD.

At time t, a £1 investment in UK bonds will offer a return of $1 + i_t$ Sterling in the next period. If this £1 was instead invested in a US bond, it would provide a return of $S_{t+1} / S_t (1 + i^*_t)$ Sterling in the next period. As it stands, the £1 would have to be exchange for dollars at a rate of $1/S_t$. After the investment period has transpired, the return of $1 + i^*_t$ would be converted back to pounds at a rate of S_{t+1}.

By assuming that the law of one price holds and making use of asset pricing fundamentals, the stochastic process M_{t+1} can be used to construct the following equations;

$$E_t (M_{t+1} (1 + i_t)) = 1 \quad (2)$$

$$E_t (M_{t+1} S_{t+1} / S_t (1 + i_t^*)) = 1 \quad (3)$$

This is then used to construct the UIP condition by log-linearizing the two equations and subtracting them from one another, finally obtaining:

$$E_t (s_{t+1} - s_t + i_t^* - i_t) = 0 \quad (4)$$

The logged variables are represented by the lower case letters, and the interest rate has been approximated by taking the value of $ln(1 + i_t)$.

This equation is used to describe the condition that the expected return on foreign bonds, $E_t (s_{t+1} - s_t + i^*_t)$, should be equal to the expected return on the domestic bond, i_t. Furthermore, the UIP condition implies that if there are any non-zero interest rate differentials, exchange rates would adjust their value such that this would be offset. A numerical example is that if the UK interest rate is 2% higher than the US dollar interest rate, i.e. $i_t - i^*_t = 0.02$, the implication is that the US dollar would appreciate against the Sterling such that $E_t (s_{t+1} - s_t) = 0.02$. This would prevent an investor from making any profit if they were to borrow in the lower interest rate currency and invest in the higher interest rate currency.

Most of the existing literature has analysed whether the existence of any variable in the time *t* information set can predict the return on foreign bonds relative to domestic bonds. In line with literature standard, "**excess currency return**" and "**excess return on foreign bonds**" will be used to describe the relative return on foreign to domestic bonds. From time *t* to *t + 1*, any excess return will be denoted as λ_{t+1};

$$\lambda_{t+1} \equiv s_{t+1} - s_t + i_t^* - i_t \qquad (5)$$

In order for the UIP condition to hold, it is necessary that the $E_t (\lambda_{t+1}) = 0$ and therefore the $Cov (\lambda_{t+1}, X_t) = 0$ for any variable X_t in the time *t* information set. This implies that any excess returns in the next period cannot be predicted by variables which are known in this period. However, most of the existing empirically research has proven that the current interest rate differential $(i_t - i^*_t)$ can be used to predict excess returns in the future.

Fama (1984) set up the econometric test (6) which inspired the UIP puzzle with the expectation that $\alpha_0 = 0$ and $\gamma_1 = 1$ under the null hypothesis for the UIP condition to hold.

$$s_{t+1} - s_t = \alpha_0 + \gamma_1 (i_t^* - i_t) + u_t \qquad (6)$$

In a study referenced earlier, the equation above was transformed using simple algebra (Engel et al, 2022) to obtain the equation (7) below:

$$s_{t+1} - s_t + i_t^* - i_t = \alpha_0 + \beta_1(i_t - i_t^*) + \varepsilon_{t+1} \quad (7)$$

To estimate these equations by using ordinary least squares, it is clear that the intercept estimates are similar, and that the estimated slope coefficient is related as $\beta_1 = \gamma_1 - 1$.The left-hand side of the equation is similar to equation (5) and thus the regression can now be set up as:

$$\lambda_{t+1} = \alpha_0 + \beta_1 (i_t - i_t^*) + \varepsilon_{t+1} \quad (8)$$

In this case, the domestic currency is the GBP and i_t is the interest rate in the UK. For the UIP condition to hold, under the null hypothesis $\alpha_0 = \beta_1 = 0$ so that the average excess returns are zero and not predictable by the current interest rates. Despite the sound theory, a number of papers have instead discovered that $\beta_1 < 0$, implying that there is an anticipation of positive excess returns in the future from currencies that offer a high interest rate today.

To analyse the effect of interest rates approaching zero lower bound, the regression has been adapted to include a dummy variable that will also interact with the interest rate differential. To analyse the effects at distinct levels of low interest rates, the dummy variable, D_x, will be set to indicate data points below four different thresholds (percentages); 1.00%, 0.50%, 0.25% and 0.10%.

$$\lambda_{t+1} = \alpha_0 + \beta_1 (i_t - i_t^*) + \beta_2 D_x + \beta_3 D_x(i_t - i_t^*) + \varepsilon_{t+1} \quad (9)$$

The dummy variable will only take the domestic interest rate into account, and this will be tested for six different horizons; one month, three months, six months, one year, two years and five years. The interaction term between the dummy variable and the excess return on domestic bonds will look at the effect of domestic interest rates approaching ZLB on the excess return on domestic bonds. Therefore, the regression above will be run four different times for each horizon and the following hypothesis will be tested;

$$H_0(null): \ \alpha_0 = \beta_j = 0 \, ; \qquad\qquad H_1: \ \alpha_0 = \beta_j \neq 0 \qquad (10)$$

where $j = 1, 2, 3$

3.1. Data Description

The values for the various spot exchange rates have been sourced from the Bank of England (GBP exchange rates | Bank of England | Database, 2022), and this data starts on the 1st of January 1990 and ends on the 31st of March 2022. To employ the methodology aforementioned, the exchange rate represents the value of the domestic currency, Pound sterling (GBP), for every one unit of foreign currency; U.S. dollar (USD), Japanese Yen (JPY) and the Euro (EUR). The frequency of this data is daily.

It is important to note that the Euro was officially adopted into circulation at the beginning of 2002 (Euro Currency | OANDA, 2022), and therefore the exchange rate for the EUR/GBP only begins from the 1st of January 2002 and ends on the 31st of March 2022. Given the zero lower bound has only become a relevant issue after 2008, this was not a hindrance. The original data for the GBP/JPY exchange rate denoted the value of the foreign currency for every one unit of domestic currency, and this was transformed by simple division *(1 / (GBP/JPY))* to fit the methodology.

The graph on the next page shows the GBP value for one unit of each foreign currency, with the EUR and the USD on the left axis and the JPY on the right axis. When the line is on an uptrend this means that the GBP has depreciated in value as one unit of the foreign currency can purchase more GBP. This can be seen in the early ninety's after 'Black Wednesday' (Gottschalk, 2021), after the financial crisis in 2008 and after Brexit in 2016. After a sharp depreciation, the GBP seems to steadily appreciate (line follows a downtrend) until the next crisis.

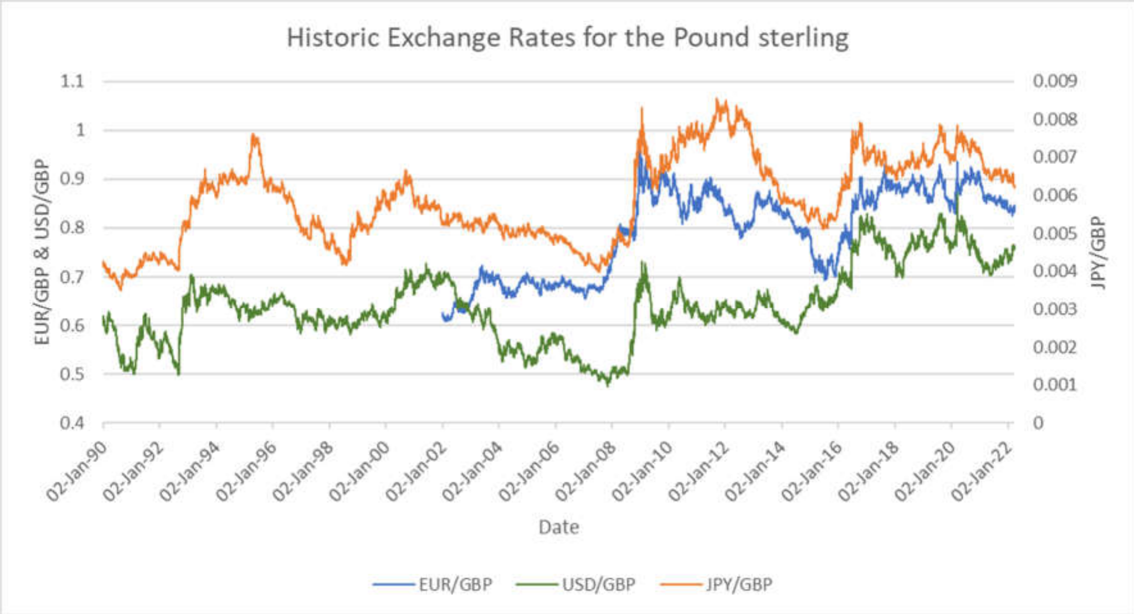

Figure 3.1.1. Exchange rates for three currency pairs; USD/GBP, EUR/GBP and JPY/GBP from 1990 to 2022 (GBP exchange rates | Bank of England | Database, 2022)

The interest rates for each respective country were sourced from 'Investing.com' (World Government Bonds – Investing.com UK, 2022). The frequency of this data is also daily, and this starts on the 1st of January 1990 and ends on the 31st of March 2022. For the Euro interest rates, interest rate data from France and Germany was used. The interest rates all had different maturity dates which are categorized as short-term (1, 3, 6 and 12 months) and medium-term (2 and 5 years). The interest rate data from Germany was used to represent the Euro interest rate at all maturity lengths but the one-month period (data unavailable), where the interest rate data from France was used. Due to the high-frequency nature of the data, data was not always available for a particular date. Thus, there will be some discrepancies in the number of observations as absent data for any variable at each horizon led to the omission of that record.

The interest rates for each country tended to be quite similar in value, and that was one of the main motivations behind selecting the domestic interest rate to construct the dummy variable. Secondly, it also provides the opportunity to focus solely on the United Kingdom. In Table 3.2.1 below, a summary of the number of observations (domestic interest rates) below each threshold at every maturity period can be found. Not surprisingly, as the threshold becomes stricter, the number of observations decrease. This is in line with the government bond yields gradually decreasing over time. Another key trend is that as the maturity period increases, the number of observations approaching the ZLB decreases.

		Horizon					
		1 month	*3 months*	*6 months*	*12 months*	*24 months*	*60 months*
Dummy Threshold	*<= 1.00*	3306	3322	3326	3298	2917	1618
	<= 0.50	2260	2208	1697	1985	1589	659
	<= 0.25	776	740	548	784	791	280
	<= 0.10	393	380	359	419	391	201

Table 3.2.1 A summary of the number of dummy observations for the domestic interest rate

The use of realised spot exchange rates as opposed to forward exchange rates meant a long-run analysis (10-year bond rates) was not possible as domestic interest rates have yet to drop below the 1% threshold before the maturity date is realised. Forward exchange rates would also not be appropriate for the UIP as they are instead used to test the covered interest rate parity, and also very difficult to accurately source historic records of.

4. Results

4.1. USD/GBP

$$\lambda_{t+1} = \alpha_0 + \beta_1 (i_t - i_t^*) + \beta_2 D_x + \beta_3 D_x (i_t - i_t^*) + \varepsilon_{t+1}$$

Horizon	Threshold; Dx=1 when i...	α0	(s.e.)	β1	(s.e.)	β2	(s.e.)	β3	(s.e.)	R sq.	Adj. R sq.	No. of Observations
1 month	< = 1.00%	-0.007**	(0.001)	-0.988**	(0.001)	0.008**	(0.001)	-0.012**	(0.001)	0.999	0.999	4,434
	< = 0.50%	-0.000	(0.000)	-0.998**	(0.000)	0.000	(0.000)	0.002	(0.001)	0.999	0.999	4,434
	< = 0.25%	0.000	(0.000)	-0.999**	(0.000)	-0.001	(0.001)	0.006**	(0.002)	0.999	0.999	4,434
	< = 0.10%	0.000	(0.000)	-0.998**	(0.000)	-0.001	(0.001)	0.047**	(0.010)	0.999	0.999	4,434
3 months	< = 1.00%	-0.005**	(0.000)	-0.989**	(0.001)	0.005**	(0.001)	-0.011**	(0.001)	0.998	0.998	6,778
	< = 0.50%	-0.001**	(0.000)	-0.997**	(0.001)	0.001*	(0.000)	0.004**	(0.001)	0.998	0.998	6,778
	< = 0.25%	-0.000	(0.000)	-0.998**	(0.001)	-0.001	(0.001)	0.010**	(0.003)	0.998	0.998	6,778
	< = 0.10%	-0.000	(0.000)	-0.997**	(0.001)	0.000	(0.001)	0.100**	(0.014)	0.998	0.998	6,778
6 months	< = 1.00%	-0.010**	(0.001)	-0.965**	(0.003)	0.012**	(0.001)	-0.033**	(0.003)	0.994	0.994	4,735
	< = 0.50%	0.003**	(0.001)	-0.994**	(0.001)	-0.005**	(0.001)	0.012**	(0.003)	0.994	0.994	4,735
	< = 0.25%	0.003**	(0.000)	-0.994**	(0.001)	-0.008**	(0.002)	0.036**	(0.007)	0.994	0.994	4,735
	< = 0.10%	0.002**	(0.000)	-0.992**	(0.001)	0.004+	(0.002)	0.235**	(0.023)	0.994	0.994	4,735
12 months	< = 1.00%	-0.130**	(0.010)	-0.705**	(0.018)	0.136**	(0.010)	-0.286**	(0.018)	0.993	0.993	3,203
	< = 0.50%	0.009**	(0.001)	-0.993**	(0.002)	-0.004**	(0.001)	0.017**	(0.003)	0.992	0.992	3,203
	< = 0.25%	0.012**	(0.001)	-0.996**	(0.002)	-0.027**	(0.002)	0.017**	(0.005)	0.993	0.993	3,203
	< = 0.10%	0.010**	(0.001)	-0.991**	(0.002)	-0.022**	(0.003)	0.039**	(0.009)	0.993	0.993	3,203
24 months	< = 1.00%	-0.000	(0.001)	-0.978**	(0.003)	0.024**	(0.002)	0.020**	(0.005)	0.979	0.978	6,993
	< = 0.50%	0.008**	(0.001)	-0.990**	(0.002)	-0.001	(0.002)	0.005	(0.005)	0.978	0.978	6,993
	< = 0.25%	0.008**	(0.001)	-0.991**	(0.002)	-0.018**	(0.005)	-0.015	(0.009)	0.978	0.978	6,993
	< = 0.10%	0.008**	(0.001)	-0.989**	(0.002)	-0.036*	(0.018)	-0.033	(0.028)	0.978	0.978	6,993
60 months	< = 1.00%	0.017**	(0.001)	-0.978**	(0.007)	0.046**	(0.004)	0.145**	(0.013)	0.862	0.862	5,941
	< = 0.50%	0.018**	(0.001)	-0.970**	(0.006)	0.038+	(0.021)	0.121**	(0.041)	0.858	0.858	5,941
	< = 0.25%	0.017**	(0.001)	-0.963**	(0.005)	0.007	(0.382)	0.042	(0.661)	0.857	0.857	5,941
	< = 0.10%	0.017**	(0.001)	-0.961**	(0.005)	(dropped)		(dropped)		0.857	0.857	5,941

note: ** p<0.01, * p<0.05, + p<0.1

Table 4.1 Regression output for the UIP condition – USD/GBP at six different horizons

Table 4.1 has been used to display the results of the regression found at the top of the table for the USD/GBP exchange rate (e.g. \$1 buys £x). The note at the bottom of the table refers to the p-value of each estimate. This is can be converted to a percentage and measures the probability that the estimates are random. A smaller p-value implies that the results indeed are 'significant' and that the null hypothesis should be rejected.

The first coefficient, α_0, represents the intercept of the regression and is fairly the same throughout the different horizons, hovering around a value of zero. It takes on a slightly negative value when estimating the regression for the one year interest rate and a domestic interest rate of less than or equal to 1.00%. This implies that when the interest rate differential is equal to zero and the domestic interest rate is greater than 1.00% (dummy variable=0), the geometric mean of the excess currency return will be 0.878 (= $e^{\alpha 0}$ = $e^{(0\text{-}.013)}$). The intercept estimates are (almost) all statistically significant at the 1% significance level, with a notable exception for the 2 year interest rate and a domestic interest rate of less than or equal to 1.00 %.

The coefficient, β_1, represents the slope estimate for the interest rate differential and is overwhelmingly similar to each other and in line with standard literature. That is, it has a value of less than 0 and very close to '-1'. This negative value implies positive excess returns in the future from currencies that offer a high interest rate today. The most notable estimate here is that for the one year horizon and a threshold of 1.00%. It takes on a value of '-0.705', statistically significant at the 1% significance level. This is slightly different to the rest of the findings and it gravitates more towards the value of 0, where the UIP condition holds. However, it is still significantly negative to the point where the UIP condition does not hold.

The coefficient, β_2, represents the slope estimate for the dummy variable. The dummy variable takes on a value of 1 if the domestic interest rate is less than or equal to the threshold, or a value of zero if the domestic interest rate is greater than the threshold. This is statistically significant at the 5% and 1% level for most horizons and thresholds, with a notable exception for some lower thresholds at the one and three month interest rates.

One notable estimate is that for the one month horizon with a threshold of 1.00% or lower, where the β_2 estimate takes on a value of 0.136, statistically significant at the 1% significance level. In this case, when the interest rate differential is held constant, this coefficient will represent the difference in the log of the expected geometric means between interest rates above and below the threshold. By taking the exponential value, a ratio can be obtained between these interest rates at the 1 percent threshold; $e^{\beta 2}$ / $e^{\alpha 0}$ = 1.305, or a 30% increase in the geometric mean of the excess returns when interest rates are above the threshold. The remainder of the β_2 coefficient estimates are not significantly different from zero.

The β_3 coefficient estimates are used to represent the slope of the interaction term- excess return on foreign bonds when the domestic interest rates are below a specified threshold. Once again, the majority of these are very close to zero, and statistically significant at the 1% level. Three estimates stand out; the first one belongs to the β_3 coefficient when the interest rate has a maturity period of one year and the threshold is at less than or equal to 1.00 percent. Here, the coefficient estimate takes on a value of '-0.286'. This implies that when these conditions are satisfied, the excess returns coefficient will take on a value of ($\beta_1 + \beta_3$) to reach a value of ≈ '-1', where the UIP condition is violated.

Additionally, the two β_3 estimates at the 5 year horizon also take on a positive value of 0.145 and 0.121 (statistically significant at the 1% level) for the 1.00% and 0.50% threshold respectively. This means that they reduce the negative coefficient of the excess returns ($\beta_1 + \beta_3$), but not enough so that the UIP condition can hold.

At the five year horizon, the β_2 and β_3 were dropped as there were no instances of the domestic interest rate being less than 0.10% corresponding with the available data. This means that the dummy variable was set to zero, thus the $D_x\ (i_t - i^*_t)$ variable would also be equal to zero. The strong correlation between these two independent variables will make it very challenging to estimate their individual regression coefficients efficiently; this is known as collinearity.

The R^2, which can take on a value between 0 and 1, is consistently very high across the various horizons. This relates to the goodness of fit, or what proportion of the change in the dependent variable is explained by the regression. A slight decrease can be seen at the five year horizon, but otherwise the model is very efficient at predicting the change in excess returns. The adjusted R^2 accounts for the number of independent variables used in the model, but it is almost similar to the R^2 in every case. The null hypothesis is rejected for this currency pair and the UIP condition violated.

It is important to note that whilst the results of the regressions for each currency pair were different, the interpretation of the coefficient estimates would be the same for all currency pairs.

4.2. EUR/GBP

$$\lambda_{t+1} = \alpha_0 + \beta_1 (i_t - i_t^*) + \beta_2 D_x + \beta_3 D_x (i_t - i_t^*) + \varepsilon_{t+1}$$

Horizon	Threshold; Dx=1 when i...	α0	(s.e.)	β1	(s.e.)	β2	(s.e.)	β3	(s.e.)	R sq.	Adj. R sq.	No. of Observations
1 month	< = 1.00%	0.005**	(0.001)	-1.006**	(0.002)	-0.006**	(0.001)	0.007**	(0.002)	1.000	1.000	4,375
	< = 0.50%	0.002	(0.000)	-1.001**	(0.000)	-0.002	(0.000)	0.001	(0.001)	1.000	1.000	4,375
	< = 0.25%	0.001	(0.000)	-1.000**	(0.000)	0.002	(0.001)	-0.003**	(0.001)	1.000	1.000	4,375
	< = 0.10%	0.001	(0.000)	-1.000**	(0.000)	0.001	(0.001)	-0.003**	(0.001)	1.000	1.000	4,375
3 months	< = 1.00%	0.006**	(0.001)	-0.984**	(0.004)	-0.007**	(0.001)	-0.015**	(0.004)	1.000	1.000	3,773
	< = 0.50%	0.003**	(0.000)	-1.002**	(0.001)	-0.005*	(0.001)	0.003**	(0.001)	1.000	1.000	3,773
	< = 0.25%	0.001	(0.000)	-1.000**	(0.000)	-0.004	(0.001)	0.001**	(0.001)	1.000	1.000	3,773
	< = 0.10%	0.001	(0.000)	-1.000**	(0.000)	-0.002	(0.002)	-0.002**	(0.001)	1.000	1.000	3,773
6 months	< = 1.00%	0.015**	(0.002)	-0.936**	(0.007)	-0.021**	(0.002)	-0.058**	(0.007)	0.999	0.999	3,674
	< = 0.50%	0.007**	(0.001)	-0.999**	(0.001)	-0.014**	(0.001)	0.004**	(0.001)	0.999	0.999	3,674
	< = 0.25%	0.003**	(0.001)	-0.997**	(0.001)	-0.029**	(0.005)	0.014**	(0.004)	0.999	0.999	3,674
	< = 0.10%	0.003**	(0.001)	-0.997**	(0.001)	0.002+	(0.010)	-0.017**	(0.009)	0.999	0.999	3,674
12 months	< = 1.00%	0.051**	(0.001)	-1.099**	(0.004)	-0.062**	(0.001)	0.112**	(0.004)	0.998	0.998	4,847
	< = 0.50%	0.013**	(0.001)	-1.003**	(0.001)	-0.024**	(0.001)	0.016**	(0.002)	0.997	0.997	4,847
	< = 0.25%	0.007**	(0.001)	-0.997**	(0.001)	-0.008**	(0.003)	-0.003**	(0.003)	0.997	0.997	4,847
	< = 0.10%	0.007**	(0.001)	-0.998**	(0.001)	-0.051**	(0.005)	0.025**	(0.005)	0.997	0.997	4,847
24 months	< = 1.00%	0.028	(0.001)	-1.007**	(0.005)	-0.037**	(0.002)	0.021**	(0.005)	0.995	0.995	4,592
	< = 0.50%	0.021**	(0.001)	-1.002**	(0.001)	-0.041	(0.002)	0.020	(0.002)	0.995	0.995	4,592
	< = 0.25%	0.015**	(0.001)	-1.001**	(0.001)	-0.037**	(0.004)	0.020	(0.004)	0.994	0.994	4,592
	< = 0.10%	0.014**	(0.001)	-1.000**	(0.001)	-0.010*	(0.013)	0.002	(0.009)	0.994	0.994	4,592
60 months	< = 1.00%	0.014**	(0.001)	-0.900**	(0.004)	0.021**	(0.004)	-0.122**	(0.006)	0.973	0.972	3,841
	< = 0.50%	0.022**	(0.001)	-0.945**	(0.003)	0.035+	(0.018)	-0.113**	(0.019)	0.969	0.969	3,841
	< = 0.25%	0.024**	(0.001)	-0.957**	(0.003)	-0.020	(0.160)	-0.050	(0.169)	0.968	0.968	3,841
	< = 0.10%	0.025**	(0.001)	-0.961**	(0.003)	(dropped)		(dropped)		0.968	0.968	3,841

note: ** p<0.01, * p<0.05, + p<0.1

Table 4.2 Regression output for the UIP condition – EUR/GBP at six different horizons

Table 4.2 displays the results of the regression found at the top of the table for the EUR/GBP exchange rate. The first coefficient, α_0, is statistically significant at the 1% significance level for the majority of the horizons and thresholds. It is also very close to zero, with a maximum of 0.051 at the one year horizon, and a minimum of 0.003 at the three month horizon. For the two year horizon, the coefficient estimate is not statistically significant at the 10% significance level when the domestic interest rate is less than or equal to 1.00.

In line with standard literature and the findings for the previous currency pair, the β_1 estimates are all very similar in value and hover around the value of '-1.000'. They are all statistically significant at the 1% significance level. One other notable estimate can be seen at the five year horizon, where the coefficient estimates decrease in magnitude, reaching a value of '0.900'. The value of the β_1 estimates for the five year horizon also seem to be slightly lower in magnitude than the rest of the horizons.

The β_2 estimates are all very similar in value and not that different from zero. The majority of these estimates are statistically significant at the 1% significance level. The rest are statistically significant at the 5% and 10% significance level. At shorter horizons and more strict thresholds, these estimates are not statistically significant.

The β_3 estimates are also very similar in value and close to zero in value. The majority are statistically significant at the 1% significance level. At a horizon of two years, three of these estimates are not statistically significant at the 10% significance level, as well as another estimate at the one month and five year horizon each. There are no notable values, except the slightly higher estimate at the one year horizon and 1.00% threshold, where the estimate takes on a statistically significant (at the 1% significance level) value of 0.112.

The R^2 is consistently very high in value across the various horizons. Overall, these estimates do not display any significant trend across the different horizons or between the different thresholds. The null hypothesis is yet again rejected and the UIP condition has been violated.

4.3. JPY/GBP

$$\lambda_{t+1} = \alpha_0 + \beta_1 (i_t - i_t^*) + \beta_2 D_x + \beta_3 D_x (i_t - i_t^*) + \varepsilon_{t+1}$$

Horizon	Threshold; Dx=1 when i...	α0	(s.e.)	β1	(s.e.)	β2	(s.e.)	β3	(s.e.)	R sq.	Adj. R sq.	No. of Observations
1 month	< = 1.00%	-0.007**	(0.001)	-0.983**	(0.002)	(dropped)		(dropped)		0.993	0.993	2,289
	< = 0.50%	0.004	(0.007)	-1.002**	(0.011)	-0.015	(0.007)	0.038	(0.011)	0.993	0.993	2,289
	< = 0.25%	-0.007	(0.001)	-0.983**	(0.002)	0.001	(0.002)	-0.007**	(0.006)	0.993	0.993	2,289
	< = 0.10%	-0.007	(0.001)	-0.982**	(0.002)	0.002	(0.002)	-0.006**	(0.011)	0.993	0.993	2,289
3 months	< = 1.00%	-0.012**	(0.001)	-0.974**	(0.002)	(dropped)		(dropped)		0.990	0.990	2,570
	< = 0.50%	0.014**	(0.003)	-1.015**	(0.004)	-0.032*	(0.003)	0.058**	(0.005)	0.991	0.991	2,570
	< = 0.25%	-0.012	(0.001)	-0.971**	(0.002)	0.006	(0.002)	-0.031**	(0.005)	0.991	0.991	2,570
	< = 0.10%	-0.012	(0.001)	-0.974**	(0.002)	-0.002	(0.003)	0.018**	(0.016)	0.990	0.990	2,570
6 months	< = 1.00%	0.027**	(0.004)	-1.013**	(0.003)	-0.055**	(0.005)	0.077**	(0.005)	0.992	0.992	4,517
	< = 0.50%	0.019**	(0.002)	-1.007**	(0.002)	-0.055**	(0.003)	0.059**	(0.007)	0.993	0.993	4,517
	< = 0.25%	-0.003**	(0.001)	-0.991**	(0.001)	-0.029**	(0.004)	0.050**	(0.017)	0.992	0.992	4,517
	< = 0.10%	-0.004**	(0.001)	-0.990**	(0.001)	-0.044+	(0.006)	0.173**	(0.039)	0.992	0.992	4,517
12 months	< = 1.00%	-0.006**	(0.012)	-0.932**	(0.009)	-0.031**	(0.012)	0.024**	(0.010)	0.975	0.975	3,565
	< = 0.50%	0.003**	(0.003)	-0.946**	(0.003)	-0.072**	(0.004)	0.108**	(0.009)	0.978	0.978	3,565
	< = 0.25%	-0.022**	(0.002)	-0.922**	(0.003)	-0.039**	(0.004)	-0.017**	(0.014)	0.977	0.977	3,565
	< = 0.10%	-0.032**	(0.002)	-0.913**	(0.003)	-0.012**	(0.006)	-0.071**	(0.026)	0.976	0.976	3,565
24 months	< = 1.00%	-0.110	(0.007)	-0.763**	(0.007)	0.013**	(0.008)	-0.031**	(0.010)	0.934	0.934	3,309
	< = 0.50%	-0.073**	(0.004)	-0.806**	(0.005)	-0.058	(0.005)	0.064	(0.012)	0.937	0.937	3,309
	< = 0.25%	-0.103**	(0.003)	-0.775**	(0.004)	-0.024**	(0.007)	0.044	(0.022)	0.934	0.934	3,309
	< = 0.10%	-0.108**	(0.002)	-0.769**	(0.004)	-0.004*	(0.018)	0.040	(0.059)	0.934	0.934	3,309
60 months	< = 1.00%	-0.334**	(0.012)	-0.524**	(0.014)	0.245**	(0.017)	-0.367**	(0.027)	0.652	0.652	2,570
	< = 0.50%	-0.228**	(0.008)	-0.649**	(0.010)	0.162+	(0.035)	-0.334**	(0.066)	0.628	0.628	2,570
	< = 0.25%	-0.226**	(0.008)	-0.652**	(0.010)	0.175	(0.179)	-0.364	(0.458)	0.625	0.625	2,570
	< = 0.10%	-0.223**	(0.008)	-0.656**	(0.010)	(dropped)		(dropped)		0.625	0.624	2,570

note: ** p<0.01, * p<0.05, + p<0.1

Table 4.3 Regression output for the UIP condition – JPY/GBP at six different horizons

Table 4.3 displays the results of the regression found at the top of the table for the JPY/GBP exchange rate. This yielded some interesting results, still in line with standard literature but slightly different to the other two currency pairs. The first coefficient, α_0, is statistically significant at the 1% significance level for the majority of the regressions, except those with a stricter threshold at the one and three month horizon, as well as the two year horizon and a domestic interest rate of less than or equal to 1.00%. It is not that different from zero, except at the five year horizon. Here, it takes on a statistically significantly (at the 1% significance level) negative value that ranges between -0.22 and -0.33, decreasing in magnitude as the threshold becomes more strict.

In line with standard literature and the findings for the previous currency pair, the β_1 estimates are all very similar in value and oscillate around the value of '-1.000'. They are all statistically significant at the 1% significance level. However, a clear trend can be seen for this currency pair. Once the horizon increases, the magnitude of these coefficient estimates seems to decrease. At the two year horizon, this coefficient estimate ranges from -0.763 to -0.806 in value and the five year horizon, it ranges from -0.524 to -0.656 (decreasing in value as the threshold gets more strict). All the available data on interest rates for the one and three month horizons coincided with the domestic interest rates being less than 1.00%; those coefficient estimates were dropped due to collinearity.

The β_2 estimates are all very similar in value and also hover around zero; the majority of them are statistically significant at the 1% significance level. The most notable estimate is that for the five year horizon and 1.00% threshold, were the value of the coefficient is estimated at 0.245, statistically significant at the 1% significance level. Also at that horizon and at the 0.50% threshold, the estimate takes on a value of 0.162, statistically significant at the 10% significance level. At the one and three month horizon, most of the estimates are not statistically significant at the 10% significance level.

The β_3 estimates are also fairly similar in value across the various horizons and thresholds, not significantly different to zero. They are also statistically significant at the 1% significance level, with the exception of those estimates for the two year horizon and the stricter thresholds. Notable estimates can be seen at the five year horizon, where two of the estimates are quite negative in value, ~ -0.350, and statistically significant at the 1% significance level.

The R^2 is also consistently very high in value, except at the five year horizon, where it drops by around 30% to a level of 0.6. The null hypothesis is also rejected for this pair and the UIP condition is violated.

5. Discussion

As seen in the results above, the uncovered interest rate parity (UIP) condition is violated for all the currency pairs at different horizons and thresholds. This section will further explore the shortcomings of the UIP condition, alongside the impact of interest rates approaching zero lower bound (ZLB) and at times, negative territory.

Fama (1984) proposed that the reason there are deviations from the UIP condition is because of a risk premium based on the interest rate. Currencies that offer a relatively higher interest rate carry more risk for an investor. Therefore, the returns on these currencies is also higher, as opposed to the UIP condition that these currencies should depreciate to offset this interest rate differential. Risk premium is defined as any return on an asset that is additional to the risk-free rate of return (What Is a Risk Premium?, 2022). The rate of return over a pre-determined time period of an investment with no (zero) risk is defined as the risk-free rate of (What Is the Risk-Free Rate of Return?, 2022).

Kumar (2019) attempted to account for the risk premium in order to explain the failure of the UIP. He made use of 22 emerging and 22 advanced currencies, including the UK, Japan and France. Additionally, the assumption that investors have rational expectations and are risk neutral has prompted many studies of the UIP to ignore the time-varying risk premium, and often find a negative β_1 coefficient. Kumar proposed that the spot exchange rate difference should be offset by the interest rate differential **minus** this risk premium. The risk premium was made up of a constant and time-varying component. Another point made was that investments in an emerging economy carried greater risk than in an advanced economy, thus the risk premium and the interest rates would be greater in the emerging economy in order to entice foreign investments. Interestingly, he found that the UIP condition was more prone to failure in emerging economies compared to advanced economies in the absence of the risk premium. Furthermore, when the risk premium was indeed present, a positive relationship between the exchange rate difference and interest rate differential was found, in line with the UIP condition. The model used for this study was CGARCH-M; component generalized autoregressive conditional heteroskedastic-in-mean.

Dahlquist and Pénasse (2022) found that the risk premium is in fact the main culprit behind any changes in the real exchange rate, and not the interest rate differential. The model used explored the link between these variables. In the long run, it seems that high interest rates carry less risk as there is a tendency for reversal for the positive relationship between the interest rate differential and the currency risk premium over the horizon. This implies that the missing risk premium and the interest rate differential have the opposite effect. Thus, a shock increase in the interest rate differential will increase returns in the future but also cause a sudden increase in the (missing) risk premium. In the short-run, the overall effect would result in a rise in the currency risk premium. In the long-run, they also looked at the relationship between macroeconomic fundamentals and the expected exchange rate. Differences in country productivity, export quality and net foreign assets were explored (Menkhoff et al, 2017); there was no qualitative difference in their results.

Gehringer and Mayer (2019) analysed the low interest rates by using evidence from the four countries also analysed in this paper. They acknowledged the fall in interest rates from the 1990s. There are two sides to this story; central bankers who blame the fall in interest rates on economic fundamentals and practitioners, who blame monetary policy on causing the fall in interest rates. The European Central Bank (ECB), alongside other economists have long argued that the gradual fall in interest rates from the 1990s can be largely associated to the market interest rates, which themselves change to reflect the long-term economic fundamentals. The research however focused on how interest rates are being determined.

On the 29th of January in 2016, the Bank of Japan introduced a negative interest rate via the "Quantitative and Qualitative Monetary Easing" in an attempt to achieve price stability of 2 percent (Bank of Japan, 2016). It also decided to track monetary easing by utilising three key measurements: quantity, quality and interest rate. At the time, the drop in crude oil prices and the uncertainty surrounding progress in emerging and commodity-exporting economies (such as China) created volatility in the global financial markets. The aim was to reach price stability as soon as possible, and the interest rate was to be reduced further if this goal needed to be achieved. Six months later, Bank of Tokyo-Mitsubishi UFJ Ltd. quit its role as the primary dealer of Japanese government bonds (Sanglap, 2016). This move came after the CEO of the bank, Takashi Oyamada, publicly came out against the policy of negative interest rates. He claimed that the purchasing obligations would prove to be too challenging for the bank. However, the bank will continue to take part in any auctions for Japanese government bonds.

Low-interest rates set by central banks serve two purposes; firstly, they encourage borrowing, spending and investment (Negative Interest Rates Are Not Working in Japan, 2022). The assumption made by central banks is that savings are detrimental to the economy unless they are invested into businesses. When interest rates approach zero lower bound (ZLB), consumers will tend to transfer the money from their savings account into either spending or investment. Secondly, it lowers the interest payments for governments that find themselves heavily indebted. This is especially common to be followed by a period when governments will spend more than they receive as revenue during a fiscal period.

The issues with debt in Japan began in the early 1990s, when Japan entered a sudden recession after bubbles in the real estate and stock market popped. In the decade that followed, the government in Japan issued various different fiscal stimulus packages whilst lowering interest rates from 6 percent to 0.25 percent. Furthermore, quantitative easing was used in 1997, 2001, 2004 and 2013. The failure of these measures is well documented by Wilson (2008), where she made the point that the fiscal and monetary policies were not coordinated efficiently to stimulate economic activity.

The Swiss franc, regarded as a safe haven currency during a crisis, also experienced negative interest rates set by the Swiss National Bank (Mombelli, 2020). These were set in 2015 as a crucial step to prevent the Swiss franc from appreciating too much. This was different in purpose to the other decisions for negative interest rates. Both the tourism sector and the export industry enjoyed the benefits of negative interest rates, as well as domestic businesses that loaned from the bank. The surplus enjoyed by the government as a result of low interest rates can be put towards reducing debt. This also lead to a boom in house prices, which have enjoyed significant growth (sometimes doubling) from 2010 to 2020. Banks, savers and pension funds were the ‘losers’ in this situation, facing an increased cost of holding money as cash.

In June 2014, the ECB introduced negative interest rates that gradually kept decreasing, and in 2019 interest rates reached -0.5 percent (Claeys, 2021). The expectation was that these rates will stay below zero for the foreseeable future, and thus the effects on the economy have become quite relevant. Negative interest rates should have the same impact as the regular cuts in interest rate, but the main difference is that agents may see their expectations change as the minimum limit of interest rates has now changed (many did not envision negative rates). Agents will seek assets with a higher risk, and a higher yield, when interest rates are lowered- the lowering of interest rates into negative territories will only amplify this effect as many would want to avoid this territory.

When interest rates are lowered, the exchange rate is affected by the interest rate parity; depreciation in the domestic currency is anticipated when the interest rate differential with respect to the foreign country is expected to be negative. Usually, this would improve exports and make imports more costly, leading to a positive impact on output and inflation. Once again, this effect could see a boost when cross-border capital flows are quite respondent to negative interest rates. Denmark, which was viewed as a safe haven when the Euro was experiencing a crisis, experienced capital flows inward that would have led to currency appreciation. This would be detrimental to exports and also bring inflation below the target level. As a result, they made use of the negative interest rates to defend its decision of pegging their currency with the Euro.

The eight oldest bank in the world, Coutts, published an article that briefly outlined the low interest rates in the UK over the past decade and what this means for the future (Higgins, 2020). They did not expect positive real returns from government bonds anytime soon. Developed countries seem to struggle with low levels of inflation and in the UK, despite the currency devaluation and low base interest rates, inflation has maintained constant at about 2% over the last decade. The spikes seen in 2011 (5.0%) and 2013 (3.0%) managed to correct themselves without the central bank intervening. Apparently, inflation being low is the main driving force behind low interest rates – central banks believe that low interest rates lead to inflation. In the absence of rising inflation central banks will not raise interest rates. If anything, tightening the monetary policy could give way to a deflationary trend. Two situations that might lead to higher interest rates are high inflation and/or an economic boom. Interestingly enough, inflation in the UK has seen a significant rise recently as the effects of the pandemic are becoming more apparent.

According to this study, the UIP fails to hold for all three currency pairs as the interest rates in the United Kingdom approach ZLB. The conclusion is very similar throughout the different currency pairs and also in line with existing literature. However, the study does have its fair share of limitations. The high frequency nature of the data used meant that the data was not always available for each variable, and that the data sourced represented the average value for the interest rates that day. This could be adjusted to improve accuracy by making use of lower frequency data, such as weekly or monthly, to verify the UIP condition. Furthermore, the countries and currencies selected for analysis shared similar traits; highly developed nations with a stable economic environment and interest rates that largely followed the same path. This study could be extended to make use of different currency pairs that may not always share the same traits. This would allow the study to also investigate the impact of foreign interest rates moving closer to zero lower bound. Furthermore, the study only analysed the impact of interest rates, not taking into account the other factors that may have an impact on the UIP condition. These factors could influence the interest rates, the exchange rates and also the exchange rates via their influence on the interest rates. This would be a great avenue to explore in order to further investigate the failure of the UIP.

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