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Survivorship Bias in Currency Carry Trade Literature

Author: J.E.C. van Holten

Student ID: 407411

Supervisor: Prof. Dr. L.A.P. Swinkels

Second Assessor: Prof. Dr. J. Zenhorst

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In this paper it is investigated whether survivorship bias is present in currency carry trade literature. Based on a literature study of over 40 influential papers it is found that currency sample choices are sometimes made in an ex-ante perspective; and currency samples are therefore subject to survivorship bias. A sample adapted for survivorship bias includes the French franc and Italian lira prior to 2000. Furthermore, the Australian dollar, New Zealand dollar, Norwegian krone, Danish krone and Swedish krona are excluded up until 2000 as, based on the literature review, they appear to be influential after this time. Specifically, the works that appear to suffer from survivorship bias are replicated both with the original sample and with the adapted sample. Minor differences are found in the returns and Sharpe ratios of the various carry trade portfolios, however these differences were not found to be statistically significant. The paper highlights the importance of survivorship bias in currency sample selection, as it is found to be influential in academic literature studying other financial assets.

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1. Introduction

Survivorship bias is the error that is made when conclusions are drawn based on people or things that made it past some selection process and ignoring those that didn't make it past that point.
In analysing the performance of financial assets, such as stocks, bonds and hedge funds, the assets are analysed based on performance over time. In the past researchers would create a sample of assets from the start and follow their value over time. In recent financial academic studies the sample is selected based on assets available today, thereby excluding currencies that don't exist anymore. Thus, the sample is by definition subject to survivorship bias, as assets that no longer exist are not used. This affects studies that have used this research method. The sample of survivors only takes into account the most successful assets, thereby possibly underestimating the effect of the non-survivors on the investor's return.
This bias may also be present in studies on currency carry trade, as money markets have to deal with disappearing and emerging currencies over time. Currency carry trade is an investment strategy in where investors invest in currencies with relatively high domestic interest rates, funding this investment by selling currencies with a lower domestic interest rate. In for example Jurek (2009) it is found that this strategy leads to excess returns when risk is taken into account. Therefore, returns to carry trade are often found to be higher than risk premia justify according to finance theory. Survivorship bias can occur for multiple reasons. In currency studies survivorship bias could be caused by disappearing currencies being excluded in studies due to decision making in an ex-post perspective. At the time of sample selection knowledge about the survival of currencies may influence decision making. This paper aims to give an overview of the currencies used in academic studies, examine if survivorship may be present, and then quantify the amount of survivorship bias present in currency trading strategies. The scope of the literature study is influential currency papers between 1960 and 2016, but the empirical investigation focuses purely on four different currency carry trade works. The following research question will be answered in the paper:

Is survivorship bias present in academic literature on currency carry trade?

In recent studies it is often not made clear whether the sample is adapted for survivorship bias or not. Investigation into this effect is therefore necessary, making this paper scientifically relevant. Wermers (1997) investigates the role of survivorship bias in mutual funds, similar to Carpenter and Lynch (1999). It is found that survivorship bias indeed affects the results. Hendricks et al. (1993) find that stock returns are significantly lower when samples are adapted for survivorship bias. Whether this effect is also present in currency literature has not yet been investigated. We will further elaborate on existing

survivorship bias literature in the literature review section of this paper. Furthermore, if survivorship bias has a significant affect on the returns earned to various carry trade strategies this is valuable information for investors. The excess returns to carry trade as found by many academics such as, Clarida, Davis &Pederson (2009), Christiansen, Ranaldo & Soederlind (2011), Menkhoff, Sarno, Schmelling & Schrimpf (2012) and Jurek (2009), might no longer be higher than their risk premium explains. An investigation into survivorship bias is therefore also socially relevant.

In order to answer this research question initially a literature study is carried out, the scope of the investigation is influential currency papers from 1960 until 2016. An overview of the currencies and the time frame examined per publication is created. This will show whether sample choices are consistent with the time span of data used, and indicate potential samples that are influenced by survivorship bias. In order to quantify this the selected studies will be replicated using a sample that is adapted for survivorship bias. Based on the results of this study several anomalies in samples are found. Based on data collected we find that systematically the German mark is the only euro currency used in current studies prior to 1999, while the Italian lira and French franc were included in samples of studies published prior to the introduction of the euro. Additionally, we find that currencies such as the Norwegian krone, Swedish krone, Danish krone, Australian dollar and New Zealand dollar, that are influential after 2000, are used in samples starting in the 1980's. Furthermore, it is found in the Literature Review that currencies that do not exist over the entire time span of investigation are sometimes excluded without further justification.

In this paper we will focus on the sample selection choice of Jurek (2014), Burnside, Eichenbaum & Rebelo (2011), Brunnermeier et al., Nagel & Pederson (2009), and Menkhoff et al. (2012) and attempt to quantify the potential survivorship bias present in these studies. Many papers use a similar carry trade and portfolio as well as selecting a similar sample, the selected works all use different carry trade strategies and were selected to allow for comparison and robustness checks of the results. The change in returns and Sharpe ratios were found to not significantly differ between original samples and the adapted samples.

The paper consists of a literature review on survivorship bias and the data sets used in influential currency and currency carry trade papers. This is followed by a theoretical framework and methodology for the investigation and a description of the data in the data section. Next the results will be presented, followed up by the interpretation and discussion sections.

2. Literature Review

2.1. Survivorship Bias

The problem of survivorship bias, as explained earlier, is examined in the work of Brown et al. (1992) who evaluate this in equity funds and acknowledges this method of research as a source for survivorship bias in performance of financial asset studies. A study where this effect is also recognized and evaluated is the work of Carpenter and Lynch (1999). They examine whether performance persistence is an important factor in how investors should choose funds. If for example, a mutual fund is earning excess returns this might indicate superior knowledge of managers. However, this could mean a contradiction to the efficient market hypothesis. This investment theory states that it is impossible to earn higher returns than the market, as all available information is incorporated in the stock price (Malkiel, 2005). The authors refer to the work of Brown et al. and state that even the disappearing stocks are used in the analysis, thereby making the sample perhaps a more realistic representation of reality. Thus, the study deals with survivorship bias by accounting for the non-surviving stock. The finding is that accounting for disappearing stocks influences the results significantly.

Wermers (1997) evaluates the role of survivorship bias in mutual fund returns. The conclusion is that the best performing funds are the worst performing funds exactly one year later if the momentum effect is not present, however the outcome is affected by survivorship bias. The momentum effect states that well performing financial assets are invested in because they are expected to continue doing so in the future. The strategy consists of investing in the best performing assets at a given moment, financed by the short selling the worst performing assets. These high performing funds tend to disappear with the same frequency as poor performers. Therefore, not including non-surviving stocks affects the results of this study. When this effect is quantified a difference of 20 percentage points per year is found between returns of surviving stocks and the average fund (adjusted for differences in risk). The presence of survivorship bias is further reinforced by Grinblatt and Titman (1992) and Hendricks et al. (1993), who also examine the volatility of returns. They find that high volatility funds have the highest expected performance conditional on survival. The conclusion is that fund survival depends on the average performance over multiple periods and survivorship bias therefore induces spurious reversals as only surviving stocks are evaluated. Their research evaluates the effect of various sample selections on the degree of persistence in stock returns. A very relevant finding posed is that survivorship biased is largely affected by the methodology of the investigation and the selection criteria of the assets included in the sample. Although the problem is excessively

discussed, no attempt is made to quantify the effect of survivorship bias on the results. Finally, Carhart (1997) finds that survivorship bias grows with the length of the sample period. Later in the empirical part of the research we will examine the various academic works investigating the abnormal returns earned in carry trade.

These academic studies show that survivorship bias is present in many works with a significant effect on the results. Investigation of whether this is also the case in currency works has not yet been done and is therefore necessary. Hereby, this paper is an addition to existing literature. In Section 2.2. we will examine the currency sample selection process in literature and examine if survivorship bias may play a role. We will highlight the currencies selected, the year of publication and the way the introduction of the euro is dealt with. In Section 2.3 we will highlight some potential cases of survivorship bias in currency carry trade literature.

2.2. Data Sets and Potential Survivorship Bias

In the work of Menkhoff et al. (2012) portfolios are formed based on the high and low interest rate countries. Data for spot rates and one-month forward rates against the US dollar are used from November 1983 until August 2009. Following a model by Fama (1984) a large sample of 48 currencies is studied, along with a smaller sub sample of 15 currencies namely: "Australian dollar, Belgian franc, Canadian dollar, Danisk krone, euro, French franc, German mark, Italian lira, Japanese yen, Dutch guilders, New Zealand dollar, Norwegian krone, Swedish krona, Swiss franc and the British pound all versus de US dollar". Additionally, as the Euro was introduced in January 1999 the sample consists of 10 currencies only. The euro series starts in January 1999. The euro area countries are excluded after this date and only the euro exchange rates are included (Menkhoff et al., 2012). In order to justify this decision, the work of Lustig is referred to. Lustig et al. (2011) use the same sample and decide to exclude certain currencies that show failures of uncovered interest rate parity. Specifically, "South Africa from the end of July 1985 to the end of August 1985; Malaysia from the end of August 1998 to the end of June 2005; Indonesia from the end of December 2000 to the end of May 2007; Turkey from the end of October 2000 to the end of November 2001; and United Arab Emirates from the end of June 2006 to the end of November 2006" (Lustig et al., 2011). Moore and Roche (2012) argue that the degree of monetary volatility determines whether covered interest parity holds. Additionally, currencies for which uncovered interest rate parity does not hold are excluded from the analysis.

The of Jylhae and Suominen (2009) finds that the abnormal returns to carry trade decrease in the amount of arbitrage capital available. Therefore, as arbitrage capital is increasing over time the

abnormal returns to carry trade are decreasing. Jylhae and Suominen also find that the new flow of arbitrage capital leads to an appreciation of the long currencies. A model is constructed to predict some additional sources to carry trade returns. The data used in the analysis is month-end exchange rates for the Belgian franc, British Pound, Canadian dollar, euro, French Franc, German mark, Italian lira, Japanese Yen, Netherlands guilder, Swiss franc, and U.S. Dollar. The time period covered is from 1976 until 2008. Not all currencies are available throughout this time range, due to for example the introduction of the euro. Additionally, some early values of exchange rates are missing, and therefore some currencies enter the analysis as they become available. For example, data for the Japanese yen begins in 1978 and the euro only starts in January 1999. The paper states "Although this is not a complete set of currencies, we cannot think of any systematic bias arising from the fact that not all currencies at all times have been included in the data set. Our dataset contains the currencies used e.g. in Burnside et al. (2011) and Jylhae and Suominen (2009)". The fact that currencies are unavailable in some periods, or disappear at a given time is not necessarily an issue, however the decision to exclude certain currencies could result in survivorship bias f such a decision is made based on ex-post information. As information about specific selection criteria is not given investigation of the effect if sample selection is necessary. Similar observations exist in Menkhoff et al. (2012) "Our effective sample size varies over time when currencies become available or cease to exist". Again, no further comments are made about the decisions regarding the currencies included in the sample. It is therefore important to examine whether the currency selection may have occurred in an ex-post perspective.

In 1971 the Bretton Woods system collapsed and most major currencies became free floating. Exchange rates now reflect interest rate differentials between countries, disasters, speculation and intervention by central banks. The American Dollar became the reserve currency used to adjust exchange rates. Many papers following the end of the Bretton Woods system therefore express exchange rates as relative to the U.S. dollar increasing the influence of the US dollar (International Monetary Fund, 2017). In fact, the US dollar is always included in literature since 1970.

In the work of Fama (1984) it is investigated whether forward rates have any power in explaining future spot rates. Fama contradicts the work of Hansen and Hodrick (1980), Bilson (1981) and Levich (1979) who state that forward rates have little predictive power. It is found that time varying premiums exist, in fact the forward premium and the expected future spot rate is negatively correlated. The nine currencies used, that are justified and defined as major influential and stable currencies are; Belgian Franc, Canadian Dollar, French Franc, Italian Lire, Japanese Yen, Dutch Guilder,

Swiss Franc, British pound and the German mark. The years 1973 to 1982 are examined, with the exchange rates relative to the US dollar. Similarly, Baillie, Lippens & McMahon (1983) used the British pound, German mark, Italian lira, French Franc, Canadian dollar and the Swiss Franc all relative to the U.S. dollar. This study found that the forward rate is not an unbiased predictor of the spot exchange rate, and that in fact a risk premium is charged. These works are of relevance to this investigation as they clearly highlight the important currencies in the 1980's. Interestingly these currencies are not all included in works published later yet using data from the 1980's. One example of this is the work of Jurek (2009).

Fenkel and Levich (1975) investigate the value of major currencies relative to the US dollar to find out whether uncovered interest rate parity holds. Over the years 1962 to 1967[1] only a few currencies are used, namely the British pound, Canadian dollar and the German mark. Interestingly, when the Euro-market is mentioned the only currencies referred to are the British pound and the German mark, these two currencies are referred to as the traditional sample. This view of currencies seems to be shared by many papers at the same time including Branson (1969) and Stoll (1968). Research that is published a little later, covering the time span of 1974 until 1990, similarly uses the value of the Canadian dollar, French franc, German mark, Japanese Yen, and the British pound (Backus et al., 1993). In the 1990's currency data was frequently used to investigate the relation between forward rates and future spot rates. Research published after 1990 does not use currencies such as the Italian lira, even though the time frame sampled often starts around the 1960. This decision may have been influenced by ex-post knowledge. This finding regarding the selection of the Italian lira will be further examined in the results section, as it seems to be excluded from many academic studies without further justification. This observation is similar in the work of Bekaert (1992), the sampling period here is 1981 until 1989, the currencies used are also the US dollar, Japanese yen, British pound and the German mark. Bekaert (1992) investigates whether the forward premiums on exchange rates is evidence of market inefficiency or simply time varying risk premiums.

2.3. Survivorship Bias in Curreny Carry Trade Literature

Survivorship bias can have an effect when the currencies used in an investigation change over time. For example, many 20th and 21st century studies are affected by the introduction of the euro. The euro replaced many influential European currencies and was also added to the G10 currencies directly after introduction. For example, Alberola, Lopez, Ubide & Cervero (1999) use the German mark as a proxy

[1] This period was selected to ensure transaction costs would remain similar over the period.

for the euro before it was introduced, thereby excluding all other currencies that were replaced by the euro. Additionally, many currencies have been demonetized over time (Middelkoop, 2015). In this next section we will examine the way the above is dealt with in currency carry trade literature specifically.

Jurek (2009) investigates uncovered interest rate party in currency carry trades and currency options. He finds that uncovered interest parity does not hold, high interest rate currencies appreciate whereas low interest rate currencies depreciate. This is exactly opposite to what is expected under uncovered interest rate parity. This finding is explained using the forward premium anomaly, where the high returns are due to crash risk premium despite high interest rates. Jurek aims to check if crash neutral carry trade also generates excess returns. Nine carry trades in pairs with the US Dollar were formed out of the G10 currencies, an average excess return of 4.42% was found, and a Sharpe ratio of 0.88. the Sharpe ratio is calculated by dividing the excess returns compared to the market returns by the standard deviation (of the returns). The period examined was 1990-2007. During this time the euro was introduced. The set of G10 currencies used include Australian dollar, Canadian dollar, Swiss franc, euro, British pound, Japanese yen, Norwegian krone, New Zealand dollar, Swedish krona, and the U.S. dollar. These currencies today are the G10 currencies. However, as previously explained, the G10 currencies did not exist in this combination in 1990. In 1990 other currencies were commonly used and seen as influential. For example, the Canadian dollar, French franc, Japanese yen, Swiss franc, British pound and German mark. This finding indicates potential survivorship bias. Additionally, the Euro referred to between 1990 and 1999 is proxied by the German mark. As a result, any currency that was replaced by the euro (excluding the German mark) is not included in the analysis. An example would be the French franc, which seized to exist due to the introduction of the euro, and as a result is not taken into account. However, when examining influential papers regarding currencies the French franc is almost always used, survivorship bias might therefore affect the currencies selected. Additionally, using the G10 as it is known today is an indication of survivorship bias as currencies such as the Norwegian krone, New Zealand dollar, Swedish krona and the Australian dollar were not seen as influential in 1990, but are used in the sample. This could be caused by survivorship bias in currency selection.

Menkhoff et al. (2012) investigate the excess returns earned in currency trading in his work. This is not a typical carry trade strategy but rather a strategy following trends. Buying currencies with recent high returns and selling recent low returns. The data used is therefore not time series data, but rather cross-sectional currency returns. Returns found in this investigation are higher than risk factors explain by about six to ten percent. Risk factors that are evaluated and calculated into the risk premium

include factors such as default risk and credit risk. Excess returns differ up to ten percent, examine both winner and loser currencies. However, disappearing currencies are not taken into account in the research. Although the abnormal returns cannot be explained using risk factors it is found that effective limits to arbitrage limit the exploitation of abnormal returns. Currencies are examined from the first month of 1976 until the first month of 2010. A problem here is that the effective sample size is constantly changing, furthermore it is never over 40 currencies. This is a small sample when compared to similar equity momentum papers. Over time the exchange rates of emerging currencies become available whereas others, for example due to the introduction of the euro, cease to exist. Additionally, over time less currencies are pegged to each other, all influencing the results. The paper aims to distinguish between systematic and unsystematic risk, compare momentum strategies to carry trades, investigate transaction costs and other sources of momentum returns, prove under-and over-reaction and examine the limits to arbitrage. In this paper we will focus on the section that compares currency momentum returns to carry trade. Menkhoff et al. suggest that excess returns in various asset classes may share a common source. However, the paper finds these returns are unrelated from the excess returns to carry trade strategies. Six carry trade portfolios are in fact examined, and they are created based on their lagged interest rate. It is found that a positive spread in lagged returns exists with an average excess return of around 15%.

Brunnermeier et al. (2009) investigate whether a relationship exists between the premiums earned in carry trade and the probability of a currency crash. Investment currencies, with relatively higher domestic interest rates, might be more prone to crash. This is explained in Brunnermeier et al. using the phenomena of negative conditional skewness. Many investors take long positions in these currencies and thereby increase the crash risk. Portfolios are created based on the domestic interest rates of eight countries. Namely, the Australian dollar, Canadian dollar, Japanese Yen, New Zealand Dollar, Norwegian krone, Swiss franc, British pound and the euro. The data runs from 1986 until 2006. Prior to 1999 the German mark is used as a proxy for the euro. Due to this, other currencies that turned into the euro are not taken into account in the evaluation. For example, the French franc is not used from 1990 to 1999, but papers published around the 1980's do include this currency as an important and influential currency. Additionally, the Australian dollar, New Zealand dollar and the Norwegian krone were not used in the 1980's, perhaps these currencies are only used because in 2009, the time the work was published, they were part of the G10 currencies.

A solution that is less frequently used is the Eurocurrency index. Works such as McCurdy and Morgan (1991) use the Eurocurrency index as a proxy for the exchange rate of the euro. Today the euro currency index is an arithmetic ratio of four major currencies that later became the euro. Their values

against the US dollar, British pound, Japanese yen and the Swiss franc. Prior to the introduction of the euro the German mark was used with the euro-mark exchange rate to be fixed on its 01.01.1999 value (S&P Global, 2017). This is another alternative method of dealing with the introduction of the euro that is less frequently used. Using this method in research may also be prone to survivorship bias as this method might be more likely to be selected in an ex-post perspective. An author prior to the announcement of the euro could have little incentive to use the euro currency index in their work.

3. Theoretical Framework

Covered interest parity states that the forward rate of a currency over a time period (T), is equal to the interest rate differential between two countries multiplied by the current spot rate. This satisfies a no arbitrage condition as buying a forward and short selling a currency would not yield risk free excess returns.

$$F_{t,T} = S_t * e^{(r_{d,t} - r_{f,t}) * T} \qquad (1)$$

Where $F_{t,T}$ is the forward rate between two currencies, thus the price at time t to receive 1 unit of foreign currency at time T. $r_{d,t}$ and $r_{f,t}$ are the domestic and foreign interest rates respectively. It is found in many studies including Jurek (2009), Frenkel and Levich (1975) and Burnside et al. (2011) that this theory frequently holds in very diverse data sets.

Under uncovered interest rate parity (UIP) the forward rate is an unbiased predictor of the future spot rate. If this holds risk neutral investors should be indifferent between buying foreign currency and investing in risk free assets, later converting back to their domestic currency, and entering a forward contract (Fenkel & Levich, 1975).

$$\frac{F_{t,T} - S_t}{S_t} = \frac{i_t - i_t^*}{1 + i_t^*} \qquad (2)$$

Where $F_{t,T}$ is the forward rate, S_t is the spot rate and $i_t$and i_t^* are the domestic and foreign interest rates respectively.

Many works have investigated the relation between currency returns and the forward premium (Hansen & Hodrick, 1980; Fama, 1984). Often finding that UIP does not hold and that currencies with a higher (lower) interest rate than the domestic interest rate are found to appreciate (depreciate). This finding indicates that investing in currencies with high interest rates and funding these

investments with currencies with relatively low interest rates may yield vary fluctuating but on average positive returns. This strategy is called the *carry trade strategy* (Menkhoff et al., 2012).

Many works have attempted to find justifications for the violation of UIP. Frenkel and Levich (1975) investigate whether in cases that covered interest parity does not hold this could be caused by transaction cost. It is found that if transaction costs are taken into account there should be no unexploited profit opportunities. Other works refer to these unexplained abnormal returns as forward premium puzzle (Fama, 1984; Bilson, 1981); Froot & Thaler, 1990); Bekaert, 1992; Engel, 1996; Bansal & Dahlquist, 2000). Due to the volatility (and other factors) investors suffer a high-risk exposure when investing in currencies, and should therefore be earning a higher return. However, literature has failed to precisely point out these risk factors. Many papers attempt to pinpoint how these risk premia can be calculated and justified. Menkhoff et al. (2012) forms portfolios based on the high and low interest rate countries. The highest interest rate quintile of portfolios was invested in and the lowest interest rate quintile was shorted. The volatility of returns was inspected to see if this rationalises the excess returns. The finding is that exchange rate volatility is indeed an explanatory factor in the large risk premia observed in the *forward premium puzzle*. It is also found that this relationship holds for other financial assets such as individual currencies excess returns, domestic corporate bonds, U.S. equity momentum, international bond portfolios and foreign exchange option portfolios (Menkhoff et al., 2012).

The return of a carry trade strategy can be calculated using the following formula:

$$R_{t,T} = i_t^* - i_t - \Delta S_{t+1,t} \qquad (3)$$

Where i_t^* is the natural logarithm of the foreign exchange rate, i_t is the domestic exchange rate and $\Delta S_{t+1,t}$ is the appreciation of the foreign currency. Defined as:

$$\Delta S_{t+1,t} = ln\ (S_{t+1}) - ln(S_t) \qquad (4)$$

Carry trade portfolios can be generated in various ways, as explained in the methodology section of the paper.

The returns to the strategy largely depend on the selected currencies. The theory of survivorship bias implies that the surviving stocks or currencies are used in research as they are still being traded. The ex-post investor knows which currencies will disappear. However, an ex-ante investor does not have this knowledge. Failing to account for this form of sample selection bias, caused by the disappearing and emerging of currencies, can influence academic literature and result in biased findings. It will be investigated whether the currencies that were important over the time of the sample period are

indeed used in an academic paper, or whether currencies are added or removed from the sample in an ex-ante perspective. As previously mentioned the research question is:

Is survivorship bias present in academic literature on currency carry trade?

As explained in the literature review, survivorship bias is an issue in many finance papers. Therefore, in the sample selection of currencies this could also be the case. Amin & Kat (2003) find that returns differ by up to 5% because of the bias in selecting funds. Hudson (2016) further supports this by finding that the excess returns earned in carry trade are due to multiple behavioural and selection biases including survivorship bias in the sample. Hudson claims that current datasets are selected based on current knowledge. Similar conclusions are drawn by Brown et al. (1992) and Carpenter & Lunch (1999), as further elaborated on in Section 2.1 of the literature review.

In order to qualitatively assess survivorship bias present in current studies, information regarding the sample choices of influential works form 1960 until 2017 needs to be collected. Based on an overview of influential currencies over time anomalies, where decisions appear to be made in an ex-post perspective, can be selected. This leads to the first hypothesis.

> *H1: Currencies selected in academic papers are determined by the influential currencies at the time of publishing.*

If data indicates that a paper uses a sample of currencies are influential at the time of publishing but not over the period investigated, this is an indication of potential survivorship bias. This type of sample selection may lead to the exclusion of influential currencies over the time of investigation. The time span covered should have an effect on the currencies used, rather than the time of publishing. The influential currencies at various points in time can be used to determine a sample of currencies adapted for survivorship bias. The answer to the first hypothesis consist of the currencies that ought to be used in survivorship bias free samples from 1960 until 2016 based on the data collected from academic papers. This data can be used as evidence in favour of H1, specifically pointing out papers that use samples that do not comply. This is the first step in answering the research question, namely if there are any studies in which survivorship bias appears to be present.

Secondly, an attempt will be made to quantify this survivorship bias. In order to do so, a study will be repeated twice, once with the original sample and once with a sample adjusted for survivorship bias (based on the findings of H1). This leads to the second hypothesis:

> *H2: The excess returns are significantly different with a sample that is adapted for survivorship bias.*

Grinblatt & Titman (1989) investigate survivorship bias in mutual funds and find that the returns are higher by about 0.5 percent when samples are adapted for survivorship bias. this finding is reinforced by Carpenter and Lynch (1999), who find that survival criteria for financial assets to be used in performance studies create survivorship bias as the negative returns to non-surviving assets are not included. The effect of this form of sample selection bias is found to be statistically significant for both stocks and mutual fund returns. These two papers, along with additional academic literature as presented in Section 2.4 of the literature review, indicate survivorship bias affect the performance of many financial assets. This may also be the case for currencies and is therefore tested under the second hypothesis.

As survivorship bias can be caused by the disappearing and emerging of currencies this hypothesis does not strictly limit itself to a one-sided test. After testing for significantly different returns the difference of the Sharpe ratios will also be tested for various academic papers.

H3: Sharpe ratios are significantly different when the sample is adapted for survivorship bias.

Adding currencies that were excluded in the original work to the sample and removing currencies that appear to be used based on an ex-post perspective will most likely affect the volatility as well as the excess returns. By evaluating a measure such as the Sharpe ratio a better insight into the effect of survivorship bias on the risk-return ratio found in academic literature. Furthermore, the Sharpe ratio is a commonly used method for evaluating returns whilst adjusting them for difference in risk.

4. Data

Data is obtained from Datastream provided by Thomson Reuters. The one- and three- month LIBOR rates are used as domestic and foreign interest rates. Not for all papers this data was available in those cases one-month interbank rates were used as a proxy, also through Datastream. The selected interest rates are as close to the original work as possible. Additionally, spot exchange rates and one-month forward rates were used for the following currencies: Australian Dollar, Austrian Schilling, Belgian franc, Canadian dollar, Danish krone, French Franc, Finnish markka, German marc, Italian lira, Irish pound, Japanese Yen, Korean won, Netherlands guilder, New Zealand dollar, Norwegian krone, Singapore dollar, Swedish krona, Swiss franc, British Pound, and the US dollar. The exact Mnemonics can be found in the Appendix section of this paper. The data is monthly and end of period from January 1986 until December 2007. In some works the authors use daily data, improving the estimation of

returns. However, for the purpose of investigating survivorship bias this is not necessary as returns are annualized either way.

The offered rates are consistently used throughout the analysis. This is because for these frequently traded currencies the transaction costs are low and the bid offer spread is small. If we were to investigate using more volatile currencies this assumption might not hold.

5. Methodology

5.1. Currencies Over Time

The first step in this paper is to examine carefully which currencies were included in samples and seen as major influential currencies from 1970 until 2015. For example, the currencies that are referred to as the G10 currencies change over time. The way a changing G10 is dealt with in academic works is investigated as many papers do not explicitly control for survivorship bias. By analysing currency papers in journals such as the American Economics Review, Journal of Financial Economics, Journal of International Economics, Journal of Political Economy and the European Economic Review. Important criteria in the selection of papers is the number of Google Scholar citations and the citations on the Web of Science. In each paper we also investigated the academic papers on which the authors base their work. Often also taking up these works in the analysis. The papers will not be limited to carry trade specifically as literature from earlier years covering topics such as uncovered interest parity, foreign exchange markets and other economics papers are also highly relevant.

Data about the publication date, years of data covered and most importantly the countries and currencies used was collected from all of the selected works. The findings are tabulated to create an overview of which currencies are used when. Additionally, it is investigated how the introduction of the euro is used as this is dealt with in various ways by authors. The comparison of historic currencies, samples and current choices of samples allows us to determine whether survivorship bias is an issue.

Lastly, we will also check how findings are presented, for example some works might choose to report two sets of results. One set of the period prior to the introduction of the euro and one set of results based on the entire time frame examined including the post euro period.

5.2. Creating Carry Trade Portfolios

There are two ways that are frequently used to create carry trade portfolios, either by creating currency pairs versus the US dollar. Each month the domestic interest rates of both currencies are compared and the currency with the lowest interest rate is the funding currency (short selling),

whereas the currency with the highest interest rate is invested in (buying), this is the carry trade strategy. This analysis is taken from a US perspective, however it is mentioned in works by various authors, including Jurek (2009), that performing the analysis from the perspective of the other nine countries leads to qualitatively comparable results (Jurek, 2009).

The second way in which carry trades portfolios are generated is by comparing all interest rates of the countries included in the specific analysis. *K* currencies with the highest interest rates are invested in (long) whereas the *k* currencies with the lowest interest rates become the funding currency (short). *K* is defined as a fixed number of currencies or calculated to be a percentage of the total amount of currencies used (Brunnermeier et al., 2009). Which of the two methods is selected depends on the specific paper that is replicated. Initially various works will be replicated, using similar data sets to recalculate the return to the strategies, this way we control for any small differences in data sets.

Other papers use alternative methods of carry trade, for example Burnside et al. (2011) compare forward rates to spot rates of 47 currencies versus the GBP. The currencies are then ranked based on forward premium (identical to ranking by interest differential as covered interest parity holds). Based on the ranks currencies are allocated to five portfolios in increasing order of forward premiums. With the lowest 20 percent in the first portfolio and the highest 20 percent in the fifth portfolio. The return of investing in portfolio 5 funded by portfolio 1 is also calculated.

The portfolios are rebalanced at the end of each month. Additionally, the trade is opened at the first date investigated and closed on the last day investigated. Under uncovered interest rate parity, we would expect the return to this strategy to be zero. However as frequently found in literature this is not the case.

5.3. Calculating Returns

The return in Equation (3) in the theoretical framework is earned when investor invests in a foreign currency. In some cases the foreign interest rate is below the domestic interest rate. In this case the foreign currency will be the funding currency and short sold. The return will therefore be the negative of Equation (3). Exchange rates are expressed in units of foreign currency per US dollar. To calculate the total return of this strategy per month the returns on all short positions are added to the returns on all long positions to calculate monthly returns. The average monthly returns (Equation (3) and Sharpe Ratios will be calculated for various papers using their specific portfolio strategy. The calculated returns can be used in a t-test to test for equality of means. If means turn out to be significantly different *H2* cannot be rejected. The returns will be tested for a normal distribution using a histogram, to check whether the assumption of normal distribution for a t-test is satisfied. If this

turns out not to be the case a non-parametric test Wilcoxon Rank Sum Test for equality of means will be more accurate. Lastly, the samples are tested for equality of variances in order to determine whether a pooled volatility can be used.

5.4. Portfolio Weights Assigned

Some papers use equal weights on all investment returns, however in other works weights are assigned to returns in various ways. For example, works such as Jurek (2009) assigns weights based on the absolute interest differential. The weight assigned to a currency's return is the interest rate difference between the investment and funding currencies, divided by the sum of all interest rate differentials. Investing relatively more in the currencies with the highest interest rate difference between the invested currency and the funding currency might yield higher returns as the returns are potentially larger when the difference in interest rates are bigger.

5.5. Quantifying Survivorship Bias

Secondly, the above methodology will be carried out using currencies that were regarded as influential in the first year of data for a specific paper, thus adapted for survivorship bias. For instance, the work of Jurek (2009) uses data from 1990 until 2007. This research will be replicated using a sample that was regarded influential in 1986 rather than the sample that is actually used by Jurek. The sample adapted for survivorship bias consists of influential currencies used in influential papers published during the time of data collection. This way it is possible to quantify the effect of survivorship bias. Currencies such as the French Franc, Japanese Yen, Swiss franc, British Pound, German mark can be added to or excluded from the sample, depending on the findings from the literature overview. The calculated returns and Sharpe Ratio can be compared to the returns and Sharpe Ratio when the original sample is used. Sharpe ratios are compared using the statistic developed by Memmel (2003). Instead of using a simple t-test with a pooled variance an asymptotic variance is used. The test statistic is calculated as follows:

$$z = \frac{\hat{S}h_i - \hat{S}h_n}{\sqrt{V}} \qquad (5)$$

Where V is the asymptotic variance of the Sharpe Ratio difference in the numerator, which is calculated as follows:

$$V = \frac{1}{T}\left(2\sigma_i^2\sigma_n^2 - 2\sigma_i\sigma_n\sigma_{ni} + \frac{1}{2}\,\mu_i^2\sigma_n^2 + \frac{1}{2}\,\mu_n^2\sigma_i^2 - \frac{\mu_i\mu_n\sigma_{ni}^2}{\sigma_i\sigma_n} \right) \qquad (6)$$

The test statistic can be compared against the critical z value in order to conclude whether the two Sharpe ratios are significantly different.

6. Results

6.1. Influential Currencies over Time

We investigated which currencies were used in academic literature published from 1960 until 2016. The findings indicate that the samples, selected currencies and time span covered, change significantly over time. The findings have been summarized in Figure 1. Intuitively, the euro is only used in studies starting in January 1999, as also seen in Figure 1. The scatterplot, logically, confirms that the Italian lira and French franc are not included in samples of post 2000's literature even though they are frequently used in the earlier years, specifically between 1980 and 1995. Rather than using the German mark as a proxy for the euro prior to 1999 the studies should be carried out using the actual influential currencies at the time studied. Based on Figure 1 a sample adapted for survivorship bias should include the French franc and Italian lira more frequently. Thus, the introduction of the Euro should not be a reason to exclude European currencies from a study's data set prior to 1999. As based on Figure 1 they were influential in an ex-ante perspective and therefore belong in the sample during this time span.

Secondly, the G10 is frequently used in an ex-post perspective. This is especially the case for publications after 2000. This results in the inclusion of currencies that were not actually influential over the time span of data sampled. The typical currencies found in literature (see Figure 1) are the Australian dollar, Norwegian krone, Swedish Krona, New Zealand dollar and in fewer cases the Danish Krone. These currencies are included in studies after 2000, even though at the time of data collection they were not influential. More specifically, from Figure 1 it seems that the Australian dollar is only frequently used in studies published from 2002 onwards, nevertheless it appears in the samples of Jurek, Menkhoff et al., Brunnermeier et al. and Burnside et al.; who as mentioned earlier use data sets starting from the 70's and 80's. This observation can also be made for the New Zealand dollar, which is only used in works published after 2006. Surprisingly, it is included in the work of Jurek and Brunnermeier et al. although data sets start in 1990 and 1986 respectively. This can also be observed for the Norwegian krone, used in works published from 2005 onwards, yet the data sampled starts in 1976. Similar to previous examples, it appears that since the Norwegian krone is included in the G10 it is used in research samples based on an ex-ante perspective. A similar observation can be made for the Swedish krona. This is also included in studies published since 2000, yet data collection was done at a time when the Swedish krona was not yet influential.

Figure 1: Selected Currencies in Academic Studies from 1960 until 2016.

The sample of Jurek (2009) can be adapted for survivorship bias to include the French franc and the Italian lira in the period of 1990-1999 and exclude the Australian dollar and the New Zealand dollar in these years. As evident in Figure 1, the Italian and French currencies were commonly used in 1990, and the New Zealand and Australian currencies are only included in studies published after the 2000's. the Italian lira is a particularly interesting case as it is frequently excluded. This could be due to the increasingly high Italian interest rates. This may have encouraged its exclusion in empirical works.

Making this adaptation to the work of Jurek and repeating the study therefore attempts to quantify the effect of survivorship bias. Similarly, the sample in work of Brunnermeier et al. (2009) should be adapted to exclude the Australian dollar and Norwegian krone prior to 1999 and include the French franc. This decision is based on Figure 1; as studies that were published in 1986 typically use this sample. Additionally, the G10 as it is used in 2006 includes the Australian dollar and Norwegian krone again, exactly as in the work of Brunnermeier et al. Therefore after 1999 the original Brunnermeier et al. sample suits the findings of Figure 1 and can be used.

To conclude, using Figure 1 the samples can be adapted for survivorship bias by removing the Australian Dollar, New Zealand Dollar, Swedish Krona and Norwegian krone prior to 1999, and including them after. The French franc, Italian lira and other EU monetary union currencies are replaced by euro after 1999, but can be included in studies prior to 1999. Based on the data presented in Figure hypothesis 1 it cannot be rejected; some currency sampling decisions appear to be made in an ex-post perspective. Survivorship bias could potentially play a role in the work of Jurek, Brunnermeier et al., Burnside et al. and Menkhoff et al. These findings require further investigation in order to verify if survivorship bias is indeed present. This finding makes Figure 1 a valuable finding regarding existing literature. Sections 6.2 and 6.3 attempt to statistically test and quantify these findings.

6.2. Effect of Survivorship Bias on Returns and Sharpe Ratios

The empirical investigations of the works of Jurek (2009), Brunnermeier et al. (2009), Burnside et al. (2011) and Menkhoff et al. (2012) lead to very similar results. In most cases the excess returns to the portfolio strategies used in the works was not statistically significantly different when the original and new samples were compared. Throughout this section a significance level of 5% will be used for statistical testing. When testing the Sharpe ratios of the original samples and the survivorship bias adapted samples, it can be seen that the ratios are often not statistically significantly different.

In the work of Jurek the returns turns out slightly higher when the sample is adapted for survivorship bias (Table 5). Only the returns of the portfolios weighted by interest rate differential were significantly different. This is mostly caused by the large volatility of the returns as indicated by the standard deviation of 0.024 and 0.013. Furthermore, Levene's test for equality of variances indicated that there was significant evidence to reject the hypothesis that the original and adapted sample had equal variances. The returns to an equal weighted portfolio strategy do not significantly differ between the original and adapted samples. In Jurek's work the Sharpe ratios of the equal weighted portfolio and an interest differential weighted portfolio are higher by 0.008 and 0.011 respectively. However, with t-statistics of -0.032 and -0.018 this difference is statistically insignificant (Table 5).

Adapting the sample of Brunnermeier et al. for survivorship bias causes a difference in returns for all three portfolio strategies. This difference, however, was close to zero and statistically insignificant (t-statistics of -0.971, -0.537, and -0.725) (Table 8). Furthermore, the Sharpe ratios of portfolios K=2 and K=3 reduced by an insignificant amount (t-statistics of -0.366 and 0.443 respectively). However, portfolio K=1's Sharpe ratio decreased by a statistically significant amount (t-statistic -2.021).

When the works of Burnside et al. and is adapted for survivorship bias the absolute value of difference in returns is around 0.004 and statically insignificant (t-statistic of 1.398) (Table 9). This finding was based on a Wilcoxon Rank Sum test. Frequency tables and scatterplots of the returns indicated that a non-parametric test had to be used as the normal distribution requirement for a t-test is not met (Figure 7 and 8). The non-parametric test for equality of means is further elaborated on in the Methodology section. The fact that Burnside et al. investigate using monthly data from 1976 until 2009, makes it plausible that the returns do not converge to a mean value, but rather follow another distribution. When testing for equality of Sharpe ratios between the original and adapted sample, the difference is found to be statistically insignificant (t-statistic 0.006) (Table 9).

The returns to the portfolios of Menkhoff et al. differ between -0.001 and 0.002, however these differences between the two samples are statistically insignificant (t-statistics of 0.027, 0.024, 0.304, 0.059, 0.104 and 0.081) (Table 12). The Sharpe ratios of the half the portfolios in Menkhoff et al.'s work increased whereas the other half decreased, both cases the results were statistically insignificant (t-statistics -0.002, 0.003, -0.036, -0.003, 0.006 and 0.002) (Table 12). Therefore in conclusion, no significant evidence exists to reject the null hypothesis that the returns and Sharpe ratios of the original samples and the adapted samples are equal. We therefore do not have significant evidence in favour of alternative hypotheses *H2* and *H3*.

6.3. Discussion

Finding that the returns are often not statistically significantly different indicates a limited influences of survivorship bias on the returns earned. However, testing this using a t-test makes the result dependent on both the average returns and the volatility of the returns. In some cases, for example Jurek (2009), the volatility of returns is very high; making it difficult to find significantly different results using this method. This also explains the decreasing Sharpe ratios in Jurek, Brunnermeier et al. and Menkhoff et al. (2012). Interestingly the returns on carry portfolios with a weight based on the absolute interest differentials have a statistically significantly different return, this could be due to a difference in risk compared to an equal weighted strategy.

The higher returns of the samples adapted for survivorship bias could be due to the currencies that are included in the sample. By examining the data set it is found that the interest rates and interest differentials are higher for the added currencies than for the replaced currencies. For example, the interest rates in France and Italy are higher than in Norway, Sweden and Denmark in the 1990's, yielding a high return when going long in these currencies (Figure 2 and 4). This could be one reason why higher average returns were found. Furthermore, it is also possible that the difference in interest rates is no longer fully represented in the change in exchange rate due to the expectation of the euro. The expectation of the euro could have discouraged trading in currencies like the French franc and Italian lira. In this case markets could fail to fully incorporate the difference in interest rates. However, whether or not and to what extend this holds is a difficult judgement to make in hindsight.

Furthermore, this finding could also be caused by the correlation of the added currencies. The G10 used in many studies is a very balanced and diversified set of currencies, with perhaps a relatively low combined volatility. When a sample is adapted to include more European currencies this reduces the diversification of the portfolio by adding two countries with strongly correlated interest rates as indicated in Figure 2. The correlation between these currencies increases the volatility of the returns, thus impacting the Sharpe ratios and the t-tests for difference of means. The announcement of a common European currency may also cause the interest rates of various European countries to converge and create correlations in the data sets. This converging creates a correlation between the currencies, increasing the volatility.

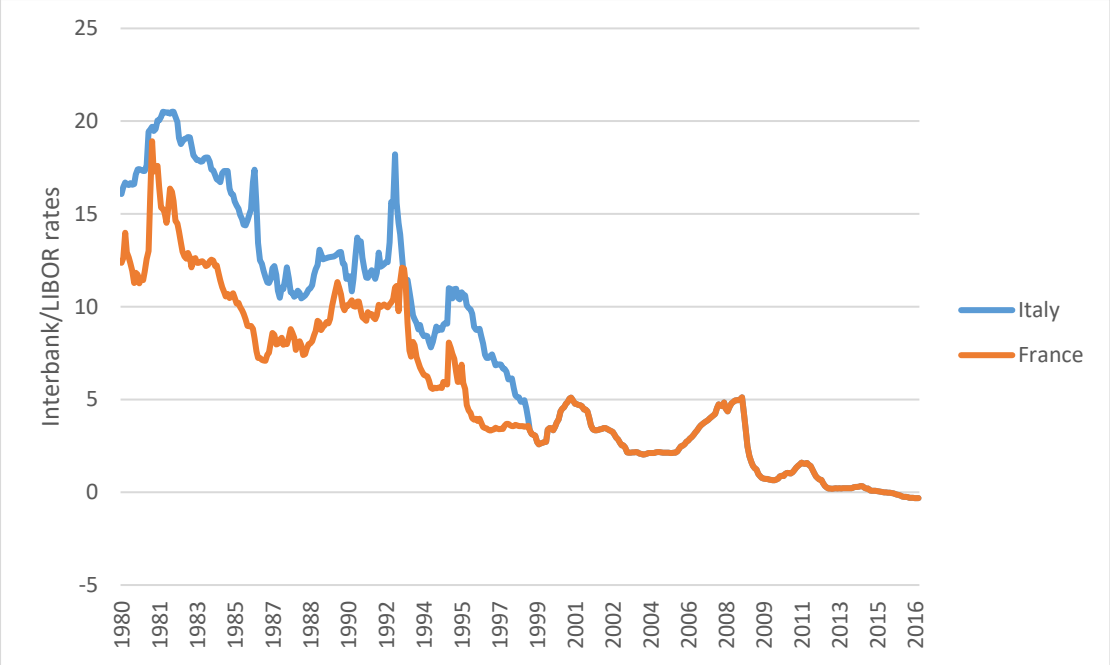

Figure 2: Interest Rates in Italy and France over Time.

Based on Figures 3 and 4 removing the Australian dollar and the New Zealand dollar reduces the diversification of the sample. As highlighted in Figure 4 the LIBOR in Australia and New Zealand are much less correlated than for example Italy and France prior to 2000 (Figure 3).

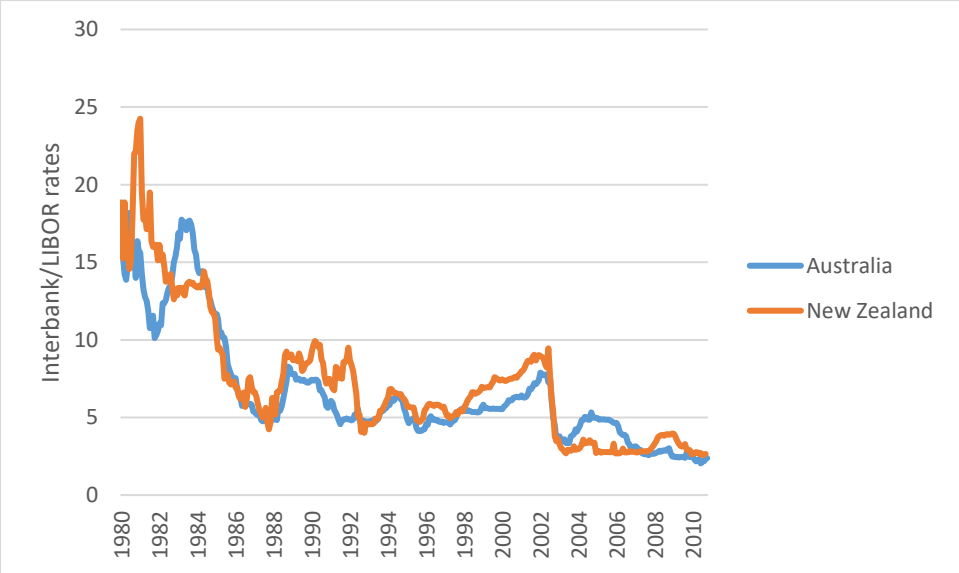

Figure 3: Interest Rates in Australia and New Zealand over Time.

Similarly, the Swedish, Norwegian and Danish interest rates are less correlated, when compared to Italy and France, prior to 2000; as depicted in Figure 5. Therefore, excluding them from the sample up until 2000 again reduces diversification and increases risk.

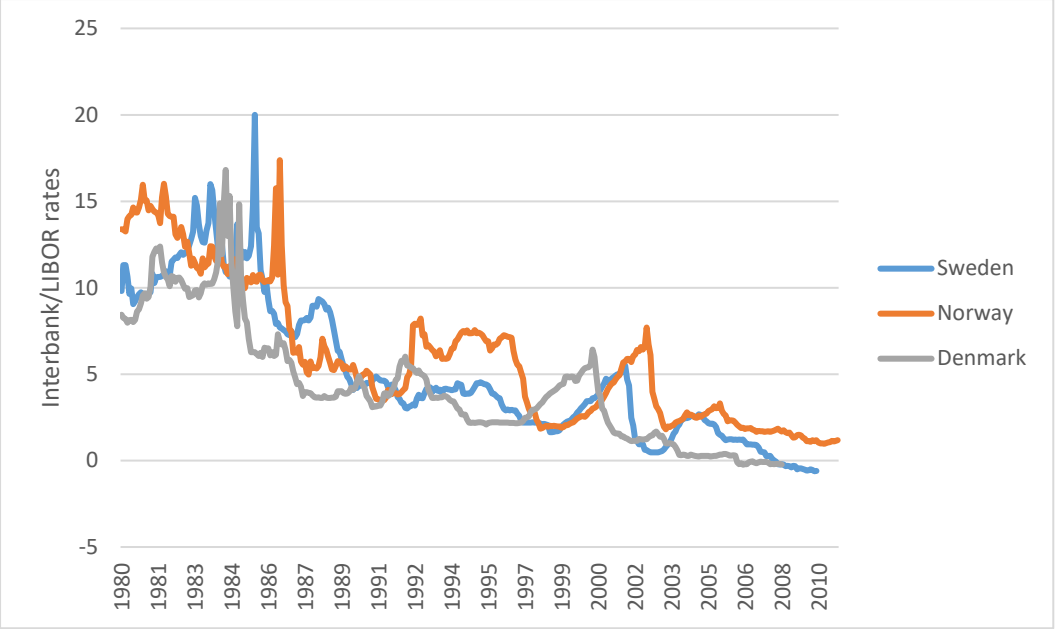

Figure 4: Interest Rates in Sweden, Norway and Denmark over Time.

Therefore in conclusion, the process of adding Italian lira and French franc from samples, and removing Swedish krona, Danish krone, Norwegian krone, Australian dollar and New Zealand dollar increases the risk of carry trade. Due to the increased correlation of interest rates the volatility of the returns may be higher. This is problematic in case of statistical tests as testing samples with high standard deviations leads to a smaller chance of rejecting the null hypothesis. Thereby, adapting samples for survivorship bias makes proving a significant difference in returns and Sharpe ratios challenging.

Another potential explanation for the statistically insignificant results could be the Treaty of Maastricht in 1992. The idea of a monetary union, a common currency and combined monetary policy may have resulted in the conversion of interest rates and exchange rates in Europe. Additionally, it may have affected exchange rates versus the US dollar and caused them to not fully adjust to interest rate changes. Lastly, the risk is increasing due to uncertainty regarding the outcomes of the treaty. It is challenging to find out how the treaty impacted the investment climate and macroeconomic confidence on an ex-post basis. It could mean increased interest in investing in the German mark, and less demand to invest in the more volatile currencies such as the Italian lira. But once again, this conclusion and its effect on investor behaviour is difficult to draw in hindsight.

6.4. Limitations and Further Research

There are several limitations to the research methods used in this paper. Firstly, using log exchange rates and log interest rates as an approximation when calculating log returns. This mathematical approximation holds when changes are only small, however currencies such as the Japanese yen and

the Italian Lira have relatively high exchange rate changes in the early years of the time span. The log approximation reduces the accuracy of the results here.

Some outliers were spotted in the data set. After cross checking the interest rates and the exchange rates obtained from data stream outliers were not removed from the sample. As the data is correct these returns represent the returns earned by investors who decided to invest in this currency. T-tests can be very sensitive to outliers as they affect both the standard deviation and the mean. This is the reason that a non-parametric test was used in some cases. The regular t-tests carried out used large samples, specifically a minimum of 240 months is investigated. Due to this sample size the central limit theorem holds, ensuring that outliers do not affect the reliability of the t-tests.

The sampling time of 240 month does have a limitation, namely that over such a long time frame the volatility of exchange and interest rates is very high. For example, the work of Burnside et al. use data from 1976 until 2008. Over this time many macroeconomic factors change affecting the currencies sampled in different ways. Removing and adding currencies to the sample may therefore incorporate many other effects besides potential survivorship bias. This makes is difficult to say with certainty that any changes are solely caused by survivorship bias. Furthermore, we found high volatility of returns, the above reasoning could be the cause of this. A suggestion for further research could therefore be to examine whether or not survivorship bias has an effect over a smaller time frame. This way the macroeconomic conditions are more stable over the time span of investigation. In order to make this investigation robust, this would require additional academic papers to be included.

Lastly, a limitation exists within the literature review. The data collected does not take into account underlying reasons for selecting a sample of currencies. Depending on the purpose of the investigation certain currencies may be in- or excluded from a sample. For example, papers investigating exchange rate volatility as an indicator of potential excess returns to carry trade, such as Menkhoff et al. (2012), may choose to exclude heavily correlated currencies and instead try to include a more diversified sample. Additionally, papers studying monetary policy may choose a very diversified sample of currencies, and not necessarily choose the most influential currencies at a given time. Other studies that investigate indicators of excess returns may be more likely to select high interest rate countries such as Brazil or Russia without further justifying this decision. Although this limits the research, incorporating this information is not possible as no information of these sample choices is given in the papers. In further research, this problem could be dealt with by screening additional literature to attempt to obtain more information about its sampling choices. A literature study of over 40 papers may not capture all the sampling decisions over such a long time frame. However, it may still be the case that this information is not available.

7. Conclusion

The investigation of the currencies selected in literature between 1960 and 2016 lead to a visual representation of authors choices. Based on Figure 1 it appears that in many works the sample choices are consistent with the data time span chosen. However, based on this literature study a few recurring sample choices appear to have been made in ex-post perspective. Firstly, currencies that were replaced by the euro ceased to exist and are sometimes excluded from studies. Typical currencies for which this was the case are the Italian lira and the French franc. Furthermore, a key finding is that the Norwegian krone, Swedish krona, Australian dollar and the New Zealand dollar are included in literature using data from the 1980's although they were only generally seen as influential post the year 2000. Based on this finding the works of Jurek (2009), Brunnermeier et al. (2009), Menkhoff et al. (2012) and Burnside et al. were replicated with both the original sample and a sample adapted for survivorship bias. This adaption did not lead to significantly different returns and Sharpe ratios. This is influenced by many different factors including high volatility of returns making the null hypothesis of equal returns difficult to reject. This result was also found for the Sharpe ratios.

To answer the research question, survivorship bias appears to be present in academic currency carry trade literature, when studying sample selection choices. However, when this bias is quantified and statistically tested the influence of the bias is not significant in most cases.

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9. Portfolio Returns and Sharpe Ratios

9.1. Jurek

	AUD	CAD	CHF	DEM	GBP	JPY	NOR	NZD	SEK
Mean	0.047	0.038	0.072	0.056	0.063	0.084	0.071	0.077	0.075
Std. Dev.	0.092	0.061	0.089	0.129	0.097	0.100	0.127	0.086	0.133
Min	-0.205	-0.101	-0.122	-0.136	-0.193	-0.155	-0.158	-0.178	-0.157
Max	0.331	0.220	0.438	1.378	0.411	0.542	0.919	0.281	0.853
Sharpe Ratio	0.514	0.638	0.816	0.435	0.644	0.842	0.558	0.896	0.559

Table 1: Return of individual currency pairs-Original 01.1990-12.2007

	Equal Weighted	Interest Differential Weighted
Mean	0.065	0.095
Std. Dev.	0.050	0.069
Min	-0.040	-0.019
Max	0.332	0.097
Sharpe Ratio	1.298	1.371

Table 2: Return of portfolio strategies-Original 01.1990-12.2007

	AUD	CAD	CHF	DEM	GBP	JPY	NOR	NZD	SEK
Mean	0.048	0.040	0.073	0.066	0.070	0.083	0.079	0.074	0.088
Std. Dev.	0.094	0.058	0.094	0.144	0.103	0.109	0.137	0.082	0.144
Min	-0.205	-0.097	-0.122	-0.131	-0.193	-0.155	-0.158	-0.178	-0.137
Max	0.331	0.220	0.438	1.378	0.411	0.542	0.919	0.281	0.853
Sharpe Ratio	0.508	0.701	0.775	0.458	0.683	0.758	0.580	0.904	0.614

Table 3: Return of Individual Currency Pairs - Original 01.1990-12.2002

	CAD	CHF	DEM	GBP	JPN	ITL
Return	0.040	0.073	0.066	0.070	0.083	0.129
Std. Dev.	0.058	0.094	0.144	0.103	0.109	0.261
Min	0.701	0.775	0.458	0.683	0.758	0.494
Max	-0.097	-0.122	-0.131	-0.193	-0.155	-0.130
Sharpe Ratio	0.220	0.438	1.378	0.411	0.542	2.858

Table 4: Return of individual currency pairs-New Sample 01.1990-12.2002

	Equal Weighted – New Sample	Equal Weighted - Original	Difference	Interest Differential Weighted – New Sample	Interest Differential Weighted - Original	Difference
Return	0.077	0.069	0.008 (1.049)	0.018	0.011	0.007 (13.276)*
Std. Dev.	0.074	0.055	0.024	0.022	0.009	0.013
Min	-0.083	-0.040	0.043	-0.010	-0.002	0.008
Max	0.729	0.332	0.397	0.285	0.063	0.222
Sharpe Ratio	1.037	1.259	-0.192 (-0.032)	0.811	1.323	-0.512 (-0.018)

Table 5: Return of Portfolio Strategies-Comparison 01.1990-12.2002

*= significant at 5% level

9.2. Brunnermeier et al.

	K=1	K=2	K=3
Return	0.001	-0.004	-0.004
Std. Dev.	0.004	0.013	0.014
Sharpe Ratio	0.201	-0.310	-0.274
Min	-0.017	-0.017	-0.061
Max	0.011	0.009	0.028

Table 6: Return of portfolio strategies-Original 01.1986-12.2006

	K=1 Original	K=1 New Sample	K=2 Original	K=2 New Sample	K=3 Original	K=3 New Sample
Return	0.000	0.001	-0.006	-0.005	-0.003	-0.003
Std. Dev.	0.007	0.005	0.011	0.008	0.014	0.011
Sharpe Ratio	0.040	0.182	-0.541	-0.604	-0.249	-0.313
Min	-0.020	-0.017	-0.017	-0.020	-0.017	-0.084
Max	0.021	0.011	0.005	0.026	0.010	0.032

Table 7: Return of portfolio strategies Original and New Sample 01.1986-12.2002

	K=1 Difference	K=2 Difference	K=3 Difference
Return	-0.001 (-0.971)	-0.001 (-0.537)	0.001 (-0.725)
Std. Dev.	-0.002	-0.003	-0.003
Sharpe Ratio	0.142* (2.042)	-0.063 (-0.366)	-0.064 (-0.443)
Min	0.037	-0.03	-0.067
Max	-0.021	0.021	0.022

Table 8: Return of portfolio strategies Differences: 01.1986-12.2002

*Significant at 5% value

9.3. Burnside et al.

	Old Sample	New Sample	Difference
Return	0.030	0.034	0.004 (1.398)[2]
Std. Dev.	0.043	0.049	0.006
Sharpe Ratio	0.695	0.705	0.010 (0.006)
Min	-0.031	-0.067	-0.098
Max	0.159	0.144	-0.015

Table 9: Returns of Equal Weighted Carry Trade Currency Pairs: 01.1976-06.2009

*Significant at 5% value

9.4. Menkhoff et al.

	P1	P2	P3	P4	P5	H-L
Return	-0.031	0.003	0.004	0.005	0.032	0.063
Std. Dev.	0.132	0.072	0.022	0.031	0.146	0.231
Sharpe Ratio	-0.231	0.035	0.173	0.152	0.222	0.272
Min	-0.676	-0.104	-0.086	-0.104	-0.111	-0.082
Max	0.189	1.213	0.098	0.366	2.215	2.027

Table 10: Returns of Equal Weighted Portfolios, Original Sample: 11.1983-07.2009.

[2] This is the test statistic of a Wilcoxon Rank Sum test, after inspecting the data, the distribution was not normal. As a result a non parametric test was used.

	P1	P2	P3	P4	P5	H-L
Return	-0.031	0.003	0.003	0.005	0.034	0.064
Std. Dev.	0.132	0.072	0.020	0.031	0.146	0.231
Sharpe Ratio	-0.233	0.037	0.163	0.150	0.230	0.278
Min	-0.676	-0.104	-0.073	-0.103	-0.104	-0.082
Max	0.189	1.213	0.098	0.366	2.215	2.027

Table 11: Returns of Equal Weighted Portfolios, New Sample: 11.1983-07.2009

	Difference P1	Difference P2	Difference P3	Difference P4	Difference P5	Difference H-L
Return	0.000 (0.027)	0.000 (0.024)	-0.001 (-0.304)	0.000 (0.059)	0.001 (0.104)	0.002 (0.081)
Std. Dev.	0.000	0.000	-0.002	-0.001	0.000	0.000
Shar-pe Ratio	-0.002 (-0.002)	0.002 (0.003)	-0.011* (-0.036)	-0.002 (-0.003)	0.008 (0.006)	0.007 (0.002)
Min	0.000	0.000	0.012	0.001	0.006	0.000
Max	0.000	0.000	0.000	0.000	0.000	0.000

Table 12: Returns of Equal Weighted Portfolios, Difference: 11.1983-07.2009

*Significant at 5% value

10. Figures

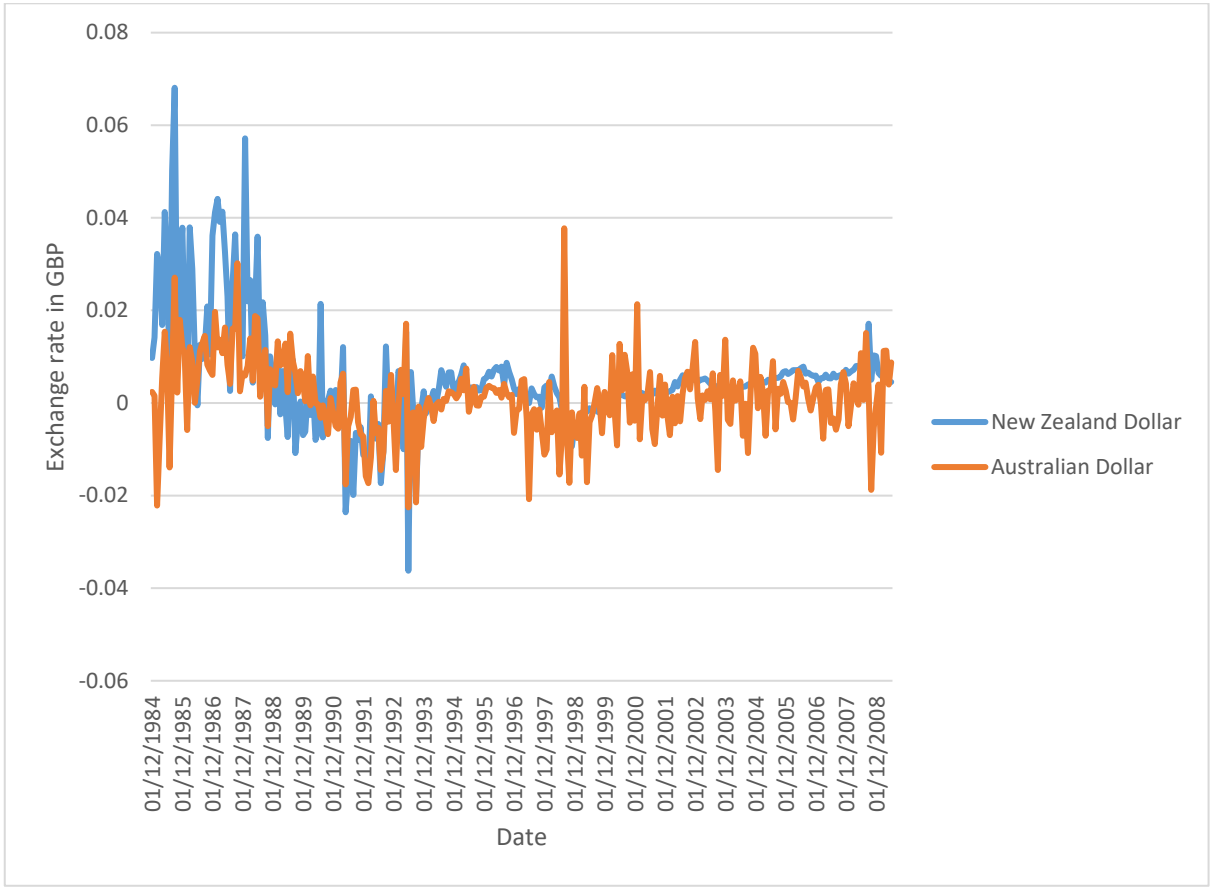

Figure 5: Exchange Rates of the Australian dollar and the New Zealand dollar over Time

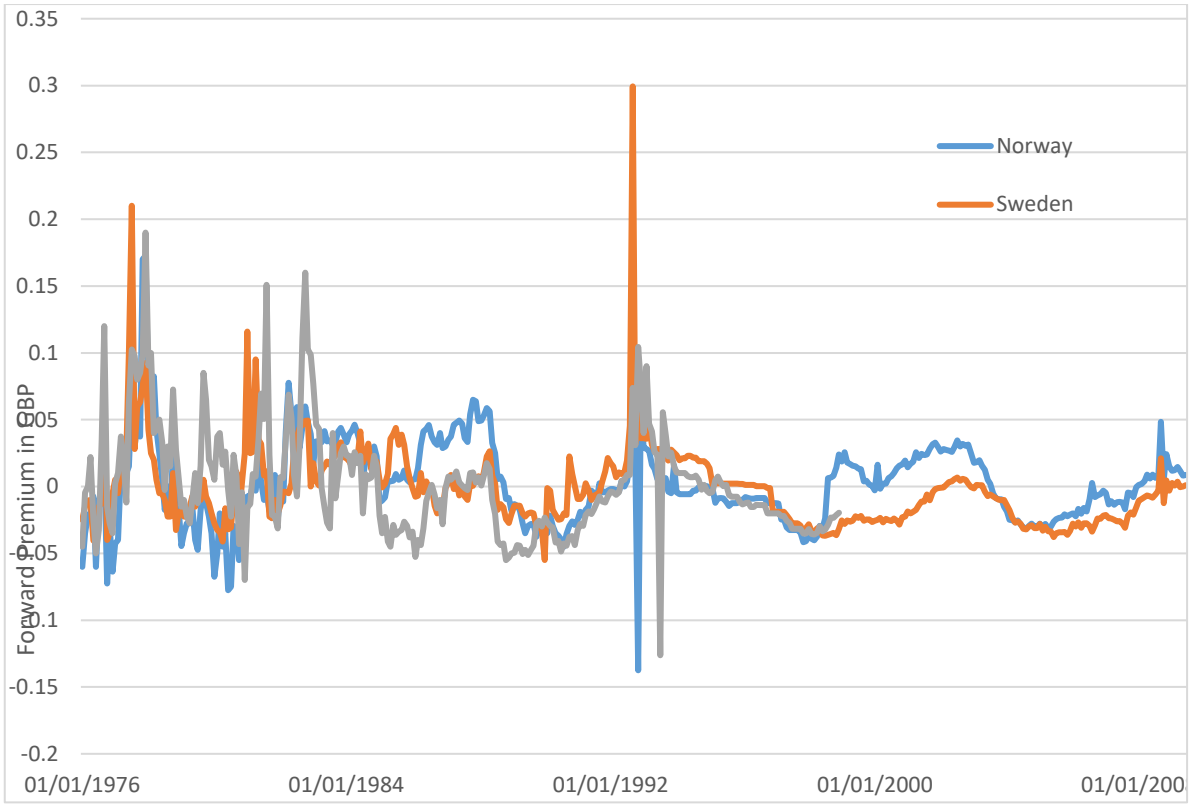

Figure 6: Forward premium Swedish krona, Norwegian krone and Danish krone over Time.

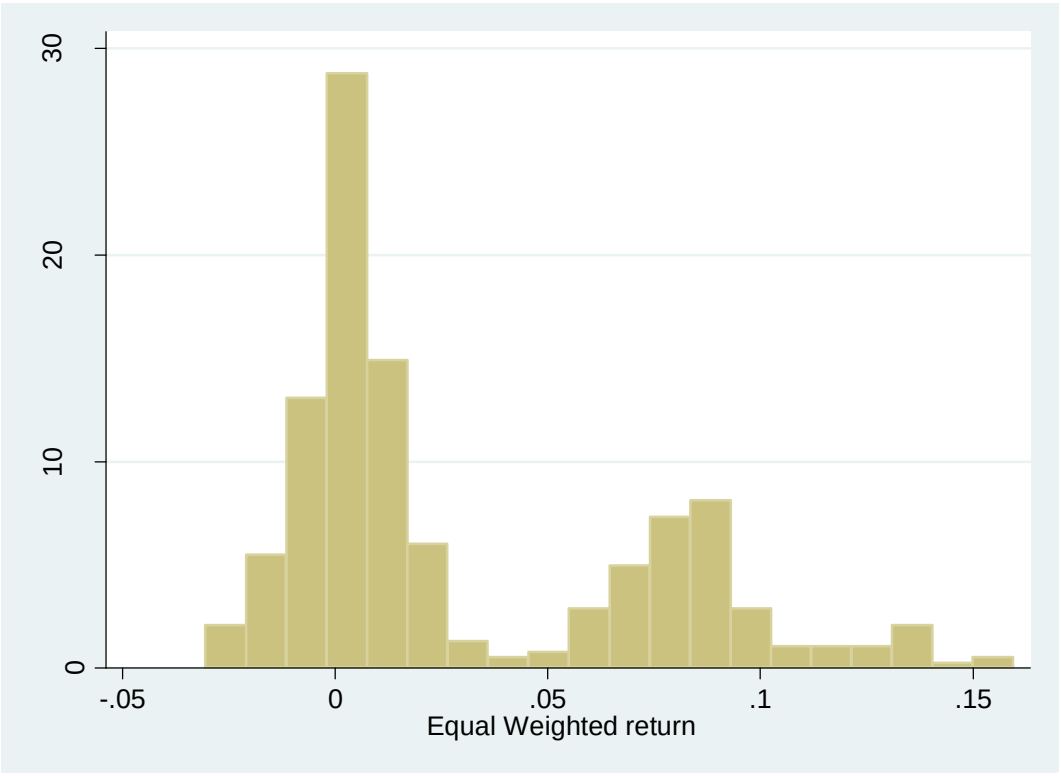

Figure 7: Histogram of Returns Equal Weighted Portfolio – Original Sample

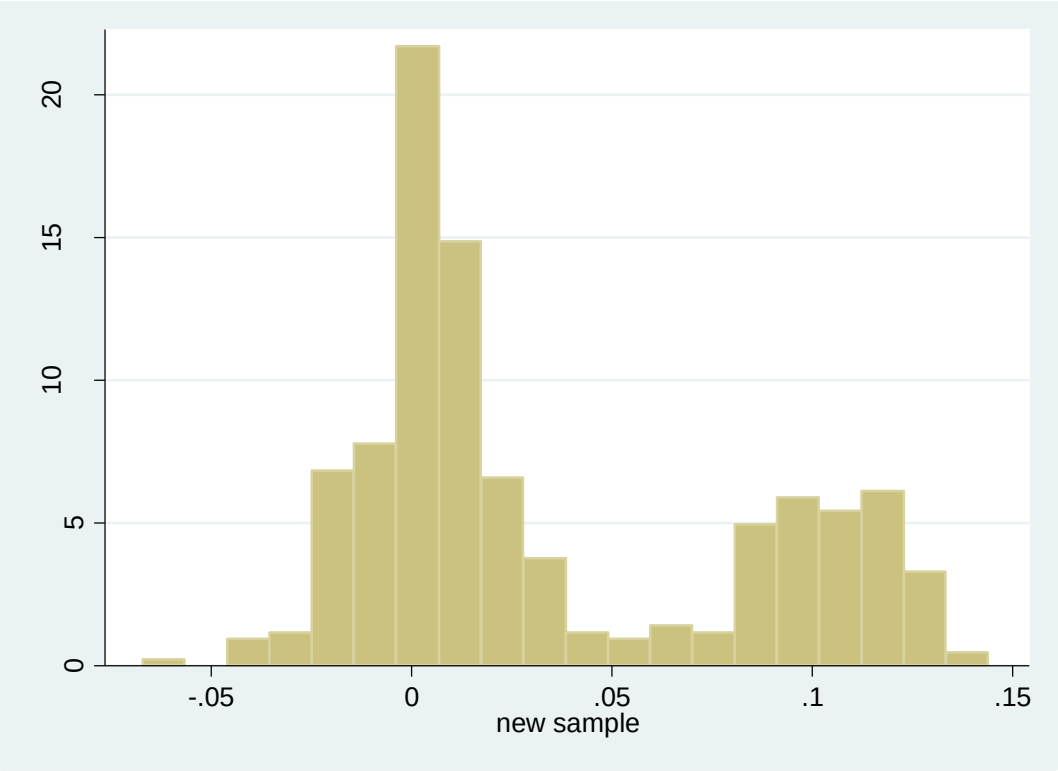

Figure 8: Histogram of Returns Equal Weighted Portfolio – New Sample

11. Appendix

11.1. Datastream Mnemonics

Spot Rates VS GBP	One- Year Forward Rates VS GBP
DANISHK	DANIS1F
NORKRON	NORKN1F
SWEKRON	SWEDK1F
SWISSFR	SWISF1F
IPUNTER	IPUNT1F
AUSTSCH	AUSTS1F
BELGLUX	BELXF1F
FRENFRA	FRENF1F
DMARKER	DMARK1F
ITALIRE	ITALY1F
GUILDER	GUILD1F
PORTESC	PORTS1F
SPANPES	SPANP1F
CNDOLLR	CNDOL1F
USDOLLR	USDOL1F
JAPAYEN	JAPYN1F

Table 13: Mnemonics Spot and Exchange Rates versus GBP 1976-2016.

Spot Rates	Forward Rates
BBGBPSP	BBGBP1F
BBCHFSP	BBCHF1F
BBJPYSP	BBJPY1F
BBCADSP	BBCAD1F
BBAUDSP	BBAUD1F
BBNZDSP	BBNZD1F
BBSEKSP	BBSEK1F
BBNOKSP	BBNOK1F

BBDKKSP	BBDKK1F
BBEURSP	BBEUR1F
BBDEMSP	BBDEM1F
BBITLSP	BBITL1F
BBFRFSP	BBFRF1F
BBNLGSP	BBNLG1F
BELGLU$	USBEF1F
FINMAR$	USFIM1F
BBIEPSP	BBIEP1F
BBHKDSP	BBHKD1F
BBZARSP	BBZAR1F
BBSGDSP	BBSGD1F
AUSTSC$	USATS1F
CZECHC$	USCZK1F
GREDRA$	USGRD1F
HUNFOR$	USHUF1F
INDRUP$	USINR1F
INDORU$	USIDR1F
KUWADI$	USKWD1F
MALADL$	USMYR1F
MEXPES$	USMXN1F
PHILPE$	USPHP1F
POLZLO$	USPLN1F
PORTES$	USPTE1F
SAUDRI$	USSAR1F
KORSWO$	USKRW1F
SPANPE$	USESP1F
TAIWDO$	USTWD1F
THABAH$	USTHB1F
BRACRU$	USBRL1F
EGYPTN$	USEGP1F
CISRUB$	USRUB1F
SLOVKO$	USSKK1F

CROATK$	USHRK1F
CYPRUS$	USCYP1F
ISRSHE$	USILS1F
ICEKRO$	USISK1F
SLOVTO$	USSIT1F
BULGLV$	USBGN1F
UKRAHY$	USUAH1F

Table 14: Mnemonics Spot and Forward Rates versus USD 1983-2016

One-Month LIBOR Rates	**Three-Month LIBOR Rates**
BBAUD1M	BBAUD3M
BBCAD1M	BBCAD3M
BBCHF1M	BBCHF3M
BBDEM1M	BBDEM3M
BBDKK1M	
BBFRF1M	FRINTER3
BBGBP1M	BBGBP3M
BBITL1M	ITINTER3
LBJPY1M	BBJPY3M
BBNZD1M	NZINTER3
BBSEK1M	
BBUSD1M	INTUSA
BBNOK1M	NWINTER3

Table 15: Mnemonics One-Month and Three-Month LIBOR/Interbank Rates.