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School of Business and Management
Master's Programme in Strategic Finance and Business Analytics

Master’s Thesis

Explanatory factors for cross-currency basis swap spreads

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ABSTRACT

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The failure of covered interest parity (CIP) has been an interesting topic for researchers and arbitrageurs to explore and to exploit after 2007. Evidence of the linkages between the failure of CIP on different cross-currency bases has been shown. The deviations in CIP cannot be explained purely by bank credit risk factors and liquidity management. Therefore, this thesis investigates the broad range of drivers behind the basis spreads and discusses how the results of the analyses could be exploited in global currency and interest markets.

The increased demand for U.S. dollars and the global regulatory tightening have resulted in a growing divergence in the monetary policies between ECB, FED and central banks of other developed countries, as well as reduced the global banks’ appetite for market-making and arbitrage trading. The thesis finds proof of the failure of the covered interest rate parity theory through multiple regression analyses. Furthermore, the research finds evidence of many significant factors affecting different basis spreads. The results suggest that cross-currency basis swap trades have offered arbitrage possibilities during 2008-2017 and, that the examined factors play an important role in modeling and calculating the fair value of the bases. The results support the previous quantitative researchers’ findings on the topic.

TIIVISTELMÄ

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Korkopariteetin epäonnistuminen on ollut mielenkiintoinen aihe tutkijoille ja arbitraasitreidereille tutkia ja hyödyntää vuoden 2007 jälkeen. Sen lisääntymisen ja koron- ja valuutanvaihtosopimuksen korkoeron välillä on havaittu paljon sidonnaisuuksia. Korkoeropoikkeamia ei voida selittää pelkästään pankkiriskitekijöillä ja likviditeetin hallinnalla. Tämän tutkielman aiheena on siis analysoida monia koron- ja valuutanvaihtosopimuksen korkoeroon vaikuttavia tekijöitä ja sitä, kuinka näiden analyysien tuloksia voitaisiin hyödyntää globaaleilla korko- ja valuuttamarkkinoilla.

Yhdysvaltojen dollarin kasvanut kysyntä ja globaalin regulaation tiukentuminen ovat johtaneet siihen, että rahapolitiikan erot Euroopan, Yhdysvaltojen ja muiden kehittyneiden maiden keskuspankkien välillä ovat kasvaneet. Samat tekijät ovat vaikuttaneet myös kansainvälisten pankkien halukkuuteen toimia markkinatakaajina sekä vähentäneet niiden arbitraasimahdollisuuksia. Tämän tutkimuksen tulokset löytävät todisteita korkopariteetin epäonnistumisesta käyttämällä regressiomalleja. Tutkimuksessa havaitaan paljon merkittäviä tekijöitä, jotka vaikuttavat koron- ja valuutanvaihtosopimusten korkoeroihin. Tulokset indikoivat, että vuosien 2008 ja 2017 välisenä aikana koron- ja valuutanvaihtosopimusten korkoeroa on hyödynnetty arbitraasitreidaamisessa ja, että valituilla muuttujilla on tärkeä rooli korkoeron käyvän arvon laskemisessa. Tulokset tukevat aikaisempien kvantitatiivisten tutkijoiden löydöksiä aiheesta.

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In Helsinki 19.6.2018

Timo Hyttinen

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ABBREVIATIONS

ASW	Asset swap spread mid
BOC	Bank of Canada
BOE	Bank of England
BOJ	Bank of Japan
CBOE	Chicago Board Options Exchange
CCBS	Cross-currency basis swap
CDS	Credit default swap
CIP	Covered interest rate parity
DFR	Deposit facility rate
ECB	European Central Bank
EIB	European Investment Bank
FED	Federal Reserve Bank
FX	Foreign-exchange
GC	General collateral
GCF	General collateral financing
GFC	Great Financial Crisis
IBOR	Interbank offered rate
IRR	Internal rate of return
LTRO	Long-term refinancing operation
OAS	Option-Adjusted Spread
OIS	Overnight Index Swap
O/N	Overnight
QE	Quantitative Easing
REPO	Repurchasing Agreement
SNB	Swiss National Bank
VIX	Volatility Index
VaR	Value-At-Risk
XCCY	Cross-currency
YTM	Yield to maturity

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1 Introduction

As stated by Zhu & Pykhtin (2007) before 2008, the standard practice in the banking industry was to mark derivatives portfolios to market prices without taking the counterparty's credit rating into account. This ended up in creating new flow trading models, because banks’ balance sheets could be expanded limitlessly in response to new flows hitting the swap trading desks. After the Great Financial Crisis (GFC), the flow model was switched to a more cost sensitive approach of balance sheet management. This meant for foreign-exchange (FX) derivatives that market and counterparty risk was priced in at all times, meaning that banks had to start applying greater credit charges to swap pricing.

The cross-currency swaps (CCS) have been showing fascinating changes in their spreads when it comes to floating rate of a currency compared to another currency. The cross-currency basis indicates the amount by, which the interest paid to borrow one currency by swapping it against another, differs from the cost of directly borrowing this currency in the cash market. The CCS basis, which is the basis spread added to, for example to, the USD London Interbank Offered Rate (Libor) when the USD is funded via FX swaps using the Japanese yen or the euro as a funding currency, has been widening globally since the beginning of 2014 (Arai et al., 2016). The spreads can be seen now as a deviation from the covered interest rate parity (CIP). It means that the interest rate differential between two currencies in the cash money markets should equal the differential between the forward and spot exchange rates. If this is not true, a trader can make riskless profit. (Sushko et al. 2016)

Empirical findings and recent studies have shown that CIP has not been perfect, thus traders have been exploiting the market possibilities for some while now. This thesis focuses on identifying and searching for the possible drivers that influence the CCS spreads. One simplified example is that if the dollar is cheaper in terms of yen in the forward market than calculated by CIP, then anyone able to borrow dollars at prevailing cash market rates could profit by entering an FX swap deal - selling dollars for yen at the spot rate today and repurchasing them cheaply at the forward rate at a future date. (Sushko et al. 2016) One of the most interesting financial market anomalies after the GFC has been the persistency on the CIP on cross-currency basis swaps (CCBS). As seen in Appendix 1, the basis spread has been spiking and widening against different currencies depending on the tenors. Before 2008, the basis was very narrow with close to none movement.

1.1 Scope, Objectives and Motivation for the study

The scope of this thesis is to study the international CCS market in different currency pairs. The pairs that will be used are CHF, GBP, JPY, and SEK against the euro and the dollar. Tenants that will be used are 3m, 2y and 5y. The timeframe will be from the beginning of 2007 until 18.12.2017 In this research, the Euro area banks will include Germany, Spain, France, Italy, Belgium and the Netherlands. All country banks are their own entities. Also, UK, US and Japanese banks will be included in the research scope.

The motivation for the study comes from the urge to understand the basics on how the financial markets operate in the short and long-term funding world and what are their modifications to the CCBS world. The object of the paper is to build a cross-currency basis spread model that takes into account different variables. The final output should give analysis for different currency pairs and, how well the models mimic with the historical CCBS spreads' data. Also, the models should give some indications on what are the most important factors that affect the spreads as well as the timing of the funding. In this thesis, timing means for example that companies or banks need more funding before quarterly statement announcements, so that they can adjust their balance sheets accordingly to their current or future funding needs in different currencies. One objective is to research on how credit and liquidity risk of underlying money market rates in different currencies, as well as supply and demand imbalances influence the CCBS spreads. To test the variables in the models, multiple regression models are created to test and explain their importance in different situations.

1.2 Research questions and the structure of the study

The research questions can be formulated as:

1. What are the factors that widen or reduce the CCBS spreads in different currency pairs and tenors?
2. How credit and liquidity risk as well as supply and demand imbalances of underlying money market rates in different currency pairs impact CCBS spreads?
3. Has there been possibilities for a trader to exploit arbitrage opportunities by using CCBS between 2007 and 2017?

The thesis consists of six sections. The introduction is followed by theoretical background in which previous studies are explored. Also, the potential determinants of the basis spreads are discussed. In addition, the theory behind using CCBS is reviewed. In the third section, the data and research methodology are opened. Results and conclusions summarize the key findings of analyses and give suggestions for further research, followed by a final summary that wraps the whole paper.

2 Theoretical background

First, a literature review is presented, in which previous results of studies are summarized. Then the basics of FX and XCCY basis swaps are demonstrated. After that different potential drivers of XCCY basis are introduced and explained in detail using examples and reflecting them to previous literature. As De Courcel (2015) illustrates in the figure below, different periods lead to different drivers for the 5y XCCY basis.

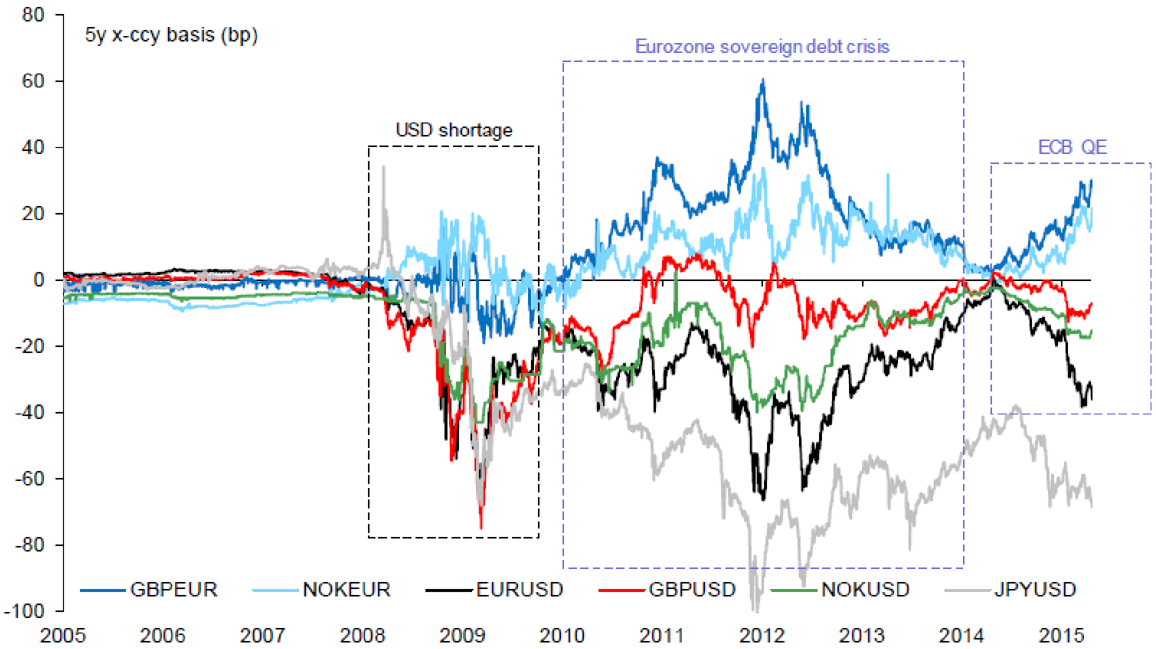

Figure 1. Different times are driven by different factors for different XCCY basis. (Source: De Courcel, 2015).

Between 2008-2010 the GFC drove banks to a situation, where there was a huge USD shortage on the market. From 2010 to 2014, Europe suffered from the sovereign debt crisis where Greece, Ireland, Portugal, Spain and Italy played an infamous role. Lastly, in 2014 ECB started the Quantitative easing (QE) program where the aim is to use expansionary monetary policy, the idea of the program is that ECB buys predetermined amounts of government bonds or other financial assets in order to stimulate the economy back to the growth track. The QE is still ongoing today.

2.1 Literature review

Covered interested parity is said to be a condition, where is no arbitrage when identical assets in two different currencies should be equal once the currency hedging cost is taken into account. Sushko et al. (2016) demonstrate in their paper that the CIP deviations are closely associated with the demand to hedge USD forwards. They note that fluctuations in FX hedging demand matter because committing the balance sheet to arbitrages can be expensive. With limits to arbitrage, CIP arbitrageurs charge a premium in the forward markets for taking the other side of FX hedgers' demand in proportion to their balance sheet exposure. Sushko et al. (2016) study CIP violations in non-crisis environment, stressing the combination of hedging demand and tighter limits to arbitrage. Their findings include a close empirical relationship between measured FX hedging demand and XCCY basis as well as acknowledge the arbitrage opportunities by banks and bond issuers in various currencies. Du et al. (2016) conclude that the covered interest parity arbitrage cannot be explained away by credit risk or transaction costs. According to the study, the basis is correlated to interest rates and monetary policy shocks. The arbitrage is related to balance sheet costs from quarter-end anomalies and IOER-Fed funds. The interest rate on excess reserves (IOER) rate gives the Federal Reserve an additional tool for the conduct of monetary policy.

According to a review by Arai et al. (2016) XCCY basis is the basis spread added mainly to the U.S. dollar London Interbank Offered Rate (Libor) when the USD is funded via FX swaps using yen or euro as a funding currency. The basis has been widening globally since the beginning of 2014. This development is driven by:

- Increased demands for U.S. dollars resulting from a divergence in the monetary policy between the U.S. and other advanced countries,
- global banks' reduced appetite for market-making and arbitrage due to regulatory reforms, and
- the decrease in the supply of U.S. dollars from foreign reserve managers/sovereign wealth funds against the background of declines in commodity prices and emerging currency depreciations.

Pinnington & Shamloo (2016) concentrate on behavior of the basis when the Swiss National Bank abandoned the currency peg in January 2015 discovering reductions in FX market liquidity. Akram et al. (2008) document that in the pre-crisis period CIP deviations on average lasted from 30 seconds to less than four minutes. Wong et al. (2016) focus on the relationship between CIP deviations in calm market situations and the counterparty and liquidity risk premia in money market rates. According to Iida et al. (2016) return spreads have replaced measures of banks' creditworthiness as drivers of CIP deviations in JPY/USD and JPY/EUR pairs. Avdjiev et al. (2016) acknowledge a link between the US dollar exchange rate and XCCY basis, where the former relates to the shadow price of bank leverage. Ivashina et al. (2015) demonstrate a model, where CIP deviations can arise when banks move part of their funding from wholesale funding markets because of default risk premia.

2.2 Supply and demand of FX

Foreign exchange markets play a vital role in financial markets. In 2013, the Triennial Central Bank Survey of Foreign exchange and OTC Derivatives Market Activity reported statistics on the amount of currencies traded daily with an average of $4 trillion traded. This was divided between $1.490 trillion traded spot transactions, $475 billion in outright forwards, $1.765 trillion in FX swaps, $43 billion in currency swaps, and $207 billion in options and other FX products. (BIS 2013)

2.2.1 Exchange rates

According to De Courcel (2015), there can be seen a link between exchange rates and the XCCY basis, as well as between funding cost differentials and the basis. There is a natural symbiosis with fluctuations in FX and monetary policy rate differentials. For example, a widening in EURUSD XCCY basis means that one needs to pay less interest to borrow euros, reflecting a diminished cost of funding in EUR versus USD. As seen in Appendix 2, the correlation between for example EURUSD spot rate and the 5y XCCY basis after 2007 shows general movements of the EUR in the currency and in the basis simultaneously. Same goes for AUDUSD currency pair and in the 5y XCCY basis. Hedging activity can be seen as a big contributor because a downward move in the EURUSD FX spot typically triggers purchase orders in FX forwards where EUR is bought by corporates as a hedge. In the end, this leads to a situation where dealers hedge themselves through FX or XCCY swaps, receiving the basis. After the GFC happened, there is nowadays a need to post collateral on XCCY basis swap contracts.

2.2.2 FX swaps and CIP

Baba et al. (2008) determine an FX swap agreement is a contract in which one party borrows one currency from, and simultaneously lends another to, the second party. Each party uses the repayment obligation to its counterparty as collateral and the amount of repayment is fixed at the FX forward rate as of the start of the contract. Therefore, FX swaps can be seen as FX risk-free collateralized borrowing and lending. The figure below demonstrates the fund flows involved in a EURUSD FX-swap. At the beginning, A borrows X-S USD from and lends X EUR to B, where S is the FX spot rate. At maturity, A returns the X-F USD to B and B returns X EUR to A, where F is the FX forward rate as of the start of the contract.

Figure 2. FX swap contract. (Source: Baba et al., 2008).

As explained earlier, an FX-swap can be explained as a contract in which one party borrows one currency from and at the same time lends to a second party at the spot rate S_t^A in f.ex. USD per foreign currency. The amount borrowed is repaid at the pre-agreed FX forward rate $F_{t,m}^B$ at maturity m. When CIP is strong, the relationship between FX spot and forward rates can be shown as below for example with two different Libor interest rates (Sushko et al., 2016):

$$F_t^B = S_t^A\left(\frac{1+r_t}{1+r_t^*}\right) \qquad (1)$$

Where f_t^B = forward bid rate (maximum price that a buyer is willing to pay) for foreign currency in USD

S_t^A = corresponding spot ask exchange rate (minimum price that a seller is willing to sell)

r_t = USD on-shore rate

r_t^* = foreign on-shore rate

FX swaps can be viewed as collateralized borrowing and lending. An FX swap is profitable when borrowing in USD and investing in EUR if

$$\frac{F_{t,m}^B - S_t^A}{S_t^A} > r_{t,m} - r_{t,m}^*$$

Where the difference between $r_{t,m}$ and $r_{t,m}^* + \frac{F_{t,m}^B - S_t^A}{S_t^A}$ forms the basis. Under the covered interest rate parity, (1) must hold true, otherwise there will be an arbitrage opportunity.

2.2.3 Cross-currency basis swaps

A cross-currency basis swap agreement is a contract in which one party borrows one currency from another party and simultaneously lends the same value, at current spot rates, of a second currency to that party. Figure 3 below illustrates the flow of funds involved in a EURUSD XCCY basis swap. At the beginning, A borrows X-S USD from and lends X EUR to B. During the contract term, A receives EUR 3m Libor+α from and pays USD 3m Libor to B every three months, where α is the price of the basis swap. The price is agreed between counterparties at the start of the contract. When the contract expires, A returns X-S USD to B and B returns X EUR to A, where S is the same FX spot rate as of the start of the contract. (Baba et al., 2008)

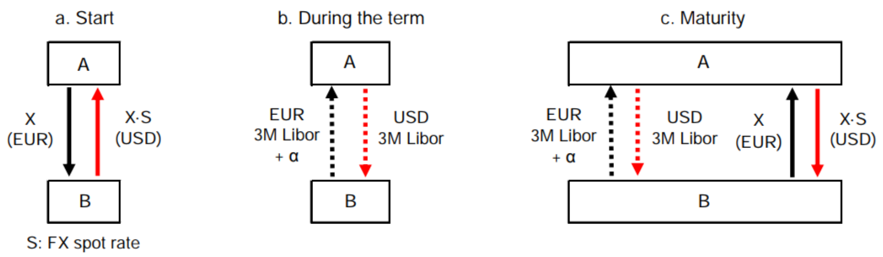

Figure 3. Cross-currency basis swap contract. (Source: Baba et al., 2008).

When entering into a CCBS contract, counterparties can temporarily transfer assets or liabilities in one currency into another currency. The basis spread is therefore the cost associated with temporary swapping of two currencies. Short term rates in different currencies reflect different credit and liquidity risk, which are partly transferred into a spread over one leg of the XCCY basis swap. As seen in Appendix 3, the shape of the term structure as of 20.9.2017 in the basis spread changes over time. Term structures are the foundation for many financial instruments and for their pricing. Arbitrageurs exploit differences in interest rate and FX term structures to earn substantial profits. As Sushko et al. (2016) point out, contrary to an FX swap, which is priced off of the forward exchange rate, a CCBS is priced off the respective Libor rates. One counterparty pays USD Libor +/- the basis $b_{t,m}$ for borrowing USD in exchange for its currency for a period m. Cross-currency basis swaps tend to be longer-term and are mostly free from FX risks.

Some cross-currency swap spread drivers are more significant for short term maturities and other drivers describe better long maturity XCCY swaps. Short end spreads, for example FX swaps appear to be more influenced by Interbank Offered rates' (IBOR) fixings and credit or liquidity premium in IBOR rates, while the long end can be seen more sensitive to supply and demand for assets in foreign and domestic currencies. The long maturity currency swaps have been less volatile than short maturity currency swaps. Long maturities have the tendency to be driven by the capacity of the market to facilitate swapping of the cross-border bond issuance. The capacity is affected for example by regulation, market size or liquidity from investors and issuers. (Baran & Witzany, 2017)

2.2.4 Pricing cross-currency basis swaps

Chang & Lantz (2013) state that cross-currency basis swap reflects the difference between the funding basis of the two currencies, where the funding basis is defined as the spread between the rate at which an investor can expect to borrow in a given currency and at that currency's benchmark rate. Determining the fair spread on a CCBS is easiest when a liquid forward FX contract is traded. For the pricing of CCBS, a FX forward rate and forward projections of each floating rate to be exchanged out to the swap maturity, are needed. Forward rates are calculated from the nominal swap curve in each currency.

Because principals are exchanged, CCBS can be seen as the exchange of two bonds: one denominated in the home currency and paying the home currency's floating rate, and the other denominated in the foreign currency, paying the foreign currency's floating rate plus the variable spread. The principals of the two bonds are set equal in the beginning, so exchanging them is fair if they yield the same. The yield to maturity (YTM) is then calculated to each bond by adjusting the internal rate of return (IRR) on the foreign bond by the foreign currency's appreciation implied by the FX forward. The fair spread of the CCBS is the spread that, when applied to the foreign bond's cash flows, results in the two bonds having the same YTM. An example of this can be seen in table below.

Table 1. EURUSD CCBS pricing as of 22.2.2013. (Source: Chang & Lantz, 2013).

					Spread (bps)	-25
Cash Flow Date	**Accrual Start Date**	**Fwd 3m LIBOR**	**Fwd 3m EURIBOR**	**EURIBOR + Spread**	**USD Cash Flow**	**EUR Cash Flow**
26-Feb-13					(1,000,000)	759,503
28-May-13	**26-Feb-13**	0.288	0.218	-0.037	728	71
27-Aug-13	**28-May-13**	0.283	0.190	-0.065	714	125
26-Nov-13	**27-Aug-13**	0.321	0.259	0.004	810	-8
26-Feb-14	**26-Nov-13**	0.348	0.310	0.055	1,000,888	759,609
			YTM		**0.31%**	**-0.01%**
			EUR Forward Appreciation			**0.32%**
			All-in YTM		**0.31%**	**0.31%**

The internal rates of returns are calculated on a USD floating-rate bond of $1M notional, and a EUR bond that pays Euribor + spread on the equivalent $759k notional. The adjusted IRR is found on the EUR bond on a level where the forward FX market expects EUR to appreciate 32bps. Then the spread is set so that the adjusted IRRs on each leg are equivalent. The -25 bps spread is equal to market pricing on 22.2.2013. The calculations suggest that FX forwards and CCBS are inherently linked, with one implying the other assuming the markets are liquid. Liquidity in FX forwards vanishes after 2y maturities in reality, whereas longer CCBS remain observable. Therefore, less than 2y maturing CCBS are generally implied from the FX forward market and longer maturing CCBS are used to back into FX forwards of longer maturities.

2.2.5 Why use cross-currency basis swaps?

Credit, liquidity as well as supply and demand forces influence XCCY basis spreads. These spreads are influenced by the ability and conditions of funding directly in a single currency, and thus by supply and demand for cross-currency financing. As stated by De Courcel (2015), CCBS can be used by e.g. supranations, agencies, corporates, and financial institutions for:

- issuing bonds or other assets in a foreign currency with restoration of the proceeds to the domestic currency,
- diversification,
- to find more advantageous funding costs,
- financing assets in foreign currencies that are used by entities with limited deposits in a foreign currency,
- investing in foreign currency bonds which are more popular in a very low rate environment when investors seek for non-traditional instruments to enhance their portfolio return
- for better liquidity: below one year maturities, FX swaps are more common but beyond that, the CCBS market is more liquid
- hedging currency risk.

In 2012, European investment bank (EIB), whose funding needs are in EUR, issued a 7y USD benchmark bond at Asset Swap spread mid (ASW) + 65bps. At the time, the 7y EURUSD XCCY basis was quoted at -40bps. By issuing in USD, XCCY swapped back to EUR, and EIB sold a 7y bond at an estimated cost of EUR ASW+25bps excluding execution costs. A 7y EIB benchmark bond denominated in EUR was trading at ASW+56bps on the same day. Another similar case is, if a USD-denominated bank borrowing in FX-markets swaps back the exposure to USD through the basis swap markets. US banks can issue bonds denominated in CAD, called Maple bonds, to allow Canadian investment without exposing debt holders to currency risks. The bank can use USDCAD basis swaps to transform most of its liability back into USD. For example, if a US company issued CAD $1bn notional of 2-year Maple bonds with a floating rate of 3m CDOR+100bps, it could then switch the CAD liability, both the principal and the coupon, to USD by receiving the spread in a 2-year USDCAD basis swap (-7bps), e.g. receiving the CAD leg and paying the USD leg. The effective currency exposure in CAD would now be limited to 107bps of CAD $1bn instead of the entire principal and interim interest payment. This will result in a liability of principal of USD 978mil, coupon of 107bps * $1bn CAD and 3m Libor ($978mil). This can be seen in on Figure 4 on market levels of 22.2.2013.

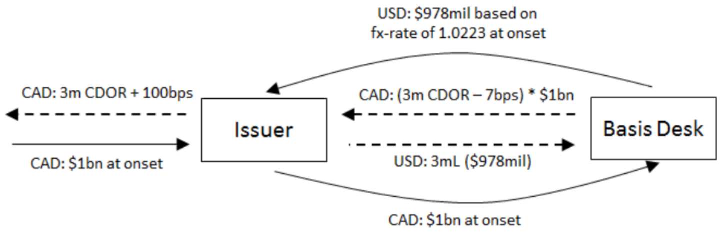

Figure 4. Swapping a CAD liability to USD. (Source: Chang & Lantz, 2013).

An American issuer can get cheaper USD funding in the Japanese yen markets with the help of the USDJPY basis swap. An issuer can first raise JPY funds and then swap the exposure back into USD with a CCBS. If on 28.9.2007 a US pharmaceutical company needed $500 million for five years, it could have raised the funds in the Japanese yen market by issuing a Samurai bond at 3m JPY Libor+45bps. The rate for the same size issue and similarly rated issuer in the US markets was around 3m Libor + 68bps. The US company could then swap the JPY exposure back into USD by using a 5-year USDJPY basis swap with a 3.75bps spread, resulting in a funding rate of 3m Libor+41.25bps, thereby providing almost 27bps cheaper funding than raising the same amount in the local USD market. Figure 5 below shows the flows of funds. (Chang & Lantz, 2013)

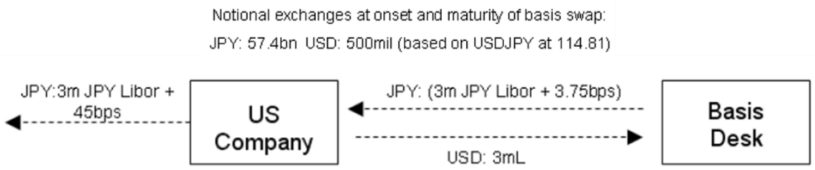

Figure 5. Using a CCBS to exploit the Samurai market. (Source: Chang & Lantz, 2013).

The lower the CCBS spread where one leg is in USD, the lower the interest rate an investor is willing to accept in return for USD-denominated funding. Therefore, the CCBS spread captures market perceptions of funding risks in the foreign currency. For example, if euro credit risk were to rise substantially, there could be a significant move for a lower EURUSD CCBS spread. Actually, this happened during the sovereign debt crisis of 2010 and 2011. If European funding concerns reoccured, driving the demand for USD funds up versus EUR, funds could be gathered by lending EUR and borrowing USD through a EURUSD basis swap. This mechanism can be seen in Figure 6 (LHS). If this would materialize, the spread would decrease further and the position could be unwound with a profit by borrowing EUR and lending USD in another basis swap with the same maturity.

If an investor on 22.10.2010 thought that there was potential for funding concerns in Europe to resurge, the investor could have entered into a short position in 1y EURUSD CCBS spread, by borrowing USD and lending EUR. On 21.1.2011, after three months, if the investor had closed the trade based on the view that the situation in Europe was stabilizing again, the investor would have gained around 10bps (with the 9m EURUSD CCBS spread at -36bps) as shown in Figure 6 (RHS).

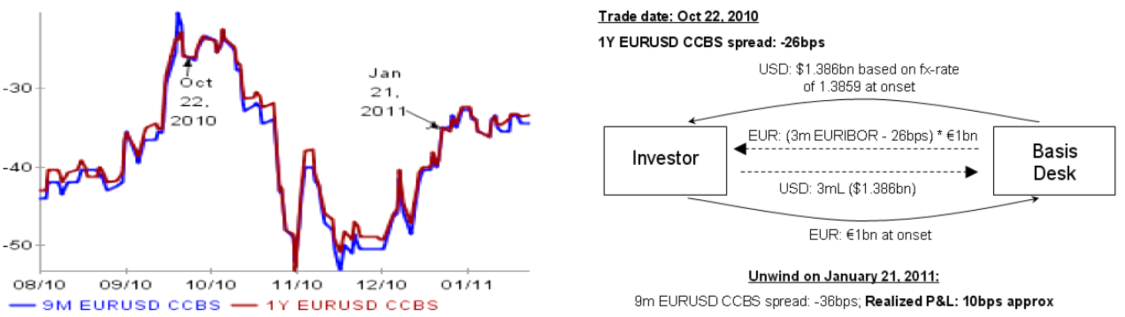

Figure 6. Funding concerns push down EURUSD CCBS spreads (LHS). Using CCBS to express view on funding stresses (RHS). (Source: Chang & Lantz, 2013).

Fast money clients as well as hedge funds are increasingly expressing speculative interest through either outright or convergence trades in CCBS. An example of a convergence opportunity has been found between EURUSD and CHFUSD basis swaps. In the past, the two XCCY basis tend to trade closely, as pointed out in Figure 7. The EURUSD basis has rebounded sharply as European financial stress improved while CHFUSD basis lagged due to issuance activity. As a convergence trade, investors received 5y EURUSD basis and paid 5y CHFUSD basis and looked for the dislocation to normalize either with renewed funding stress in Europe or a slowdown in such issuance activity.

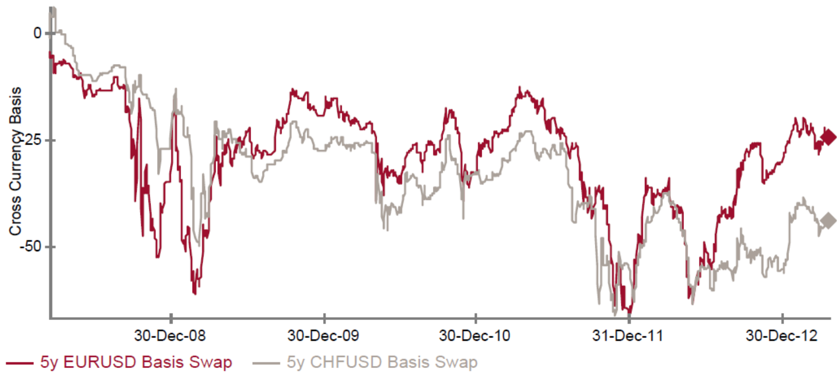

Figure 7. Example of a 5y EURUSD / CHFUSD CCBS convergence trade. (Source: Chang & Lantz, 2013).

2.3 Liquidity risk

Sushko et al. (2016) categorize the institutional aspects of FX hedging demand to three main sources: demand by banks, by institutional investors and by non-financial corporates. Banks and institutions use the cross-currency market to swap out of home currencies to fund long-term assets by exploiting the negative pressure on different basis. The basis can be seen as a cost of position on a currency hedge for banks, institutional investors and non-financial corporates.

2.3.1 Funding gaps

Globalization of banks over the past decade with increasing complexity of bank balance sheets has made it very hard to measure the funding vulnerabilities from the account mismatches in currencies and maturities. Bank of international settlements (BIS) banking statistics can be combined to provide measures for banks' funding positions on a consolidated balance sheet level. The analysis suggests that many European banking systems built up long US dollar positions vis-à-vis non-banks and funded them by interbank borrowing and via FX swaps, exposing them to funding risk.

The funding gaps are estimated by calculating together cross-border and local claims subtracted by cross-border and local liabilities in different currencies. The data is available quarterly from 1983. The currencies available are USD, EUR and

JPY. The funding gap can be seen as a proxy for banks' different currency lending e.g. USD funding needs in FX swap markets. The data is available for many countries, but in this research, the bank data for the Netherlands, Spain, Japan, Germany, Belgium, Italy, the US, France, the UK, Sweden and Switzerland will be used. (McGuire & von Peter, 2009)

As seen in the right box on Appendix 4 by BIS semi-annual OTC derivatives banking statistic, approximately, after the GFC non-US banks' USD funding gap have almost tripled in size to $1 trillion by 2015. Also, as seen in the left box on Appendix 4, the volume of XCCY swaps has been increasing rapidly alongside with FX forwards and swaps. Sushko et al. (2016) introduce a XCCY basis model that includes, for example, a parameter for calculating the banks', institutional investors', and corporates' total demand of specific currency via FX swaps to hedge their currency exposure forward:

$$D_t^{XC} = Bank^{XC} + Corp^{XC} + Inst^{XC}$$

Where $Bank^{XC}$ = Banks' use of FX swaps to fund currency lending
$Corp^{XC}$ = f. ex. US Corporates' use of FX swap to convert cheap FX funding into USD
$Inst^{XC}$ = Insurers' use of FX swaps to hedge f. ex. USD portfolio

Unfortunately, due to the limits in availability of data, only $Bank^{XC}$ will be used as proxy for D_t^{XC} in this research.

2.3.2 Foreign currency bond issuance

In link to the previous subtopic is the foreign currency debt issuance in the bond market. When Eurozone entities issue in USD, they pay the basis. When US entities issue in EUR, they receive the basis. A typical flow of USD-denominated issuance by EUR-denominated entities in January often tightens the EURUSD XCCY basis as interest to pay the basis dominates (Appendix 4). De Courcel (2015) determines that net volume of issuance equals USD issuance initiated by Eurozone entities less the EUR issuance initiated by US entities, when looking at the EURUSD XCCY basis, for example. When interest to pay the basis dominates, meaning that European entities issue bonds in USD, the basis tends to tighten. When interest to receive the basis dominates meaning US entities issue bond debt in EUR, the basis tends to widen.

2.3.3 General collateral financing

Repurchasing agreement (REPO) is a form of short-term financing for dealers in government securities. The dealer usually sells for overnight the government securities to investors, and buys them back the following day. The repo rate can be determined as the rate of interest at which banks can borrow or deposit funds at the local central bank for a period of seven days. For the seller and repurchaser in the future, the security is a REPO, and for the buyer and seller in the future, it is a reverse repurchase agreement. A type of repurchase agreement which is executed without the imposition of specific securities as collateral is called general collateral financing (GCF). Trades of GCF allow both borrowers and lenders in the repo market to reduce their costs and decrease the complexity of handling securities and fund transfers for repo agreements. (Tuckman 2002, 313)

Investors that use the repo market to earn interest on cash balances with U.S. Treasury securities collateral do not usually care about which Treasury securities they take as collateral. These investors are said to accept general collateral (GC). When commercial or investment banks agree into a REPO deal, they must deliver specific securities as collateral. Same goes for trading with short positions. These parties require special collateral. The REPO market equilibrates the supply and demand for general collateral to emerge with a GC interest rate for REPOs in which the lender of cash accepts any Treasury security as collateral. This also equilibrates the supply and demand for individual securities. The GC rate is typically below the fed funds target rate because loans through REPO are effectively secured by collateral, while loans in the fed funds market are not. The spread between the fed funds target rate and the GC rate varies with the supply and demand for U.S. Treasury collateral. (Tuckman 2002, 314)

2.3.4 Short selling constraints in quarter ends

Sushko et al. (2016) notice some interesting spikes in REPO spread differences especially in 1 week USDJPY on the quarter-ends. This trend started to appear in late 2014, as seen in Figure 4 (LHS). It shows the difference between USD and JPY REPO spreads. The graphs point to the presence of short-selling constraints. Rising repo spreads in the US dollar or the increasingly negative repo spreads in the yen have made it costly to fund CIP arbitrage to close the negative USD/JPY basis.

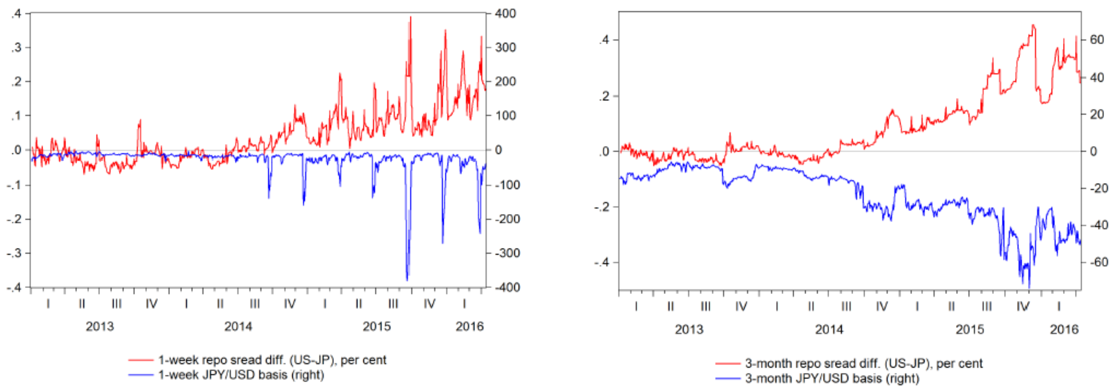

Figure 8. Repo market funding conditions vs JPY/USD basis. (Source: Sushko et al., 2016).

Du et al. (2016) and Arai et al. (2016) see the main driver of the quarter-end spikes of funding costs to be the balance sheet management and constrains by global banks. These spikes can be seen in Figure 8 (RHS). Since 2013, US banks have deleveraged due partly to the stricter leverage ratio in the US, where the ratio is calculated based on daily averaged assets. For example, the Basel standards required public disclosure of the leverage ratio by international banks starting from 2015 even though the leverage ratio becomes a mandatory part of the Basel III Pillar 1 requirements starting from 2018. Since the middle of 2014, European banks in particular, had increased positions in the US money market. Then they started to shrink their assets at quarter-ends, partly to keep the leverage ratio at quarter-ends low. In many countries, except for the US, banks report only the leverage ratio at quarter-ends. At quarter-ends, US banks increase market-making and arbitrage-trading activities in the money market at higher rates, reflecting regulatory charges. The difference is that FX swap markets and GC repo markets rely on arbitrage-trading and market-making by banks, whereas the Tri-party repo market also gets US dollar supply from real money investors not subject to the leverage ratio. However, this anomaly may disappear entirely by 2019, when the daily leverage computation of the leverage ratio will apply to non-US banks as well.

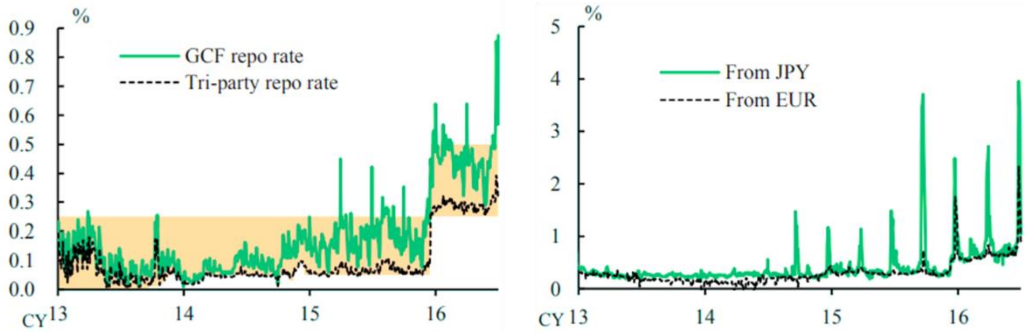

Figure 9. Overnight repo rates (LHS), and USD funding costs via 1w FX swaps (RHS). (Source: Arai et al., 2016).

2.3.5 Central bank funding

Sushko et al. (2016) remark that central bank announcements have been associated with the widening of the longer-term basis from the beginning of 2014 in EURUSD and JPYUSD as shown in Appendix 6. Contrast to this, in the GFC between 2011 and 2012, the short-term basis widened dramatically as a USD liquidity shortage drove non-US banks into FX swap markets for USD funding. After 2007, concerns about credit risk and higher demand for liquidity placed extraordinary strains on the global market for interbank funding especially in USD. Austerity of interbank lending for banks outside US was difficult in funding dollar-denominated assets on the balance sheets. Federal Reserve was not sure whether easing of the dollar inland would also mitigate the funding pressure overseas. A system for FX funding was created, called “Swap Lines”. It was originally an arrangement between the European Central Bank and the Swiss National Bank. Later, other central banks were also included, as seen in Table 1. This move allowed central banks to provide lender-of-last-resort liquidity in US dollars without being forced to draw down dollar holdings of FX reserves or to transact directly in the open market. The swap lines are bound to Overnight USD Indexed Swap rate with a fixed margin. (FED 2010, Goldberg et al. 2011 and FED 2014)

Table 2. Fed swap lines from 2008 to date. (Source: FED 2010 and FED 2014).

Date	29.9.2008	13.10.2008	9.5.2010	21.12.2010	29.6.2011	30.11.2011	31.1.2013	31.1.2013
Type of contr.	Agreement	Agreement	Agreement	Extension	Extension	Extension	Extension	Extension
BOC	not drawn	not drawn	OIS + 100 bps	OIS + 100 bps	OIS + 100 bps	OIS + 50 bps	OIS + 50 bps	OIS + 50 bps
BOE	not drawn	OIS + 100 bps	OIS + 100 Bps	OIS + 100 bps	OIS + 100 Bps	OIS + 50 bps	OIS + 50 bps	OIS + 50 bps
BOJ	OIS + 100 bps	OIS + 100 bps	OIS + 100 bps	OIS + 100 bps	OIS + 100 Bps	OIS + 50 bps	OIS + 50 bps	OIS + 50 bps
ECB	not drawn	OIS + 100 bps	OIS + 100 bps	OIS + 100 bps	OIS + 100 Bps	OIS + 50 bps	OIS + 50 bps	OIS + 50 bps
SNB	not drawn	OIS + 100 bps	OIS + 100 bps	OIS + 100 bps	OIS + 100 Bps	OIS + 50 bps	OIS + 50 bps	OIS + 50 bps

Overnight Index Swap (OIS) is an instrument that allows financial institutions to swap the interest rates they are paying without having to refinance or change the terms of the loans they have taken from other financial institutions. Usually, when two financial institutions agree to an overnight index swap, one institution is swapping an overnight interest rate and the other institution is swapping a fixed short-term interest rate. The market for OIS is quite large, and the movements in it can provide a lot of information for economists and analysts who are trying to understand what is happening in the global financial markets. One reason to look at OIS rates is to watch, what is the borrowing rate for the institutions, who have loans with variable interest rates.

Central bank actions often affect interest rates and borrowing conditions and may cause moves also in basis swap spreads. Baran & Witzany (2017) calculate the ratio between the Fed and ECB balance sheets. By doing this, they construct a simple estimator of relative supply of EUR to USD and compare it to changes in basis swap spread levels. In this thesis, the same estimator is constructed for other central bank ratios as well in cases where the total assets of the balance sheets are available (Appendix 7). The movements in the FED/ECB ratio can be somehow explained so that the Fed continued to expand on US Treasury bond-buying while the ECB repaid between 2012 and 2014 its long-term refinancing operations. The expansion of the Fed balance sheet relative to the ECB balance sheet led to basis spread tightening by USD supply increase. In June 2014, ECB started to expand its balance sheet while the Fed decreased its pace of buying US Treasuries and froze it in October 2014. This, together with the ECB QE, created an excess supply of EUR over USD and basis spreads started to get wider. Baran & Witzany (2017) noticed that an increase in the supply of USD liquidity decreases USD funding costs and tightens the basis. Correspondingly, an increase in the supply of EUR liquidity decreases EUR funding costs and widens the basis. Interestingly, as seen in Appendix 7, the different central bank total asset ratios have been driven by central governors and decision-makers into a state where the total assets in different central banks have become a lot closer to each other from the beginning of 2007.

When ECB introduced the fixed-rate tender with full allotment procedure in 2008, banks were given unlimited access to EUR funding. This has generated excess liquidity as banks' demand for funding exceeded liquidity needs. Because banks have easier access to ECB funding than to the Fed funding, it became easier for banks to fund in EUR with ECB, and simultaneously swap this funding to USD through the CCBS market. Some linkages between increases in the ECB's excess liquidity and in synthetic USD funding can be seen in Appendix 8. To some extent, this can explain a widening of the basis as excess liquidity rises and a tightening as excess liquidity goes down. The two different 3y long-term refinancing operations (LTROs), launched in 2011 and 2012, as well as the ECB QE in 2015, have all had clear impact on the XCCY basis. The LTROs have eased the risk-off sentiment, having contributed to restoring confidence in the Eurozone. The ECB QE expectations resonated in a dramatic decline in EUR yields and credit spreads led to a surge in EUR-bond issuance activity from overseas. A rise in excess liquidity cheapens the cost of funding in a currency when large amounts of cash invades the market resulting in a depreciation of the basis as less interest is required to borrow in euros. (De Courcel, 2015 and Financial Times 2017)

2.4 Credit risk

Traders have a couple of years ago started to pay attention to the difference between Libor and the OIS rate. The difference between these two rates is called the LOIS spread. As seen in Appendix 9, there was no spread before the GFC, but after the crisis, the spread started to widen radically.

2.4.1 Bank credit risk

Markets consider the Libor-OIS spread as a key measure of credit risk in banking sector, calculating the risk and liquidity in the money market. The reason, why they differ is on that Libor is the average interest rate that banks charge each other for short-term in unsecured loans, whereas OIS presents the different interest rates controlled by local central banks in different tenors. The spreads have dynamic changes and when the gap widens, markets move to more unstable state and lenders start to worry about solvency. The spread can be determined as the measure for the probability of borrowing banks to default. For example, Euribor-Eonia spread is used for the Eurozone and whereas Stibor-OIS spread is used in SEK environment. (Investopedia 2017a)

As Gefand et al. (2011) state, in addition to credit risk, Libor-OIS spreads can also contain a liquidity risk premium. It is a premium demanded by investors when a security is illiquid. Depending on the convertibility into cash for its fair market value, investors demand additional compensation for the added risk of investing their assets over a longer period, since valuations can fluctuate with market effects. Liquidity risk has been noted to play a prominent role during crises and for short maturities. Instead, for longer maturities, credit risk has been seen with a much more important role. (Investopedia 2017b)

According to De Courcel (2015) the correlation between for example EURUSD interest rates differential and the XCCY basis has become much more interesting since 2012, because the ECB cut the deposit facility rate (DFR) to zero and since 2014, it became even more meaningful, when the DFR fell to negative for the first time ever. When this started to happen, European financial institutions started to swap some of their excess euros into USD and onto US financial institutions or to the Fed, to avoid the negative carry on holding reserves in Europe. Baran & Witzany (2017) noticed that the credit element in the short end can be approximated by the IBOR-OIS spreads. Their research concludes that the EURUSD basis spread can be derived from the difference between IBOR-OIS spreads in two currencies plus a residual spread:

$$BS_{EURUSD\ OIS,3M} \approx BS_{EURUSD\ OIS,3M} + (r_{USD\ Libor,3M} - r_{USD\ OIS,3M}) - (r_{EURIBOR,3M} - r_{EONIA,3M})$$

Where $BS_{EURUSD\ OIS\ 3M}$ = EURUSD OIS basis swap, meaning Fed funds vs. Eonia + spread on a quarterly basis

Baran & Witzany (2017) have removed the embedded credit and liquidity risk of the two IBOR rates so that only the overnight rates in two currencies are left. This shows that the basis can be fully explained neither by the different credit and liquidity risk of Euribor and USD Libor nor the remaining spread, $BS_{EURUSD\ OIS\ 3M}$, which is tradable in the market and reflects the demand and supply for one currency versus the other. For example, a negative EURUSD CCS spread indicates that market participants prefer to trade EUR and hold USD. Therefore, OIS can be seen as a cleaner measure for the balance between supply and demand.

2.4.2 Credit Default Swap spreads

A credit default swap (CDS) is an over-the-counter derivative security designed to transfer credit risk. A default swap is close to a bond insurance contract. The buyer of protection pays periodic insurance coupons, until the expiration of the contract or until a contractually defined credit event occurs. If such an event happens, the party will then make a payment to the first party, and the swap will terminate. The size of the payment is usually linked to the decline in the reference asset's market value following the determination of the occurrence of a credit event. The spread fee is the annual amount that the protection buyer must pay to the protection seller for the entire duration of the CDS contract. The spread is calculated as a percentage of the nominal amount. If the CDS spread is for example 30bps where the nominal is USD 10M, then the paid spread will be USD 30 000 per year. When comparing CDS transactions, ceteris paribus, the one with the highest CDS spread is considered to be likeliest to default by the market. (Investopedia 2017c)

Credit default swaps are largely linked to credit ratings issued by the ratings agencies. When an entity is downgraded, it results in a CDS spread widening, because the perceived credit risk of the entity has increased. The spreads are also affected by other factors such as worsening macroeconomic conditions, equity market's implied volatility rise, sector or industry, financial leverage of the reference entity, the risk-free rate and liquidity of the CDS contract. Often CDS spreads affect the stock prices. It can be seen as a bearish sign when CDS spreads widen and then the stock prices of the firms commonly fall. Baran & Witzany (2017) construct two blended CDS indices for Libor and Euribor panels' average CDS spreads using the panel banks. They group the spreads and use five-year EUR and USD senior unsecured debt for them. They use CDS spreads instead of credit spreads of bond indices because they often react faster than cash markets. In this thesis, the same CDS spreads are calculated for Euribor, USD Libor, JPY Libor, GBP Libor and CHF Libor banks using their 5y denominated unsecured debt. The average CDS spreads can be seen in Appendix 10.

2.4.3 Option-adjusted spreads

Corporate bond issuance in foreign currencies influences the currency basis through the associated hedging. E.g., US corporates that issue in foreign currency because of a credit risk-adjusted funding cost advantage, often swap the issued amount back to USD. By doing this, they create demand for forward USD hedges. The currency basis is more negative for currencies where the corporate option-adjusted spread (OAS) differential is higher: for example, $OAS^{US} - OAS^{LC}$, where LC is the local currency and US meaning USD. Swapping the associated EUR proceeds into USD would have exerted a negative (widening) pressure on the basis. OAS indicates a measure of the level of risk in spreads in different currencies. Therefore, it indicates the direction in which the marginal funding and investment flows should go, ceteris paribus.

The option-adjusted spread is the difference of corporate issuers in the issuer country and another country. It can be said to be the spread of risky fixed-income security relative to a riskless security of a similar maturity. Typically, a riskless security can be a government bond. (Sushko et al. 2016). In this research, the credit spreads in bps in different currencies e.g. USD A 5y swap - EUR A 5y swap, will be used. The factor is constructed by first taking the yields in different currencies of different rated bonds, then taking the swap rates for same currencies, which can be used as bond benchmarks, and then subtracting yields from swap rates and converting the results to basis points.

2.4.4 Volatility

In general, one of the main measures of market risk is the implied volatility. Generally, it increases when the market is bearish and decreases when the market is bullish. This is due to the common belief that bearish markets are more risky than bullish markets. For the perceived market risk of foreign currency collateral, Sushko et al. (2016) rely on FX option-implied volatility $\rho\sigma_s^2$. As Appendix 11 shows, FX option-implied volatility has increased sharply at the same time the currency basis has begun to widen in 2008, 2011 and 2014. These spikes point to the link between the riskiness of foreign currency collateral and CIP deviations. When Sushko et al. (2016) derive the XCCY basis from first principles with risk-averse arbitrageurs, the association comes from CIP arbitrageurs' pricing their balance sheet exposure to FX collateral by taking the other side of the FX hedging demand. Baran & Witzany (2017) used VIX volatility index as one of their independent variable in their regression models. Increased volatility may indicate increasing market distress and preference of major global currencies such as USD. Therefore, it might impact on the widening of the EURUSD basis spread, for example.

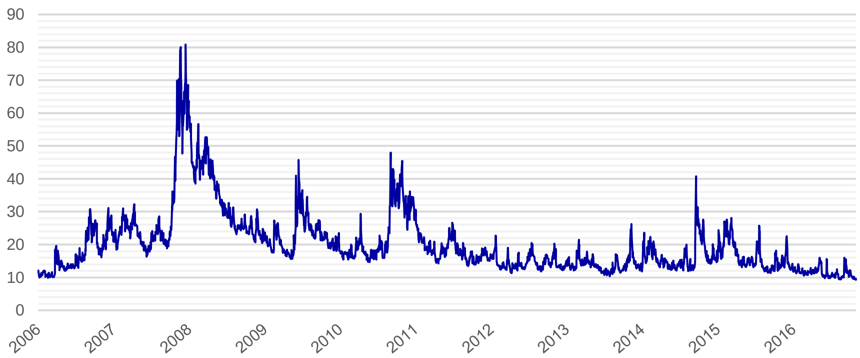

Figure 10. VIX -index movements 2006-2018. (Source: Bloomberg).

The Chicago Board Options Exchange (CBOE) Volatility Index (VIX) is determined as the market's expectation of 30-day volatility. It is constructed using the implied volatilities of a wide range of S&P 500 index call and put options. The VIX index can be seen as a measure of market risk. Values greater than 30 are generally associated with a large amount of volatility as a result of investor fear or uncertainty in the markets. (Bloomberg). As shown in Figure 10, the index has crossed the 30-point line many times during the past few years. For example, during the GFC between 2007 and 2009, Greece sovereign debt crisis 2010, US housing bubble 2011, Chinese stock market crash 2015 and, during the Brexit decision 2016.

2.5 Cross-currency basis models

All the different fundamentals explained earlier in this section are now being concluded into different XCCY basis models that are introduced next. Using these three models, Nordea Markets' own XCCY basis model will be constructed exploiting the three models' characteristics. The BIS model will be explained in more detail, because it will be the foundation for the upcoming analysis. The fundamentals of the BNP Paribas and ESM models are also being exploited for the final model. The final model with regressions and used variables will be explained in fourth section.

2.5.1 BIS model

In their XCCY basis model for EURUSD and USDJPY, Susko et al. (2016) represent banks', institutional investors', and corporates' demand of total USD via FX swaps to hedge their USD exposure forward with D^{XC} . Because they do not pose enough USD on hand in period t = 0, they enter into a swap contract $\frac{D^{XC}}{S}$ of local currency for $x_{f,s}$ of USD supplied to the swap market by CIP arbitrageurs, such as hedge funds, supranational and agency bond issuers. At the expiration date, t = 1, currency hedgers repay the borrowed USD amount with interest given by the forward points $\frac{F}{S} * x_{f,s}$, where F > S, and receive back $\frac{D^{XC}}{S}$ of the local currency that was used in the swap. CIP arbitrageurs effectively charge more in the forward leg on the other side of the swap market for the foreign currency that they sell back to currency hedgers, earning the forward points $\frac{F-S}{S}$ per dollar lent on the swap contract. This process is illustrated in detail in Appendix 12.

Using (1) and what was illustrated in Appendix 12, Sushko et al. (2016) introduce an equation for USD currency forwards:

$$f_t^B = s_t^A + r_t - r_t^* + \theta_t \rho \sigma_s^2 D_t^{XC} \qquad (2)$$

Where in addition to equation (1):

D_t^{XC} = banks', institutional investors', and corporates' demand of total currency

θ_t = the risk of counterparty default to payback the dollars at date t + 1 at rate f_t introduces a probability,

ρ = coefficient of absolute risk aversion, which can also be interpreted as the Lagrange multiplier on a Value-At-Risk (VaR) constraint. Where, VaR in general determines the maximum loss in a portfolio and the probability of the occurrence for the defined loss in a specified time frame.

$\rho \sigma_s^2$ = FX option-implied volatility, and therefore:

$\theta_t \rho \sigma_s^2$ = hurdle rates

Although the interest rates in the two currencies and the currency forward rate are known at time t, there is uncertainty that stands out from the counterparty risk in the swap. Hurdle rates represent the different factors that could determine the attractiveness of the resulting trade combination in addition to a positive return, e.g., the use of credit lines and capital, its role in balance sheet restrictions and the relative attractiveness of other business opportunities. While both θ_t and $\rho \sigma_s^2$ have been low since 2014, the currency basis has widened. Mancini-Griffoli & Ranaldo (2012) acknowledge that some arbitrageurs may be liquidity-constrained. For instance, hedge funds typically establish a position in repo markets by borrowing some of the needed USD cash to lend through FX swaps by posting securities as collateral. In that situation, arbitrageurs maximize the objective augmented by short-selling costs, in the corresponding equation, the last term describes the additional cost stemming from the reliance on repo funding:

$$f_t^B = s_t^A + r_t - r_t^* + \theta_t \rho \sigma_s^2 D_t^{XC} + c(r_t^{REPO} - r_t) \quad (3)$$

Where in addition to equation (2):
c = fraction of arbitrage funded via REPO markets
r_t^{REPO} = corresponding repo rate

With REPO financing, it is referred here as a REPO contract, where one party sells a security as collateral against cash, and repurchases back the security at maturity. Repo rates in both currencies influence the arbitrage cost. Sushko et al. (2016) note that this is because CIP arbitrageurs financing themselves in USD REPO would lend the swapped foreign currency in foreign currency REPO markets for the duration of the swap. And because of this, the equation for the forward rate turns into:

$$f_t^B = s_t^A + r_t - r_t^* + \theta_t \rho \sigma_s^2 D_t^{XC} + c[(r_t^{REPO} - r_t) - \left(r_t^{*,REPO} - r_t^*\right)] \quad (4)$$

Where modification to equation (3):
$c[(r_t^{REPO} - r_t) - \left(r_t^{*,REPO} - r_t^*\right)]$ = short-selling constraint

Because of this, the forward exchange rate can now be calculated by the weighted average of the relevant funding and investment rates in two different currencies. The importance of the short-selling constraint in the presence of positive demand shocks, $D_{i,t}^{XC}$, are to be found, when REPO funding costs are bund. When covered interest rate differential is positive, the arbitrage induces if $f_t - s_t < r_t - r_t^*$, then (4) yields to a forward ask rate formula of:

$$f_t^A = s_t^B - r_t + r_t^* + \theta_t \rho \sigma_s^2 D_t^{*,XC} + c[\left(r_t^{*,REPO} - r_t^*\right) - (r_t^{REPO} - r_t)] \quad (4.1)$$

Where $D_t^{*,XC} \equiv -D_t^{XC}$ indicates, that the investor's hedging demand on the foreign-currency asset yields a higher yield r^*. This means that the investor is swapping out of r_t assets when $r_t^* > r_t$.

Ultimately, an observable basis, $\hat{b}$, is created by using mid spot and forward rates as a function of bid and ask rates' yields for the no-arbitrage bounds within which the positive and negative basis can persist. The basis is a function of risk premia and uncertainty (cost of capital), demand shocks, REPO market spreads (cost of secured funding), and bid and ask spreads (transaction costs). Transaction costs are estimated by using an approximation suggested by Sushko et al. (2016), as follows:

$$f_t - s_t \equiv \frac{1}{2} * [(f_t^B - s_t^A) + (f_t^A - s_t^B)]$$

Therefore, the basis can be approximated with the no-arbitrage bounds:

$$\widehat{b_t^-} \equiv r_t - (r_t^* + f_t - s_t)$$
$$\geq -\theta_t \rho \sigma_s^2 D_t^{XC} - c[(r_t^{REPO} - r_t) - (r_t^{*,REPO} - r_t^*) - \frac{[(f_t^B - s_t^A) + (f_t^A - s_t^B)]}{2} = b_t^- \qquad (5)$$

Where $\theta_t \rho \sigma_s^2 D_t^{XC}$ = balance sheet costs of FX derivatives

$c[(r_t^{REPO} - r_t) - (r_t^{*,REPO} - r_t^*)]$ = secured funding costs / funding liquidity

$\frac{[(f_t^B - s_t^A) + (f_t^A - s_t^B)]}{2}$ = transaction costs / market liquidity

if $(r_t^* + f_t - s_t) - r_t < 0$, and

$$\widehat{b_t^+} \equiv r_t - (r_t^* + f_t - s_t)$$
$$\leq \theta_t \rho \sigma_s^2 D_t^{XC} + c[(r_t^{*,REPO} - r_t^*) - [(r_t^{REPO} - r_t) + \frac{[(f_t^A - s_t^B) - (f_t^B - s_t^A)]}{2} = b_t^+$$

if $(r_t^* + f_t - s_t) - r_t > 0$

Therefore, (4) and (5) determine the no-arbitrage bounds as follows:

$$b_t^- \leq \widehat{b_t} \leq b_t^+$$

This can be summarized to situations where, as long as θ_t and $\rho\sigma_s^2$ are minuscule and FX forwards and swaps are hit by sufficiently big demand shocks, raising the balance sheet costs for CIP arbitrageurs offers arbitrage opportunities also in non-crisis environments. Using the previously defined parameters, Sushko et al. (2016) create a final regression model that will also be used as the foundation of modifications in this research:

$$\begin{aligned}\Delta b_t &= \beta_\theta \times \Delta\theta_t + \beta_\sigma \times \Delta\rho\sigma^2_{s,t} + \beta_D \times \Delta D^{XC}_t + \beta_{\theta\times\sigma\times D} \times [\Delta\theta_t \times \Delta\rho\sigma^2_{s,t} \times \Delta D^{XC}_t] \\ &+ \beta_{Repo} \times \Delta\left[(r^{REPO}_t - r_t) - (r^{*,REPO}_t - r^*_t)\right] \\ &+ \beta_{bid-ask} \times \Delta[(f^B_t - s^A_t) - (f^A_t - s^B_t)]/2 + \alpha + \epsilon_t\end{aligned}$$

2.5.2 BNP Paribas model

De Courcel (2015) introduces two distinct models for different times on the financial markets. One regression model for crisis times for EURUSD XCCY basis is as follows:

$$\alpha + \beta_1\left(\frac{USD\ OIS}{BOR}\right) + \ \beta_2(CDS\ Sov\ Italy) + \ \beta_3(ECB\ XL)$$

Where $\frac{USD\ OIS}{BOR}$ = spread changes in credit risk premia and concerns over liquidity,
CDS Sov Italy = to factor changes in sentiment towards the Eurozone and
ECB XL = ECB excess liquidity

Another model for the XCCY basis when the market confidence returns is given as:

$$\alpha + \beta_1(\ EUR\ FRA\ rate - USD\ FRA\ rate) + \ \beta_3(ECB\ XL)$$

Where $EUR\ FRA\ rate - USD\ FRA\ rate$ = changes in anticipation over the degree of monetary policy divergence between two currencies and
$ECB\ XL$ = ECB excess liquidity, or ECB balance sheet value

2.5.3 ESM model

Baran & Witzany (2017) create a regression model that consists of 492 observations between January 2008 and June 2017. The data is divided into three samples, capturing different market periods. They regress weekly changes in 3m and 5y EURUSD basis swap spreads against the drivers that are listed below. The basis model for 3m and 5y is:

$$\begin{aligned}\beta_1\left(\frac{\Delta EUR}{USD}\right) &+ \ \beta_2(\Delta EUR\ ST\ spread) + \ \beta_3(\Delta EUR\ MT\ spread) + \ \beta_4(\Delta USD\ ST\ spread) \\ &+ \ \beta_5(\Delta USD\ MT\ spread) + \ \beta_6(\Delta FED/ECB\ ratio) + \ \beta_7(\Delta VIX) + \ \varepsilon\end{aligned}$$

Where $\frac{\Delta EUR}{USD}$ = spot rate

$\Delta EUR\ ST\ spread$ = Euribor 3m - Eonia 3m in %

$\Delta EUR\ MT\ spread$ = Euribor banks' average CDS spread in bps

$\Delta USD\ ST\ spread$ = USD Libor 3m - USD OIS 3m in %

$\Delta USD\ MT\ spread$ = USD Libor Banks' average CDS spread in bps

$\Delta FED/ECB\ ratio$ = ratio between FED and ECB balance sheets

ΔVIX = S&P 500 volatility index in bps

3 Data and methodology

The data is gathered from various information systems but mainly from Bloomberg, Thomson Reuters, internal databases and BIS banking statistics. The model is built by using a specific information system where all the data is gathered together. Unlike in Sushko et al. (2016), funding gap is constructed only by using information from the BIS international banking statistics, not from insurers' FX bond holdings adjusted by time-varying hedge ratios or from non-financial corporates' foreign-denominated bonds outstanding. The different currency pairs being examined are CHF, GBP, JPY, and SEK against the euro and the US dollar. All the used prices are mid prices.

Modifying McGuire and von Peter (2009), funding gap is calculated by taking the difference between the consolidated on-balance sheet assets and liabilities. If the banks do not run open FX positions, when the corresponding assets exceed the liabilities, the gap is a proxy for the funding of these assets using swaps to convert foreign funding into domestic. The national banks that will be included in calculating the funding gaps in the Euro area are German, Spanish, French, Italian, Belgian and Dutch banks. Also, different country banks are as their own entities and UK, US Swedish, Swiss and Japanese banks will be also included in the data.

To analyze differenced time-series dependencies, three different tenor models for all the currency pairs are created. The first one approximates the 3-month basis swap spread as the dependent variable, trying to explain the influencers of short-term basis spread changes. The second conducts changes in medium-term two-year basis spread changes. The last one tries to explain drivers of long-term changes in the basis spread with a 5-year tenor. The null hypothesis is that the independent variables used in the analysis do not have any effect on the dependent variables. In other words, they are statistically significant and differ from 0. In the analyses, the number of observations (N) varies from 2847 to 2851. The observations are from 1.1.2007 to 18.12.2017 including all the banking days.

3.1 Stepwise regression

In the previous section, a wide variety of possible drivers behind CCBS spreads was discussed. The main drivers consist of different modifications in credit and liquidity risk, as well as supply and demand indicators. The objective of this section is to explain these drivers, and their individual importance with a statistical approach known as stepwise regression. It is a method of fitting regression models in which the choice of predictive variables is done by using an automatic procedure. Every step involves the consideration of adding or subtracting from the used explanatory variables. It is taken in the form of sequences of F-tests and t-tests. In this thesis the bidirectional elimination, which is the combination of forward and backward selection is used. Forward selection starts with no variables in the model, testing the addition of each variable using a chosen model fit criterion. A variable is added if it gives statistically significant improvement of the fit, and after that, the method repeats this process until none improves the model's statistically significance. With the backward elimination, the method starts with all the possible variables, then it deletes a variable with the model fit criterion if it is statistically insignificant. The method repeats this process until no further variables can be deleted. (Draper & Smith, 1998)

In the stepwise regression analyses, every independent variable is tested to see whether the dependent variable statistically significantly differs from zero. Different estimates describe the positive or negative magnitude of changes for the dependent variable. T-test is used to determine this and every value is given a t-value. The result of the test shows whether the independent variable's t-value can be seen statistically significant and therefore differ from 0. The t-value is the coefficient divided by its standard error. It describes how the mean of a sample with a certain number of observations is expected to behave. The regressions compare the t statistic on variable with values in the Student's t distribution to determine the P value. The p-value describes, how confident one can be that each individual variable has some correlation with the dependent variable. The values of Pr(>|t|) describe the statistically significant levels and significance codes. The significance codes vary from 99,99 % to 0 % significance level. (Draper & Smith, 1998)

Another parameter describing the success of the regression model is the residual standard error. This figure indicates the standard deviation of the errors in the regression model. The bigger it is, the higher is the dispersion of the error terms and, at the same time, the smaller explanatory power of the model. The magnitude of the estimate's standard error always depends on the depth of the regression model and the metric of the variable to be explained. The standard error is an estimate of the standard deviation of the coefficient, and it varies across values. It can be seen as a measure of the precision with which the regression coefficient is measured. If a coefficient is large compared to its standard error, then it is probably different from 0. Controlling variables are an important part of statistical modelling. They refer to variables or contributing factors that are fixed or eliminated in order to clearly identify the relationship between an independent variable and a dependent variable. (Harrell, 2001)

The R-squared of the regression is the fraction of the variation in dependent variable that is predicted by variations in the independent variables. The R-squareds vary between zero and one. It is calculated by the correlation of the square of the dependent variable and the predicted values produced by the model. The corrected / adjusted R-squareds are used when comparing the results of two regression analyses with each other. The number of degrees of freedom is the number of values in the final calculation of a statistic that are free to vary. The F-test is a statistical test that tells whether variables in the regression analysis can, in fact, explain the fluctuation of the variable that is being explained. Since it is a statistical test, it also gives the variable a significance level. (Harrell, 2001)

4 Results

In this section, the results of 27 different basis spread models are shown. In total, there are 13 different variables available, and the most statistically significant are chosen in accordance with the stepwise regression method. In Tables 3 (3m), 4 (2y) and 5 (5y) are shown the results from the regressions with key statistics. In Appendices 13 (3m),14 (2y) and 15 (5y) are shown graphs that demonstrate how the actual basis spread moves with comparison to the constructed basis spread model by using the stepwise regression results on banking days.

If the value of the coefficient in the table is negative, 1 standard deviation increase in a factor is associated with widening of the basis, making it more negative. If the value is positive, 1 standard deviation increase in the factor is associated with tightening of the basis. In t-values, if the value is more than 1,96 or less than -1.96, the variable is statistically significant based on the t-distribution. It must be noted that in USDGBP, the FX-rates' t-values have to be analyzed in their intrinsic values, instead of their absolute values, because of the actual quotations in the markets. The FX-quote is always in the form of direct quotation, implying how many domestic-currencies can be bought with one foreign-currency. For example, EURUSD = 1.24; with one EUR (FOR) is given 1.24 US dollars (DOM).

4.1 Short-term cross-currency basis models

As is shown in Table 3 (in text onwards, t-stats are in parenthesis, in most cases), volatility index affects unsurprisingly almost every basis, whereas in EURUSD (-12.7), USDGBP (-13.5) and USDJPY (-13.1) t-tests and p-values show the highest significance for the index. Instead, in EURJPY and EURCHF, there is no significant VIX effect. Also, unsurprisingly, FX-rate affects in almost every basis, excluding EURCHF and USDJPY. Swap line influences four USD-related currency pairs because of the FED USD funding actions, although it is not a significant factor for USDSEK 3m basis spread. It can be noted, that swap lines affect most in the short term, compared to the mid-and long-term funding basis models. Spreads between Libor-OIS spread, Euribor-Eonia spread or Stribor-OIS spread impact every basis, being at their strongest in cases of EURGBP (42.3), EURJPY (48.6) and USDSEK (-17), based on t-stats. This implies that bank credit risk is highly relevant in the different 3m basis models. All available credit spreads between differently rated bonds that are denominated in the related currencies have impacts on the currency bases. A-rated denominated yen bonds have the lowest influence, whereas BBB-rated spreads have a high impact.

With respect to average Credit Default Swap spreads, the effect varies a lot depending on the basis model. The highest influence in average Euribor banks' CDS spread is in EURSEK (11.8) and EURJPY (-10.3). Correspondingly, in USD Libor, the highest effects are in EURUSD (-13.0) and in USDGBP (-12.0). Unfortunately, Stibor banks' CDS spreads' data was not available. Clearly, funding gaps in all available data in different currencies affect the 3m basis values, indicating that shortage in, for example, USD funding on quarter ends might have influence on the markets in USD FX-rates. Central banks' total assets' ratios seem to have an impact in all currency pairs basis models, except for Swedish krona -pairs, implying that Riksbank's actions on reducing or increasing its asset portfolio do not affect the 3m SEK basis spread. Respectively, yen-related pairs, EURJPY (15.0) and USDJPY (22.0), generate the highest t-values, implicating that Bank of Japan's operations have an impact on the basis.

Implied FX volatility has an effect in every pair, except for EURUSD, which is interesting because it is one of the most followed and used currency pairs in the markets. Instead, EURCHF (-16.6) and USDCHF (-21.3) are greatly influenced by the FX volatility. This might be explained by the fact that about three years ago, the Swiss National Bank shocked currency markets by scrapping the franc's peg to the euro, and it now faces a tough task to normalize its ultra-loose monetary policy. As pointed out by Revill & Gruber (2018), if SNB raises rates, the franc strengthens. The same also happens if it sells off its massive balance sheet, or if a global crisis becomes reality again. Bearing these factors in mind, the franc's volatility impacts the 3m basis models greatly. Spread between general collateral overnight REPO funding affects five different currency basis spreads, with the highest impact in EURCHF (15.5) and USDCHF (-15.8). In line with Sushko et al. (2016), the presence of short-selling constrains with USDJPY (7.3) and EURJPY (-6.3) REPO spreads are also notable.

The lowest adjusted R-squareds are reported for USDJPY (0.5407), USDCHF (0.2948) and EURCHF (0.2808) due to the fact that the actual bases do not have as many observations as seen in Appendix 14. The highest adjusted R-squareds are documented for EURJPY (0.7969) and EURGBP (0.7376). Table 3 demonstrates the summary of 3-month basis models with stepwise regression coefficients, t-stats are in parenthesis, and the number of observations, as well as adjusted R-squareds are on the bottom-2 rows of the table.

Table 3. 3m cross-currency swap basis spread models.

Coefficient	EURUSD	EURGBP	EURSEK	EURJPY	EURCHF	USDGBP	USDSEK	USDJPY	USDCHF
VIX	-0.6983*** (-12.672)	0.2187*** (4.811)	0.1929** (2.869)		-0.07205 (-1.4651)	-0.7143*** (-13.483)	-0.256693*** (-6.555)	-0.604*** (-13.094)	-0.1777** (-2.725)
Fx-rate	89.08*** (16.273)	-11.16*** (-10.618)	9.536*** (10.902)	0.1711*** (5.073)	-4.957 (-1.5048)	50.26*** (12.198)	-4.569157*** (-12.837)		-14.83* (-2.432)
Swap Line	4.426*** (6.561)					-3.681*** (-8.559)		1.12** (2.883)	-7.603*** (-12.186)
LOIS spread	-9.946*** (-4.757)	0.7954*** (42.317)	0.2309*** (13.197)	0.8383*** (48.574)	0.05356* (2.5445)	0.1183*** (6.555)	-0.113297*** (-17)	14.91*** (13.66)	-0.04769*** (-3.433)
OAS spread1	-10.18*** (A) (-13.145)		3.567*** (AA) (5.974)	-1.497* (A) (-2.015)			-5.187864*** (AA) (-12.319)	-2.529* (A) (-2.394)	
OAS spread2	5.664*** (BBB) (6.761)		-4.96*** (GOV) (-15.691)	6.56*** (BBB) (8.954)			1.058177*** (GOV) (5.034)	-6.174*** (BBB) (-10.377)	
CDS spread ccy1		0.04642*** (3.985)	0.06882*** (11.768)	-0.1517*** (-10.322)		-0.9149*** (-11.998)	-0.041072*** (-7.485)	0.2609*** (8.224)	0.6596*** (6.772)
CDS spread ccy2	-0.1888*** (-12.99)	0.121*** (5.878)		0.3459*** (15.233)	-0.1194*** (-11.551)	0.8407*** (11.547)		-0.147*** (-4.934)	-0.6294*** (-7.003)
Funding gap ccy1	0.000139*** (8.223)	-0.0001487*** (-20.49)	-0.0001946*** (-16.732)	-0.0003123*** (-21.194)	-0.00006452*** (-5.5775)	0.00001777*** (4.755)	-0.000031*** (-3.662)	-0.00002569*** (-8.347)	-0.0001854*** (-16.76)
Funding gap ccy2	0.00003642*** (13.435)			0.0001328*** (10.854)				-0.000507*** (-18.372)	
Central Banks' ratio	22.98*** (13.976)	-7.253*** (-4.14)		13.81*** (15.003)	7.049*** (8.9956)	7.594*** (4.165)	-0.045811** (-2.797)	25.39*** (22.047)	4.209*** (7.851)
Implied FX volatility		-119.8*** (-7.574)	-494.7*** (-20.821)	-70.14*** (-6.538)	-255.3*** (-16.5868)	-51.89*** (-3.354)	-0.622706*** (-5.868)	-139.6*** (-11.642)	-377.7*** (-21.289)
GC O/N repo spread	1.164* (2.029)	1.342* (2.128)		-2.199*** (-6.372)	14.74*** (15.5157)	3.856*** (7.482)		8.554*** (7.32)	-6.942*** (-15.82)
Constant	-140.6*** (-15.026)	46.77*** (13.149)	-58.22*** (-7.615)	5.591 (1.125)	-5.353 (-0.9208)	-69.65*** (-8.655)	33.912788*** (16.055)	-31.49*** (-7.348)	16.87** (2.917)
Observations	2849	2851	2852	2849	2852	2850	2851	2848	2850
Adjusted R^2	0.6347	0.7376	0.5567	0.7969	0.2808	0.6499	0.663	0.5407	0.2948

Notes: Regression coefficients are listed here with significance levels: *** p<0.001, ** p<0.01, * p<0.05, . p<0.1. T-values are in parentheses. In OAS spreads, bond rating in parantheses. Ccy1 = first currency of the currency pair, ccy2 = second currency of the currency pair.

When looking at individual 3m basis models, EURUSD (11/13), USDJPY (12/13) and EURJPY (11/13) have the highest number of explanatory influencing variables affecting the basis, whereas, EURCHF has only six and EURSEK eight such variables. As Table 3 shows, independent variables, that are statistically significant and affect the 3m basis do exist and therefore, the null hypothesis is rejected.

4.2 Mid-term cross-currency basis models

For 2y XCCY swap basis models, Table 4 shows that the VIX index has a causality with every basis expect for USDCHF, for which it is statistically insignificant. Highest VIX impacts are documented for EURCHF (-15.2), USDGBP (-8.3) and EURUSD (-7.5). For mid-term funding, FX-rate has effect in every single model with high t-values in every currency pair, which is reasonable. Surprisingly, the FED swap lines factor only EURUSD (8.6), indicating that predetermined and cheap FED USD funding of OIS+50 bps has only impact on the EURUSD of all the basis models in the two-year tenor. Spreads between Libor-OIS spread, Euribor-Eonia spread or Stribor-OIS spread impact every basis spread, apart from EURCHF, with the highest t-stats and the lowest p-values for EURGBP (32.8), EURJPY (26.8) and USDCHF (-18.2). This indicates that bank credit risk is featured strongly in almost every 2y basis model. It seems that EURUSD (A & BBB), EURSEK (AA & Gov), EURJPY (A & BBB), USDSEK (AA, Gov) and USDJPY (A & BBB) corporate bond issuances in foreign currencies influence the currency basis through the associated hedging. Therefore, a company with a main currency of ccy1 can get a credit risk adjusted funding cost advantage by swapping the issued amount in ccy2 back to ccy1. By doing this, they create demand for forward ccy2 hedges and affect the basis spreads.

Euribor banks' average CDS spreads impact every EUR basis model, except for EURCHF, whereas CHF Libor banks' CDS average spread affects the basis. In turn, USD Libor banks' CDS spread affects every USD basis model, with highest t-stats in USDGBP (-28.1) and USDCHF (14.4). Funding gaps in all available currencies effect the 2y basis models, indicating that shortage in EUR and USD funding influence the currency markets, having the strongest t-stats and effect on the basis in EURGBP (-27.7), USDJPY (-29.5) and USDCHF (-28.6). In the same way as in the short term (3m), the central banks' total assets' ratios also seem to have a strong impact in all currency pairs in the medium term, except for 2y EURSEK basis spread.

Respectively, pound pairs, EURGBP (-13.8) and USDGBP (19.8), have very high t-stats, implying that Bank of England's monetary policy decisions in its balance sheet against ECB and FED have an impact on the basis spreads.

Implied FX volatility affects every basis spread pair, with the highest t-stats in EURUSD (-14.6), USDJPY (-14.5) and USDCHF (-22.6). Unlike in short-term basis, in mid-term models, spread between general collateral overnight REPO funding affects every single currency basis, with the highest impacts on EURJPY (33.3) and USDCHF (-35.3), indicating that short-selling constrains, for example in quarter ends, may have been present. All the models generate high adjusted R-squareds, ranging from 0.7059 in USDSEK to 0.9008 in USDJPY. This can be interpreted as a sign that the variables chosen by the stepwise method are quite good as seen in Table 4.

Table 4. 2y cross-currency swap basis spread models.

Coefficient	EURUSD	EURGBP	EURSEK	EURJPY	EURCHF	USDGBP	USDSEK	USDJPY	USDCHF
VIX	-0.189***	0.1097***	-0.1526***	-0.1039***	-0.2958***	-0.2011***	-0.15***	-0.08736**	0.04159
	(-7.533)	(4.683)	(-5.543)	(-4.063)	(-15.196)	(-8.27)	(-6.126)	(-2.87)	(1.445)
Fx-rate	63.06***	-6.518***	2.988***	-0.1709***	22.96***	37.37***	-7.404***	-0.4429***	-57.14***
	(23.622)	(-11.141)	(6.731)	(-10.631)	(13.12)	(21.25)	(-22.12)	(-14.468)	(-23.873)
Swap Line	2.656***							0.6665.	
	(8.645)							(1.89)	
LOIS spread	-5.503***	0.3247***	0.0779***	0.2366***		0.02863***	-0.06502***	-4.696***	-0.1162***
	(-7.066)	(32.795)	(8.292)	(26.769)		(3.41)	(-11.862)	(-6.462)	(-18.161)
OAS spread1	-10.92*** (A)		-1.466*** (AA)	-20.55*** (A)			-2.869*** (AA)	10.09*** (A)	
	(-11.856)		(-6.017)	(-26.401)			(-13.674)	(7.142)	
OAS spread2	12.97*** (BBB)		-1.61*** (GOV)	14*** (BBB)			1.808*** (GOV)	-9.462*** (BBB)	
	(15.77)		(-9.97)	(25.253)			(9.028)	(-10.449)	
CDS spread ccy1	-0.05971***	0.1715***	0.09871***	-0.03862***		-1.009***	-0.03958***	0.08164**	0.6459***
	(-12.623)	(26.414)	(31.498)	(-5.694)		(-28.115)	(-10.103)	(3.225)	(14.421)
CDS spread ccy2	-0.06431***	-0.09535***		0.01809.	-0.06538***	0.9795***		-0.2513***	-0.695***
	(-7.483)	(-8.278)		(1.678)	(-13.645)	(28.423)		(-11.571)	(-16.853)
Funding gap ccy1	0.00004305***	-0.0001108***	-0.0001395***	-0.00008388***	0.00005142***	0.00003976***	-0.00005084***	-0.00009703***	-0.0001424***
	(6.928)	(-27.693)	(-21.99)	(-12.065)	(9.621)	(20.972)	(-9.244)	(-29.524)	(-28.638)
Funding gap ccy2	0.000003613**			-0.00006869***				-0.0004205***	
	(2.681)			(-10.965)				(-22.781)	
Central Banks' ratio	13.73***	-13.15***	0.0214	8.602***	-2.439***	17.02***	0.06247***	7.124***	2.742***
	(19.161)	(-13.849)	(1.557)	(18.853)	(-6.704)	(19.75)	(4.829)	(8.18)	(12.832)
Implied FX volatility	-206.6***	-76.99***	0.3822***	66.72***	-133***	-107.2***	0.2712**	-215.3***	-282.9***
	(-14.635)	(-6.956)	(12.323)	(6.947)	(-13.675)	(-10.232)	(3.003)	(-14.548)	(-22.577)
GC O/N repo spread	-0.6259**	-1.101**	6.691***	6.597***	12.41***	1.105***	1.544***	-7.973***	-5.416***
	(-2.941)	(-3.019)	(12.755)	(33.372)	(28.027)	(7.044)	(7.329)	(-9.396)	(-35.278)
Constant	-84.75***	41.82***	-25.99***	8.3**	-22.53***	-64.86***	40.67***	123.9***	53.55***
	(-16.208)	(18.789)	(-5.995)	(3.057)	(-7.106)	(-17.848)	(20.796)	(31.899)	(19.725)
Observations	2847	2851	2850	2848	2853	2851	2850	2847	2851
Adjusted R^2	0.8869	0.8007	0.7584	0.8625	0.7688	0.799	0.7059	0.9008	0.7777

Notes: Regression coefficients are listed here with significance levels: *** p<0.001, ** p<0.01, * p<0.05, . p<0.1. T-values are in parentheses. In OAS spreads, bond rating in parantheses. Ccy1 = first currency of the currency pair, ccy2 = second currency of the currency pair.

In the individual 2y basis spread models, EURUSD (13/13), USDJPY (12/13) and EURJPY (11/13) got the highest number of influencing variables affecting the basis with the significance level of 5 %. By contrast, EURCHF (7/13) has the lowest number of variables that have a significant impact on the basis. As Table 4 shows, there are many independent variables statistically significant that affect the 2y basis, and therefore, the null hypothesis is rejected.

4.3 Long-term cross-currency basis models

For the 5-year basis spread models, the Volatility Index does not have an explanatory power on USDSEK at the 5% significance level (see Table 5). This is means that in the long-term market risk strongly contributes to the basis spreads. The strongest impacts are reported for USDGBP (-11.6), USDCHF (-8.6) and EURJPY (-8.4). For the long-term funding, FX-rate has effect in every single model with high t-values for every currency pair, indicating similar results as for 2y basis models. The FED swap lines have an impact on only three 5y bases: EURUSD (5.4), USDGBP (2.7) and USDCHF (-8.7). In 5y basis spreads, the effect of spreads between Libor-OIS spread, Euribor-Eonia spread or Stribor-OIS spread is lower compared to 3m and 2y. The bank credit risk has therefore an influence on 6 basis models, at its highest for EURUSD (-12.7) and USDCHF (-12.5).

Corporate bond issuance in foreign currencies influence the 5y currency basis models, but surprisingly unlike for 3m and 2y tenors, AA-rated EURSEK bond spreads have no effect with on the 5y EURSEK basis. Otherwise, the corporate option-adjusted spreads strongly impact the basis, where data is available. Credit Default Swap spreads seem to have the strongest effect on 5y basis spreads, compared to other tenors. Euribor banks’ average CDS spreads impact most on EURSEK (37.5) and EURGBP (34.5), whereas USD Libor banks’ CDS spread affects USDGBP (-27.7) and EURUSD (-17.0) most. At the 5% significance level, funding gaps in all available currencies affect the 5y basis models, indicating that shortage in EUR and USD funding influence the long-term currency markets, where the strongest effect is for EURSEK (-38.7) and USDJPY (-48.0) 5y basis spreads.

For every tenor, EUR and USD funding gaps have a strong impact on the basis models.

It seems that the longer the maturity of the basis, the more central banks' total assets' ratios affect the basis spreads, because for 5y tenor, all the ratios are statistically significant. This makes sense, because monetary policies often have more long-term than short-term goals to impact on the markets. The effect is the highest in four different bases: EURUSD (24.1), EURJPY (24.2), EURCHF (-24.9) and USDGBP (36.1). This indicates that every central bank's decision on their balance sheet affects every single 5y basis.

For 5y basis models, implied FX volatility has the lowest effect compared to 3m and 2y bases. This is reasonable as the longer the maturity of FX swap contract, the smaller the actual effect of the FX volatility in the FX swap. The highest t-stats are for EURUSD (-14.7), USDJPY (-11.9) and USDCHF (-18.9). Spread between general collateral overnight REPO funding has an effect in every single currency basis, with weakest effect for EURUSD (-2.3). GC O/N REPO spread has a very low effect on EURUSD in 3m and 2y basis models as well, indicating that other variables than affect the EURUSD in all tenors examined. All the models have quite high adjusted R-squareds, ranging from 0.7239 for USDSEK to 0.9189 for EURUSD indicating that the used variables with stepwise method have a strong influence on the long-term 5y cross-currency swap basis models, as shown by Table 5.

Table 5. 5y cross-currency swap basis spread models.

Coefficient	EURUSD	EURGBP	EURSEK	EURJPY	EURCHF	USDGBP	USDSEK	USDJPY	USDCHF
VIX	-0.1377***	-0.0976088***	-0.1429***	0.1943***	-0.1303***	-0.2587***	-0.03645.	0.2238***	0.2259***
	(-8.029)	(-4.468)	(-6.729)	(8.424)	(-6.887)	(-11.59)	(-1.866)	(7.297)	(8.627)
Fx-rate	56.32***	-6.0605607***	3.357***	-0.5232***	27.84***	33.21***	-7.814***	-0.6755***	-37.74***
	(28.262)	(-11.765)	(8.866)	(-31.191)	(17.214)	(20.936)	(-32.617)	(-20.568)	(-14.053)
Swap Line	1.306***					0.5339**			-2.384***
	(5.42)					(2.658)			(-8.743)
LOIS spread	-7.007***	0.0889457***		0.03239***	-0.01289	0.03694***	-0.02313***		-0.07767***
	(-12.681)	(9.163)		(3.509)	(-1.518)	(4.412)	(-5.059)		(-12.461)
OAS spread1	-9.403*** (A)			-11.23*** (A)			1.148*** (AA)	14.85*** (A)	
	(-11.27)			(-12.927)			(8.79)	(12.892)	
OAS spread2	14.12*** (BBB)		-2.699*** (GOV)	4.085*** (BBB)			1.72*** (GOV)	-9.813*** (BBB)	
	(19.672)		(-19.136)	(7.041)			(10.894)	(-13.035)	
CDS spread ccy1	-0.03152***	0.2146766***	0.1228***	-0.1272***	-0.03227***	-0.9901***	-0.03375***	0.08754**	0.4971***
	(-9.576)	(34.495)	(37.472)	(-17.417)	(-7.307)	(-27.65)	(-9.074)	(3.167)	(11.592)
CDS spread ccy2	-0.1048***	-0.1906896***		0.05343***	-0.01748*	0.9941***		-0.3589***	-0.6019***
	(-16.982)	(-17.285)		(4.549)	(-2.361)	(29.314)		(-15.308)	(-15.22)
Funding gap ccy1	0.00004861***	-0.0001087***	-0.0001461***	0.0000407***	0.00003268***	0.00004663***	-0.00008923***	-0.0001256***	-0.0000759***
	(10.732)	(-29.34)	(-38.656)	(5.5)	(7.327)	(26.148)	(-20.158)	(-47.91)	(-15.549)
Funding gap ccy2	-0.00000171*			-0.00007999***				-0.0003356***	
	(-1.97)			(-12.95)				(-15.098)	
Central Banks' ratio	11.94***	-7.1249878***	-0.05776***	11.24***	-7.279***	28.85***	0.1838***	-8.535***	-2.348***
	(24.125)	(-7.966)	(-4.303)	(24.223)	(-24.904)	(36.052)	(17.282)	(-10.741)	(-9.859)
Implied FX volatility	-201.4***			-72.2***	-1.011***		0.5506***	-228.2***	-274.5***
	(-14.662)			(-7.689)	(-10.532)		(6.888)	(-11.884)	(-18.871)
GC O/N repo spread	-0.3614*	-2.8055724***	4.952***	6.204***	9.858***	-1.236***	2.183***	-11.33***	-6.104***
	(-2.314)	(-8.399)	(11.225)	(28.121)	(26.98)	(-5.179)	(13.484)	(-14.106)	(-31.704)
Constant	-71.08***	34.8217343***	-15.36***	37.11***	-28.67***	-80.98***	36.25***	183.2***	43.62***
	(-17.117)	(25.891)	(-4.206)	(13.397)	(-9.924)	(-28.394)	(21.888)	(40.305)	(15.881)
Observations	2847	2852	2853	2848	2851	2851	2850	2849	2850
Adjusted R^2	0.9189	0.7918	0.7648	0.8961	0.882	0.7491	0.7239	0.9148	0.8542

Notes: Regression coefficients are listed here with significance levels: *** p<0.001, ** p<0.01, * p<0.05, . p<0.1. T-values are in parentheses. In OAS spreads, bond rating in parantheses. Ccy1 = first currency of the currency pair, ccy2 = second currency of the currency pair.

The individual 5y basis spread models in EURUSD (13/13), EURJPY (12/13) and USDJPY (11/13) have the highest amount of explanatory variables at the 5 % significance level. Correspondingly, EURSEK (8/13) has the lowest number of such variables. As Table 5 shows, many independent variables are statistically significant affecting the 5y basis and therefore, the null hypothesis is rejected.

5 Conclusions

In this thesis, different factors affecting cross-currency basis swap spreads are discussed. On an aggregate level, five factors can be identified: market risk, credit risk, liquidity risk, as well as supply and demand pressures. It can be argued that basis spreads in the short end of the term curve are more influenced by short-term rates, fixings and the credit or liquidity premiums. For the mid and long end of the term structure, the influence is more on the supply and demand side. The results of the thesis show the historical development of different basis spreads compared to the structured basis models with a high correlation to one another in different tenors. The built stepwise regression models are tested in a time frame, that includes the GFC, European debt crisis and large scale monetary policy interferences to the markets.

The different bases seem to open up because of large and imbalanced FX hedging demands. Due to unconventional monetary policies in major currency areas, the term and credit spreads have rapidly fluctuated resulting in cross-currency investments and more one-sided funding flows. Hedging the FX-risk on these flows puts pressure on the forward-spot rate differential, causing the basis to widen in many cases. The basis remains open due to balance sheet commitment to take the other side of net FX hedging imbalances. As Sushko et al. (2016) also note, the models emphasize the costs stemming from risks involved in taking exposures to FX derivatives. The market impact of these risks is scaled by the size of these positions. The resulting risk premia will cause the market-clearing forward FX-rates to remain out of line with CIP, when FX hedging demand is large and imbalanced across currencies.

The proxies for hedging demand combined with various indicators of possible balance sheet costs of trading against CIP violations can, to some extent, explain the different currency basis. The exact balance sheet costs of CIP arbitrage are unknown, meaning that natural limits to arbitrage arise from the risk management with regulatory requirements in place. Therefore, arbitrage possibilities can arise, for example, when something major happens in the global markets. These kinds of factors have been proxied using considerable amount of market data and computation. The used proxies and their coefficients are concluded in Table 6.

Table 6. Cross-currency basis spread models' proxy factors and their coefficients.

Proxy factor	Coefficient
Market credit risk	Spread between f.ex. Libor-OIS spread and Euribor-Eonia spread
Bank credit risk	Spread between Libor banks' avg. CDS spread and Euribor banks' avg. CDS spread
Monetary policy	Total assets' ratios between central banks
Short-selling costs	Spread between general collateral overnight REPO funding
Aggregate incentive to swap out of FX funding into other ccy investments	Different ccy denominated rated bonds' spreads
Monetary policy	Swap line funding for central banks in USD
Market risk	Implied volatility index
Implied FX volatility	Implied volatility in ccy pairs
FX-risk	FX-rate
Banks' use of FX swaps to fund ccy lending	Funding gap on ccy on a country/area

It is impossible to be sure whether one factor widens, narrows or has zero impact on the basis on different currency pairs, but for example, Baran & Witzany (2017) concluded in their results, that the regressions' results largely confirmed their expectations; an increase in short-term or medium-term credit risk of European banks widens both 3m and 5y EURUSD basis spreads, whereas an increase in US short-term credit risk tends to tighten the 3m basis, or the appreciation of the euro against dollar drives the 5y basis tighter. The results in this research also support similar findings. The regressions' results of this thesis show that for different periods of time of the bases, are affected by different coefficients in most cases.

It is noteworthy that coefficients of determinations are quite high in many cases, all models being statistically significant, except for 3m EURCHF and 3m USDCHF. According to the results, the used variables explain the different basis better for longer maturities. EURUSD and USDJPY have the highest numbers of significant explanatory variables and they also get the highest adjusted R-squareds, indicating possibilities to best mimic the changes in the actual basis. The null hypothesis is rejected in every model, implying that the models are statistically significant even at the 0,01 % significance level.

Table 7 presents the conclusions from the stepwise regression models with the indication on the direction of the basis movements, giving a better understanding of the effects and an edge to arbitrageurs. If the value is negative, 1 standard deviation increase in a factor is associated with widening of the basis, making it more negative. This confirms that CIP deviations tend to increase when risks in the interbank funding markets increase. If the value is positive, 1 standard deviation increase in the factor is associated with tightening of the basis. Of course, this is only an indication, meaning that even though the change is as presented below, the correct reaction is still never guaranteed.

Table 7. Summary of factors that potentially widen or tighten the basis.

Basis model	VIX	Fx-rate	SL	CB ratio	OAS spread1	OAS spread2	LOIS spread	FG ccy1	FG ccy2	Impl. FX vol.	GCF repo spread	CDS spread ccy1	CDS spread ccy2
USDJPY													
3m	-	0	+	+	- (A)	- (BBB)	+	-	-	-	+	+	-
2y	-	-	0	+	+ (A)	- (BBB)	-	-	-	-	-	+	-
5y	+	-	0	-	+ (A)	- (BBB)	0	-	-	-	-	+	-
USDSEK													
3m	-	-	na	-	- (AA)	+ (Gov)	-	-	na	-	0	-	na
2y	-	-	na	+	- (AA)	+ (Gov)	-	-	na	+	+	-	na
5y	0	-	na	+	+ (AA)	+ (Gov)	-	-	na	+	+	-	na
USDGBP													
3m	-	+	-	+	na	na	+	+	na	-	+	-	+
2y	-	+	0	+	na	na	+	+	na	-	+	-	+
5y	-	+	+	+	na	na	+	+	na	0	-	-	+
USDCHF													
3m	-	-	-	+	na	na	-	-	na	-	-	+	-
2y	0	-	0	+	na	na	-	-	na	-	-	+	-
5y	+	-	-	-	na	na	-	-	na	-	-	+	-
EURUSD													
3m	-	+	+	+	- (A)	+ (BBB)	-	+	+	0	+	0	-
2y	-	+	+	+	- (A)	+ (BBB)	-	+	+	-	-	-	-
5y	-	+	+	+	- (A)	+ (BBB)	-	+	-	-	-	-	-
EURJPY													
3m	0	+	na	+	- (A)	+ (BBB)	+	-	+	-	-	-	+
2y	-	-	na	+	- (A)	+ (BBB)	+	-	-	+	+	-	0
5y	+	-	na	+	- (A)	+ (BBB)	+	+	-	-	+	-	+
EURSEK													
3m	+	+	na	0	+ (AA)	- (Gov)	+	-	na	-	0	+	na
2y	-	+	na	0	- (AA)	- (Gov)	+	-	na	+	+	+	na
5y	-	+	na	-	0	- (Gov)	0	-	na	0	+	+	na
EURGBP													
3m	+	-	na	-	na	na	+	-	na	-	+	+	+
2y	+	-	na	-	na	na	+	-	na	-	-	+	-
5y	-	-	na	-	na	na	+	-	na	0	-	+	-
EURCHF													
3m	0	0	na	+	na	na	+	-	na	-	+	0	-
2y	-	+	na	-	na	na	0	+	na	-	+	0	-
5y	-	+	na	-	na	na	0	+	na	-	+	-	-

Notes: Different values for factors are presented for the table; " - " means that the basis widens, " + " means that the basis tightens, " 0 " means that the factor is insignificant with the significance level of 95 %, " na " means that the factor is not available for the model. The rating of the bonds in OAS are presentented in brackets after the value if used in the model. CB = Central Bank, FG = Funding Gap, SL = Swap Line, ccy1 = first currency of the currency pair, ccy2 = second currency of the currency pair.

As the results show, it is hard to find a proxy that would have the same effect on every currency pair basis. It is also noteworthy that 3m factors seem to have totally different impact on the basis compared to the longer-term maturities. The findings indicate that the models are useful to better understand CIP deviations at longer maturities, which are associated with the use of XCCY markets for foreign currency funding and long-term foreign currency investment management. The research has also addressed CIP deviations for 3m tenors, indicating, that the factors are mainly associated with short-term liquidity management. Due to this, the pricing of 3m FX swaps respond more to measures of interbank credit and liquidity risks than the pricing of long-term cross-currency swaps. However, as Sushko et al. (2016) also noted, even then, the impact of measures such as Libor-OIS spreads on the FX swap-implied basis arise predominantly due to the interaction with the aggregate demand for currency hedges, which banks must meet as CIP arbitrageurs. Hence, the underlying risks are scaled by the total balance sheet exposures even at shorter tenors.

A couple of good opportunities for arbitragers to exploit the basis has emerged: One opportunity peaked at the end of 2011, right before coordinated actions by central banks, which effectively capped the basis spreads. The central banks started to intervene with swap lines and then European banks could borrow dollars directly from the ECB against euro collateral. Baba & Packer (2008) showed that dollar term funding auctions by the ECB have stabilized the FX swap market. For example, the EURUSD basis has significantly narrowed during Q1 of 2014 and the arbitrage opportunity vanished. Another arbitrage opportunity arose in the beginning of 2015, when ECB announced its QE, which is still ongoing, meaning that the excessive supply of EUR has not yet been absorbed. Therefore, arbitrage opportunities can still exist, either through outright or convergence trades in different tenors of cross-currency basis swap spreads with different interest rates and currency pairs.

6 Summary

This research was originally established because of the interest to understand better, what happens in the global markets in currency and interest rate markets. Also, understanding how monetary policies change the way banks and corporates do business, was another interesting point of view for the subject. Then the idea to study cross-currency basis swaps spreads was established, because the subject incorporates all the topics mentioned above. Understanding, how the cross-currency basis swap spreads are constructed and what affect them, are intriguing questions and, what this thesis is all about. The data was constructed by creating a semi-automated model for first downloading the data and then creating an automated flow to analyze and create stepwise regression models for 9 different currency pairs with the different tenors of 3m, 2y and 5y. The goal was to find out, what are the various proxies affecting the basis. By doing this, different basis models were created to mimic the actual basis spreads to better understand, how the spreads fluctuate in different maturities and market conditions.

The thesis finds proof of the failure of the covered interest rate parity theory. The used variables were chosen on the basis of the literature review and with the aim to discover something new and useful. Interestingly, tremendous amounts of variables that may affect the XCCY swap basis spreads were found. It is very difficult to identify all the factors, but at least this thesis introduced several possible proxies with fairly good and understandable results. The results are somewhat in line with previous research papers with a little different angle of approach. Some usable findings for real life situations to help understand better the XCCY swap basis spreads' market were also reported. The results suggest that cross-currency basis swap trades have offered arbitrage possibilities during 2008-2017. The constructed models show that, to some extent, the basis spreads could be estimated and forecasted. The examined factors play an important role in modeling and calculating the fair value of the bases. Forecasting the movements of the basis would be an interesting but at the same time a challenging subject for future research.

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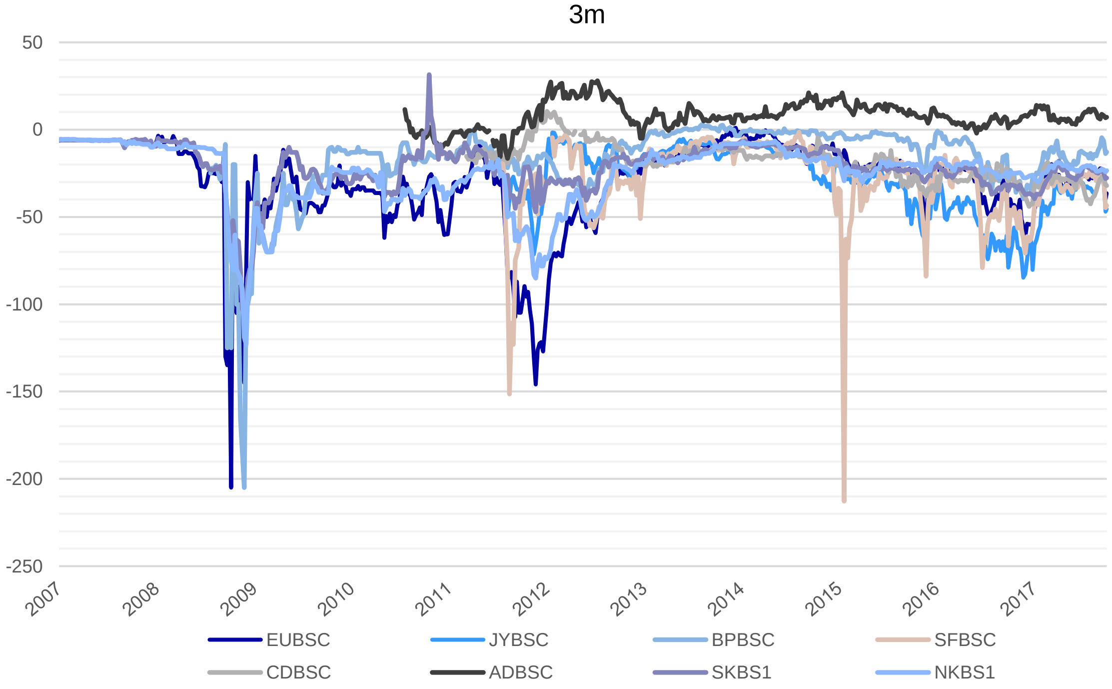
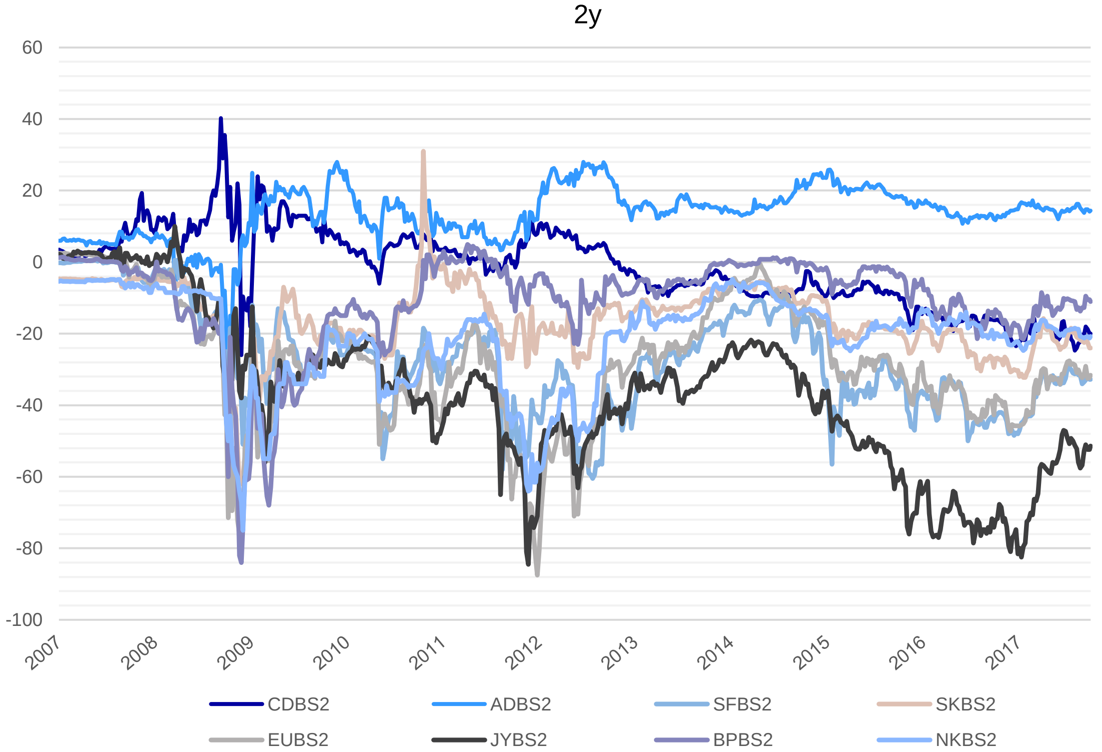
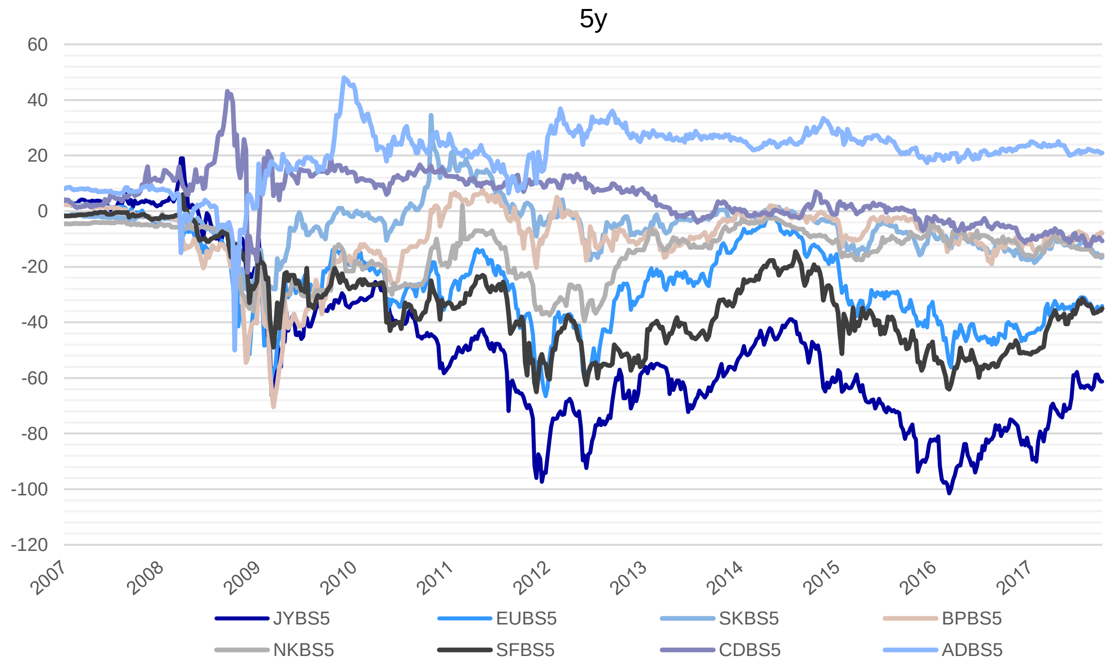
APPENDICES

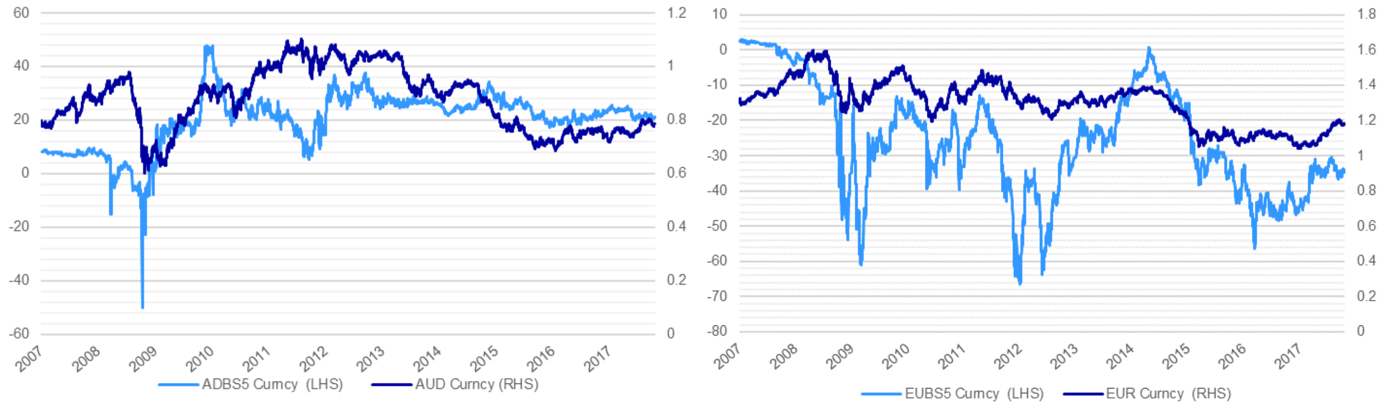
Appendix 1. 3m, 2y and 5y CCBS spreads vs different currencies in bps. (Source: Bloomberg).



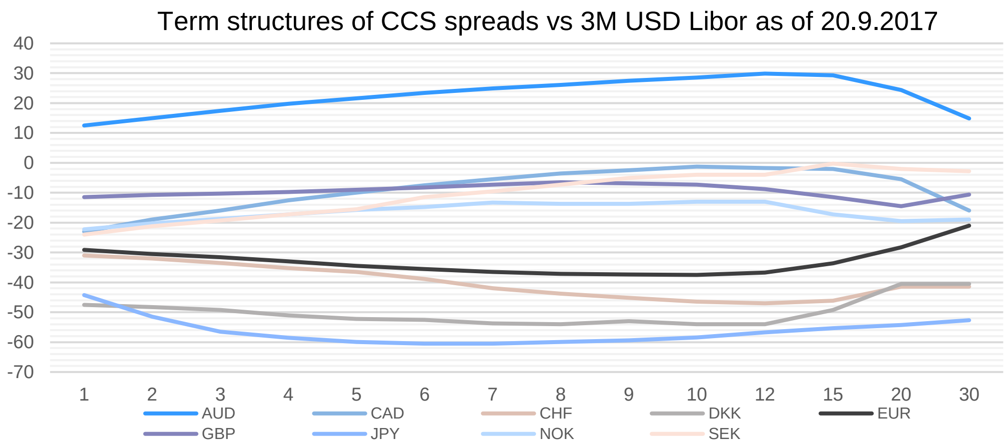


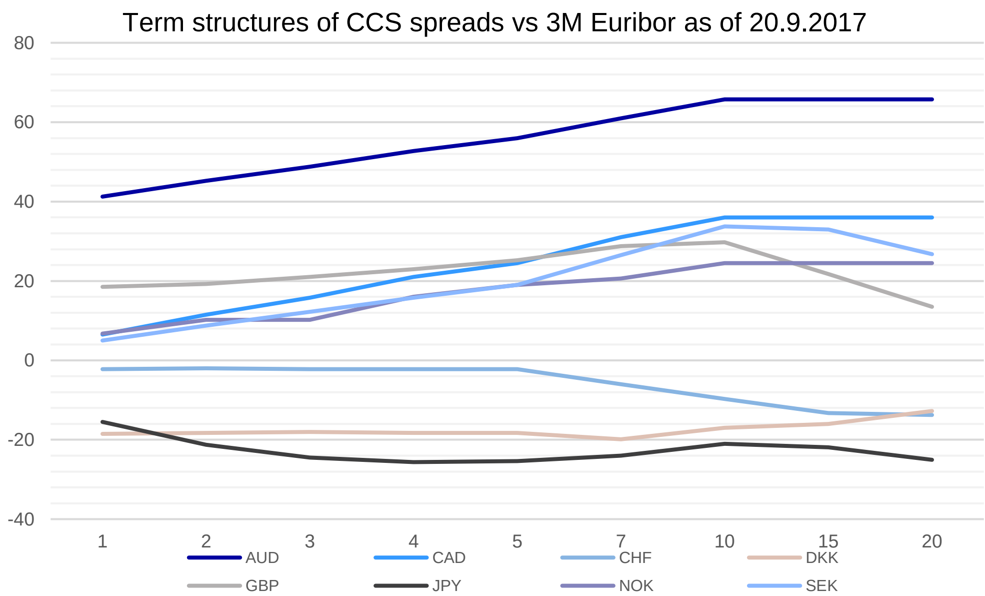


Appendix 2. Linkage between the spot rate and 5y XCCY basis. (Source: Bloomberg).

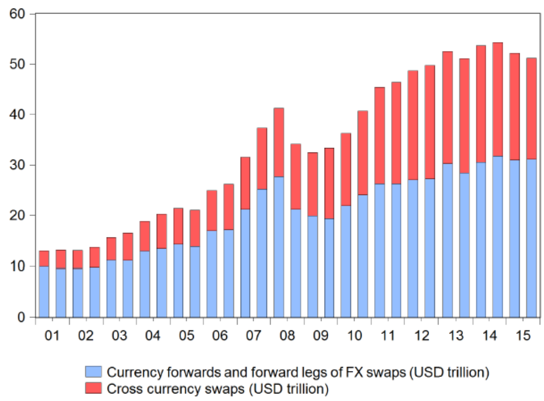


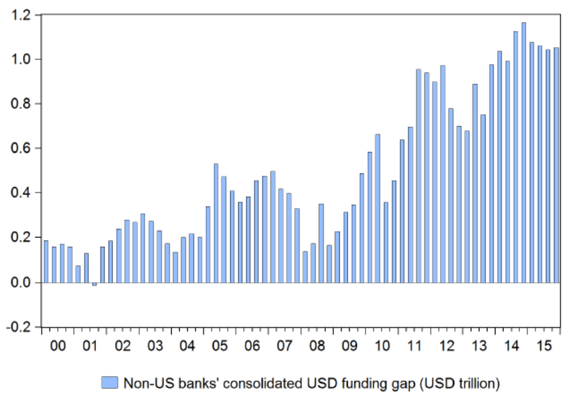
Appendix 3. Term structures of different CCBS spreads vs 3m Euribor and USD Libor as of 20.9.2017. (Source: Bloomberg).



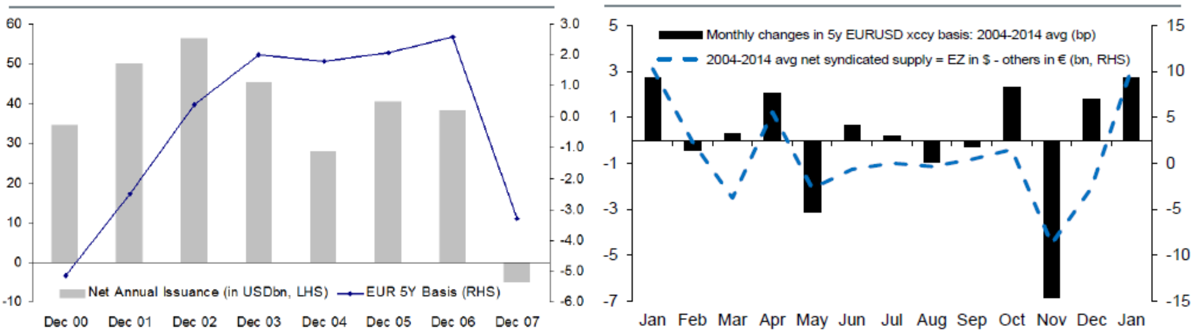


Appendix 4. The rising maturities of cross-currency funding instruments and USD XCCY funding of global banks. (Source: Sushko et al., 2016).

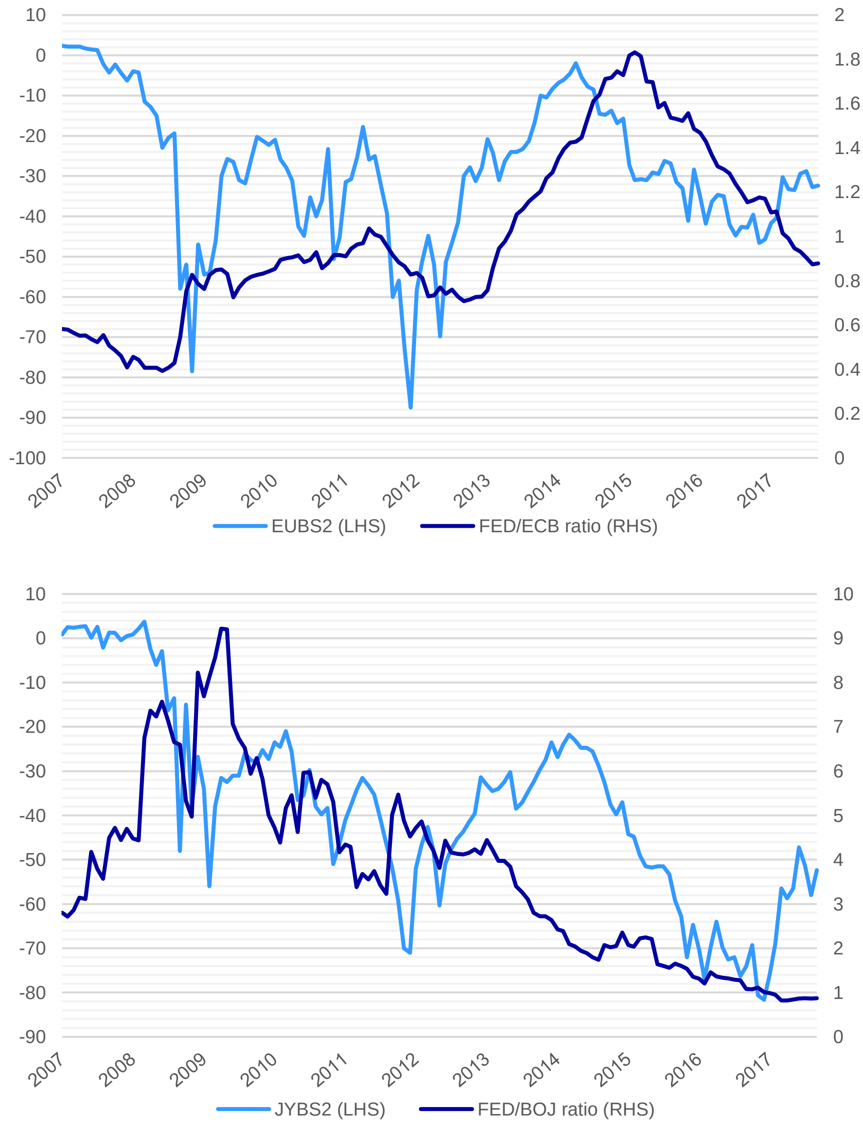




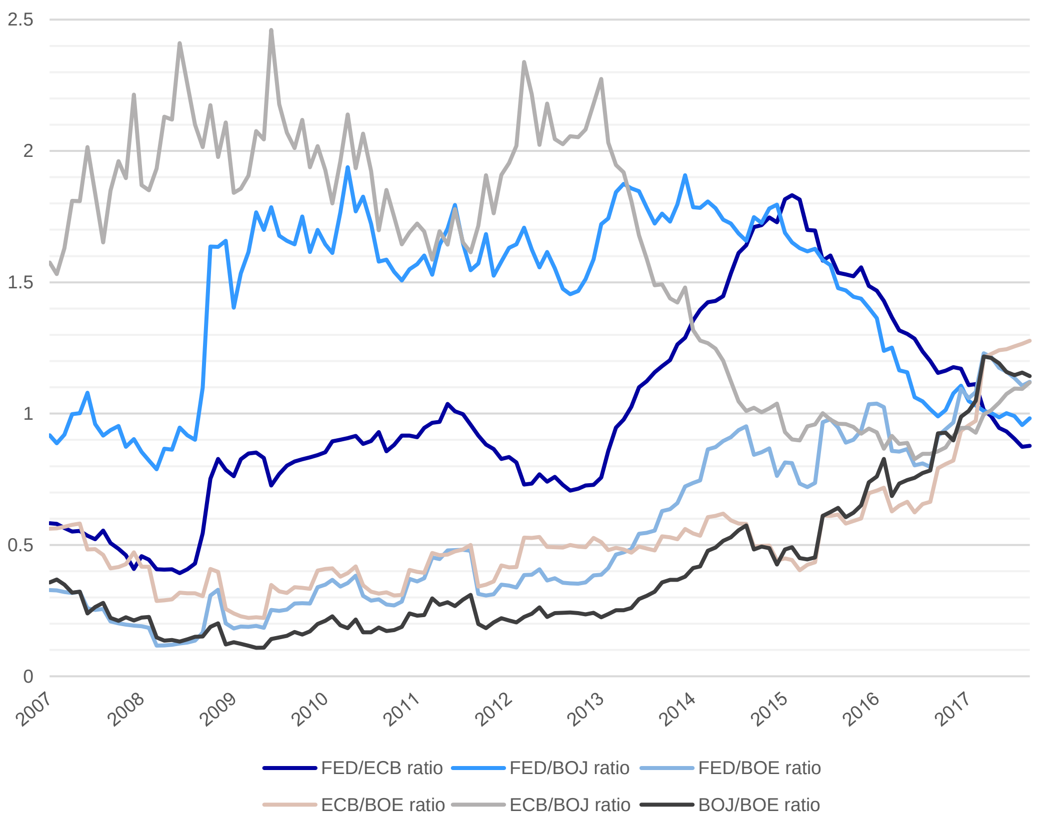
Appendix 5. Net bond issuance in USD vs 5Y EURUSD XCCY Basis (LHS). Monthly issuance and changes in the basis (RHS). (Source: De Courcel, 2015).



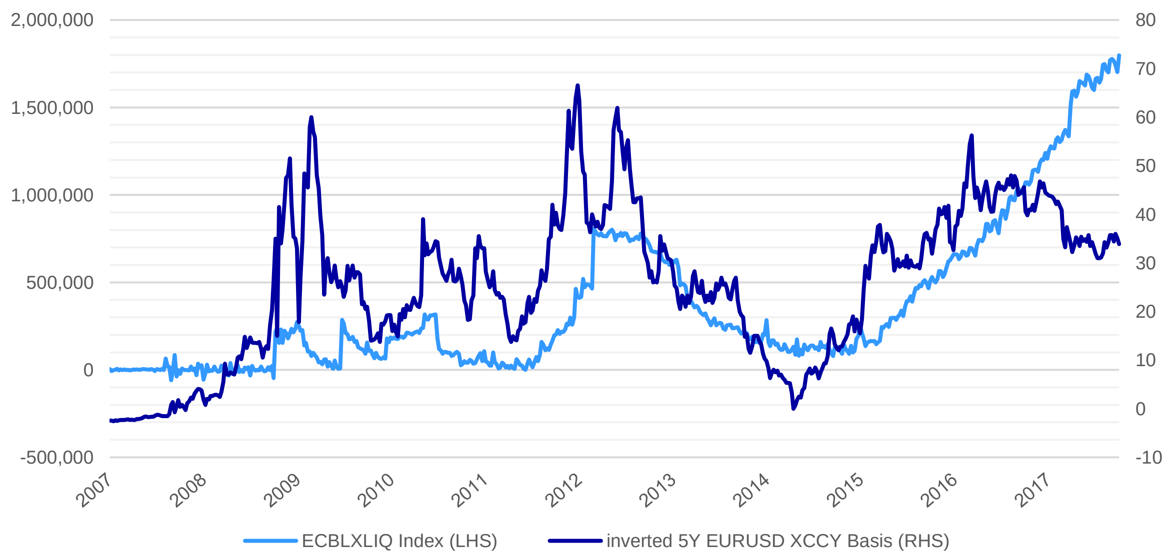
Appendix 6. Central banks' total assets' ratios vs 2y XCCY basis. (Source: Bloomberg and author's calculations).



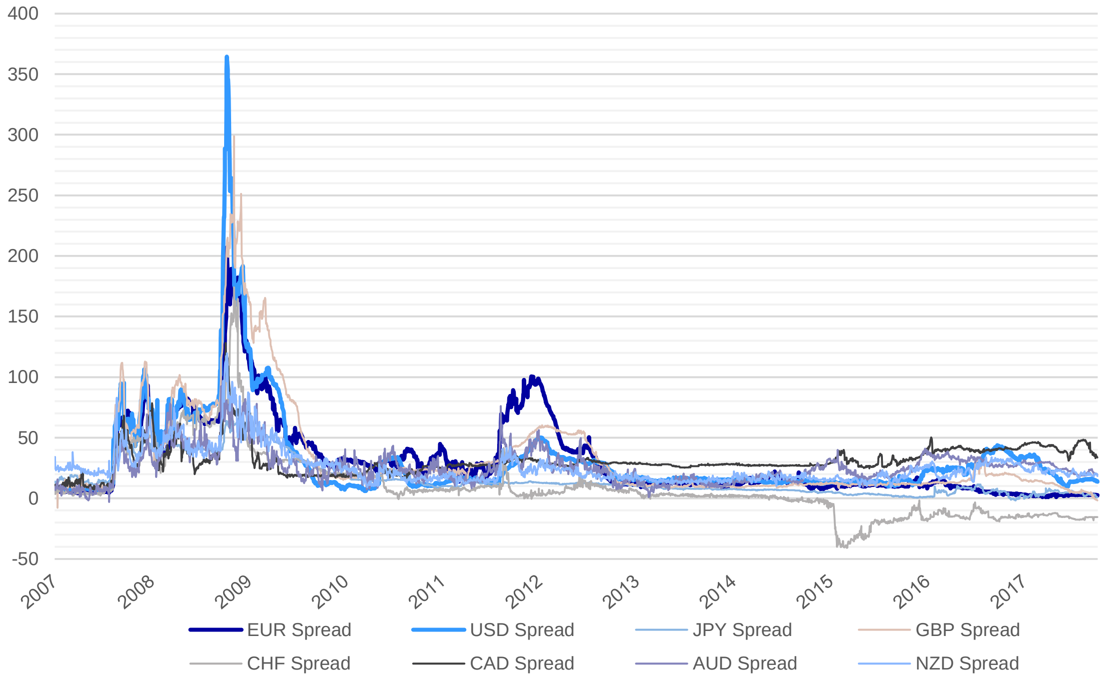
Appendix 7. Central banks' total assets' ratios. (Source Bloomberg and author's calculations).



Appendix 8. ECB Excess liquidity vs inverted 5y EURUSD XCCY basis. (Source: Bloomberg).

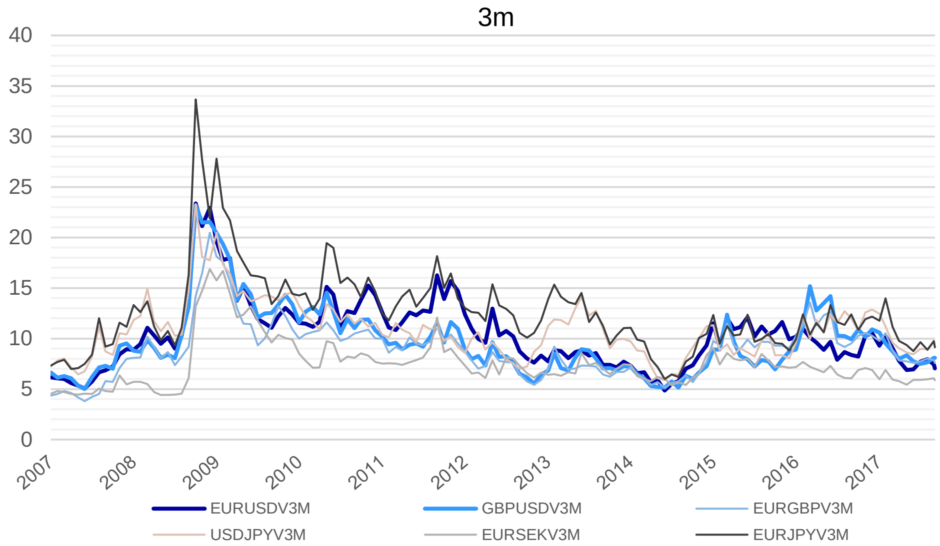


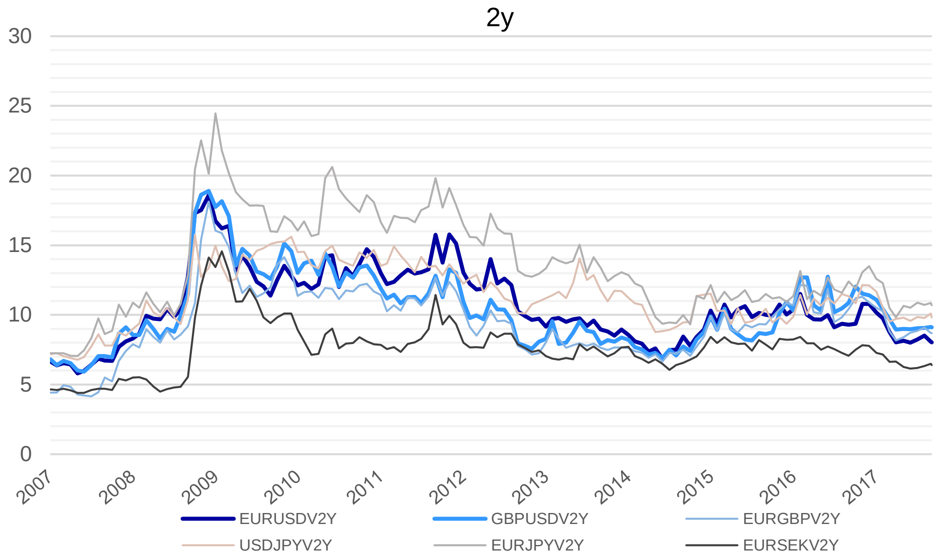
Appendix 9. 3m Libor-OIS spreads in main interest rates in bps. (Source: Bloomberg).

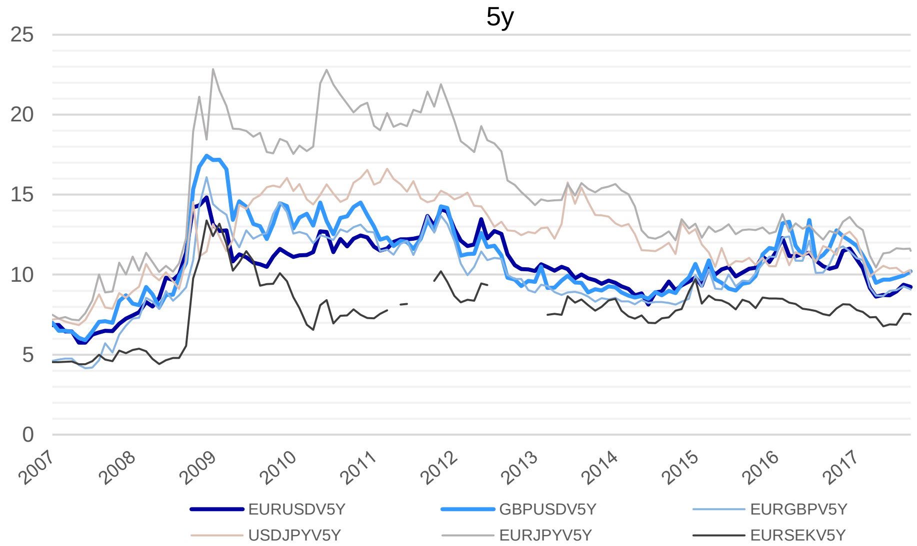


Appendix 10. CDS spreads of Euribor and Libor banks. (Source: Bloomberg and author's calculations).

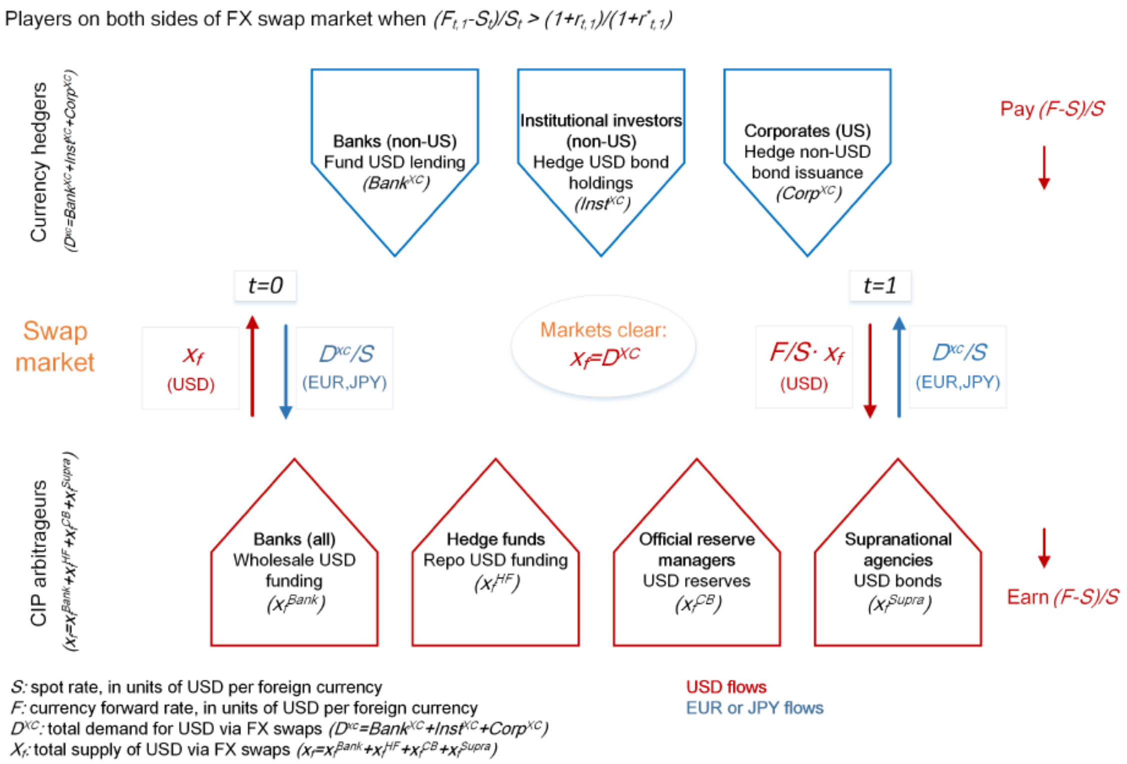
Appendix 11. 3m, 2y and 5y FX option-implied volatility in different currency pairs between 2007 and 2017. (Source: Bloomberg).







Appendix 12. Cash flows in an FX swap between currency hedgers and CIP arbitrageurs. (Source Sushko et al., 2016).

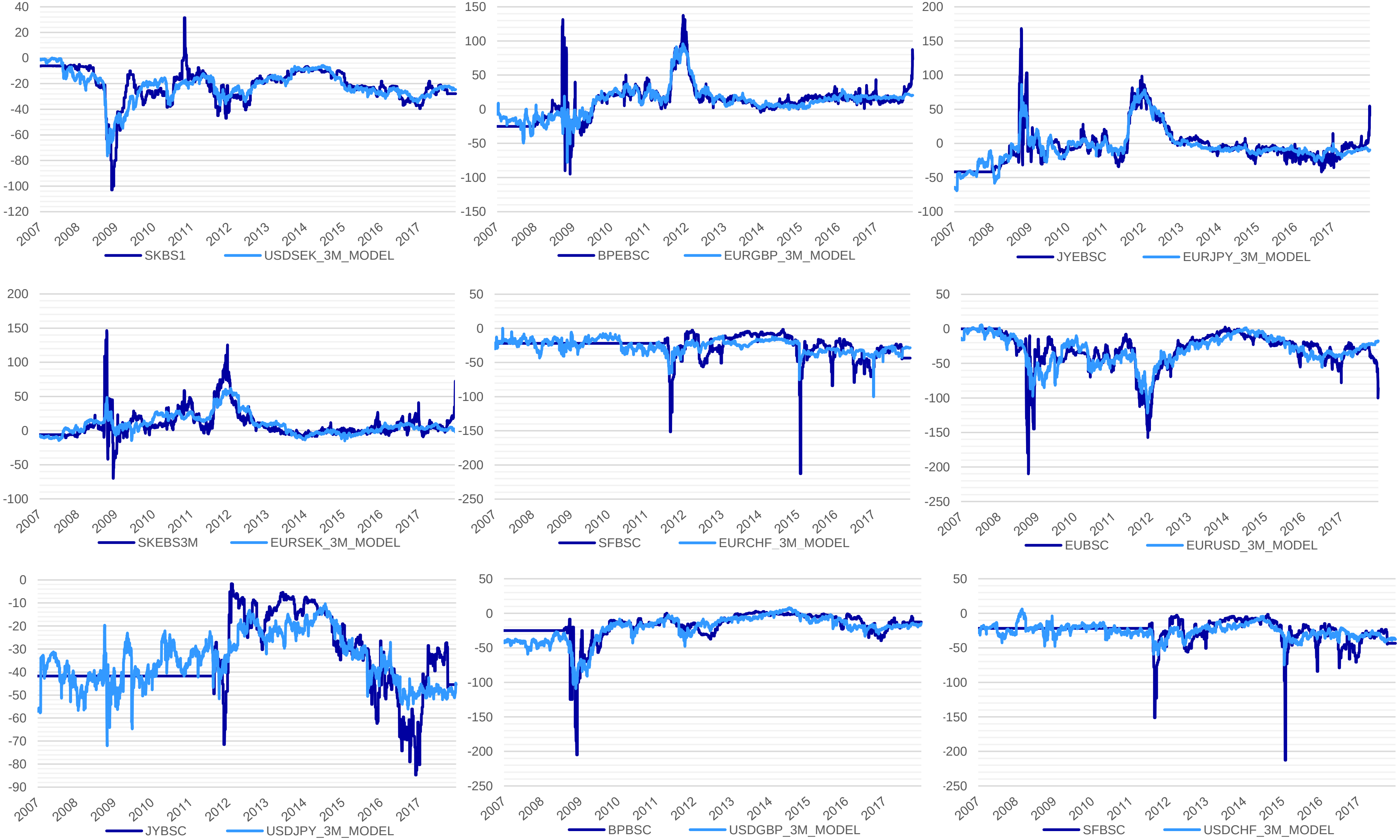


Appendix 13. Variables that significantly impact the different tenors' basis models.

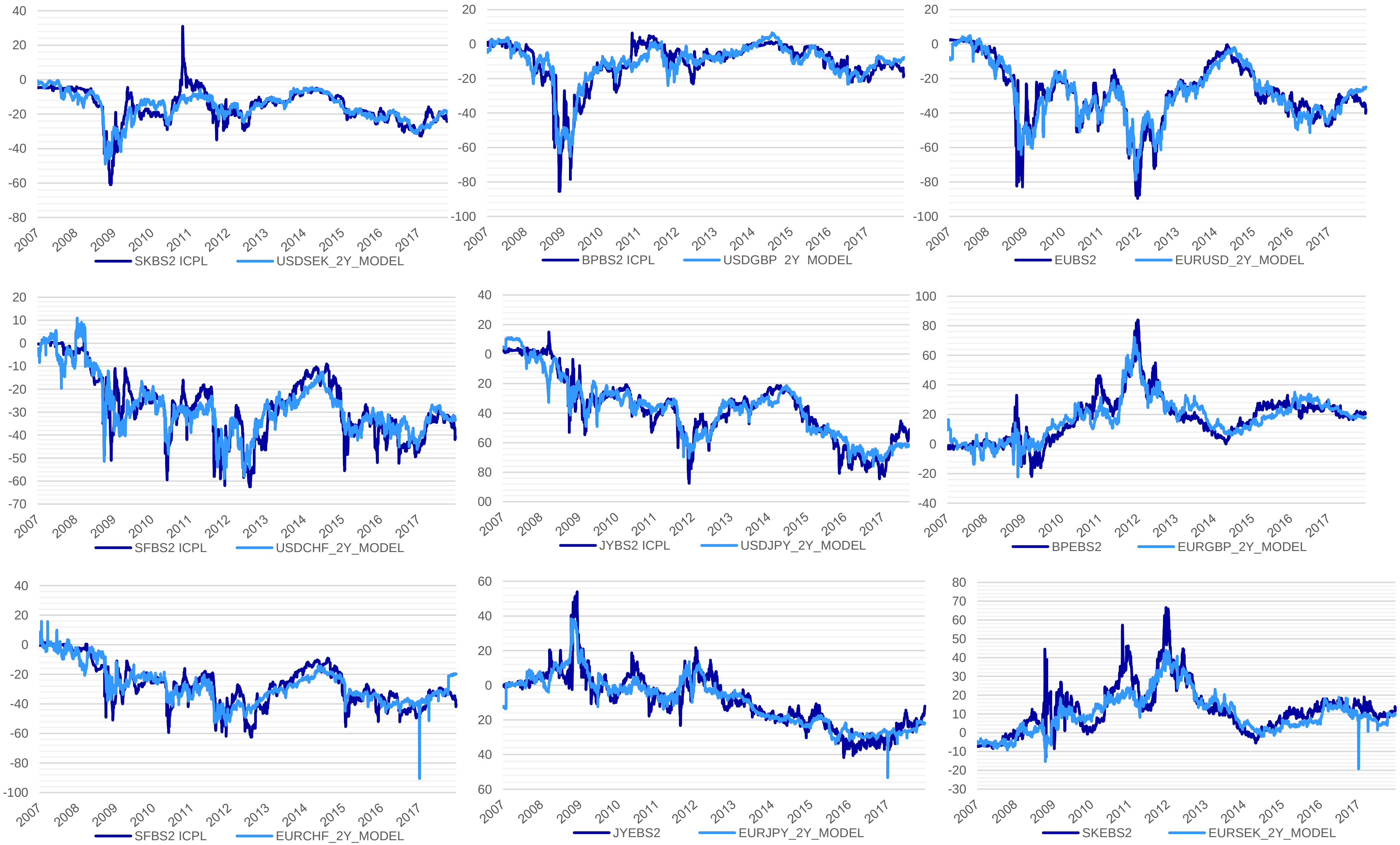
EURUSD	EURGBP	EURSEK	EURJPY	EURCHF
• USD Libor banks' CDS spread and Euribor banks' CDS spread • Total assets ratio between FED and ECB • Funding gap on US dollars in 9 Euro countries • Spread between general collateral overnight REPO funding for USD and EUR • Credit spreads between AA-and BBB-rated USD and EUR bonds denominated in their currencies with 3m, 2y and 5y tenors • Spread between USD Libor-OIS spread and Euribor-OIS spread • Swap line funding for ECB in USD • Implied volatility index • Implied volatility in USDEUR for 3m, 2y, 5y tenors • EURUSD FX-rate • Funding gap on Euros in US	• Euribor banks' CDS spread and GBP Libor banks' CDS spread • Implied volatility index • Total assets ratio between ECB and BOE • Funding gap on euros in Great Britain • Spread between general collateral overnight REPO funding for EUR and GBP • Spread between Euribor-OIS spread and GBP Libor-OIS spread • Implied volatility in EURGBP for 3m, 2y, 5y tenors • EURGBP FX-rate	• Euribor banks' CDS spread • Total assets ratio between ECB and Riksbank • Funding gap on euros in Sweden • Spread between general collateral overnight REPO funding for EUR and SEK • Credit spreads between AA-rated and government EUR and SEK bonds denominated in their currencies with 3m, 2y and 5y tenors • Spread between Euribor-OIS spread and Stibor-OIS spread • Implied volatility index • Implied volatility in EURSEK for 3m, 2y, 5y tenors • EURSEK FX-rate	• Euribor banks' CDS spread and JPY Libor banks' CDS spread • Implied volatility index • Total assets ratio between ECB and BOJ • Funding gap on euros in Japan and funding gap on yens in 9 European countries • Spread between general collateral overnight REPO funding for EUR and JPY • Spread between Euribor-OIS spread and JPY Libor-OIS spread • Implied volatility in EURJPY for 3m, 2y, 5y tenors • EURJPY FX-rate • Credit spreads between A-rated and BBB-rated EUR and JPY bonds denominated in their currencies with 3m, 2y and 5y tenors	• Euribor banks' CDS spread and CHF Libor banks' CDS spread • Implied volatility index • Total assets ratio between ECB and SNB • Funding gap on euros in Switzerland • Spread between general collateral overnight REPO funding for EUR and CHF • Spread between Euribor-OIS spread and CHF Libor-OIS spread • Implied volatility in EURCHF for 3m, 2y, 5y tenors • EURCHF FX-rate

USDGBP	USDSEK	USDJPY	USDCHF
• USD and GBP Libor banks' CDS spreads • Total assets ratio between FED and BOE • Funding gap on US dollars in Great Britain • Spread between general collateral overnight REPO funding for USD and GBP • Spread between USD Libor-OIS spread and GBP Libor-OIS spread • Swap line funding for Bank of England in USD • Implied volatility index • Implied volatility in USDSEK for 3m, 2y, 5y tenors • USDGBP FX-rate	• Implied volatility index • USD Libor banks' CDS spreads • Funding gap on US dollars in Sweden • Total assets ratio between FED and Riksbank • Spread between general collateral overnight REPO funding for USD and SEK • USDSEK FX-rate • Credit spreads between AA-rated and government USD and SEK bonds denominated in their currencies with 3m, 2y and 5y tenors • Spread between USD Libor-OIS spread and Stibor-OIS spread • Implied volatility in USDSEK for 3m, 2y, 5y tenors	• Funding gap on US dollars in Japan and funding gap on Japanese yens in US • Spread between USD Libor-OIS spread and JPY Libor-OIS spread • Implied volatility in USDJPY for 3m, 2y, 5y tenors • Credit spreads between A and BBB-rated USD and JPY bonds denominated in their currencies with 3m, 2y and 5y tenors • Swap line funding for Bank of Japan in USD • Spread between general collateral overnight REPO funding in USD and JPY • JPY and USD Libor banks' CDS spreads • Ratio between FED and BOJ total assets • Implied volatility index • USDJPY FX-rate	• USD and CHF Libor banks' CDS spreads • Total assets ratio between FED and Swiss National Bank • Funding gap on US dollars in Switzerland • Spread between general collateral overnight REPO funding for USD and CHF • Spread between USD Libor-OIS spread and CHF Libor-OIS spread • Swap line funding for SNB in USD • Implied volatility index • Implied volatility in USDCHF for 3m, 2y, 5y tenors • USDCHF FX-rate

Appendix 14. 3m actual basis vs constructed 3m basis models.



Appendix 15. 2y actual basis vs constructed 2y basis models.



Appendix 16. 5y actual basis vs constructed 5y basis models.