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Covered Interest Rate Parity Violations: Can they be anticipated?

By

Dominic Piana
Matriculation number: S13557079

Submitted to:
Dr. Peter Schwendner
Senior Lecturer for Asset Management and Risk Management
ZHAW School of Management and Law

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Management Summary

The covered interest rate parity (CIP) condition is widely known and taught in academia. Since the Great Financial Crisis, sustained violations of the CIP condition have occurred, pointing to arbitrage opportunities. Pinnington and Shamloo (2016) investigated these deviations for the foreign currency cross-currency basis (basis) against Swiss franc, with a focus on the first half of 2015.

The objective of this paper consisted of analyzing violations from CIP between January 2011 and December 2016 for the US dollar, Euro and British sterling basis against Swiss franc and whether changes in the basis could have been anticipated with implied FX volatilities. A focus was laid on the negative deviations, signifying that the interest rate earned over the synthetic replication is higher than over the direct investment. Therefore, the cross-currency bases from 4 January to 30 December 2016 for the maturities of one-, two-, three- and six-month were analyzed, which led to a data sample per currency and tenor of n=1515. First of all, the data set was investigated for violations of the CIP condition. As the cross-currency basis was hardly never zero, a CIP trading range of 10 basis points above and 10 basis points below zero was determined to differentiate minor from substantial violations. In a second step, the changes in the basis were scatter plotted against the changes in implied FX volatilities.

The analysis revealed that CIP violations occurred during the covered period. The US dollar cross-currency basis exhibited the most negative CIP violations of all currency bases analyzed. It was found that the Euro bases showed more positive than negative violations, whereas positive and negative violations were approximately balanced for the British sterling. Generally, the shorter the tenor, the more negative deviations were observed. The cross-currency basis tended to decrease one month before the end of the year. This was detected for most tenors and currencies under analysis. The highest R^2 observed from the scatter plots stood at 0.0586.

It was concluded that the CIP violations offered substantial arbitrage opportunities. Generally, the cross-currency bases corrected around one month before year-ends and the shorter the tenor, the more pronounced the correction tended to occur. Furthermore, interest rate shocks or sudden changes in central bank policies were followed by a sharp correction of the basis which recovered within one month. Lastly, no evidence was found that changes in bases can be anticipated by changes in implied FX volatility.

Banks and financial institutions with ample balance sheet capacities should investigate if they want to take advantage of CIP violations, as they offer a possibility to increase their profits. With the acceptance of interest rate risk, the profits could be further increased as Swiss banks can borrow foreign currency from their clients and deposit the Swiss francs on the sight deposit at the Swiss National Bank. But before engaging in CIP arbitrage transactions, banks should calculate the resulting capital costs thoroughly, to evaluate whether the risk-free profits outweigh the capital costs involved.

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List of abbreviations

Base currency	First currency denominated in a currency pair
bps	Basis points
CDS	Credit default swap
CIP	Covered interest rate parity
CSA	Credit Support Annex
ECB	European Central Bank
FX	Foreign Exchange
G10 currencies	US dollar, Euro, British sterling, Japanese yen, Swiss franc, Australian dollar, New Zealand dollar, Canadian dollar, Norwegian krone and Swedish krona
GFC	Great Financial Crisis
IOER	Interest rate on excess reserves
IRS	Interest rate swap
ISDA	International Swap and Derivatives Association
LIBID	London Interbank Bid Rate
LIBOR	London Interbank Offered Rate
OTC	Over-the-counter
Quote currency	Second currency denominated in a currency pair
SNB	Swiss National Bank

1. Introduction

The covered interest rate parity (CIP) states, that borrowing in one country and lending in another, yields the same return for similar interest bearing assets when the Foreign Exchange risk is hedged with cross currency swaps, Foreign Exchange (FX) swaps or FX forwards (Akram, Rime and Sarno, 2008, pp.237). Any violation from CIP offers a riskless profit and would therefore be arbitraged away quickly (Akram et al., 2008, p.237). But since the Great Financial Crisis (GFC), persisting deviations from the CIP have been observed (Sushko, Borio, McCauley and McGuire, 2016). Sushko et al. (2016) concluded that the inclusion of market risk and counterparty risk in the pricing of FX derivatives increased the balance sheet costs and made trading against any CIP deviation costly. The repricing of market and counterparty risk increased the hedging cost for foreign currency. A hedging transaction, which generally involves the sale of foreign currency for a value date in the future, using currency swaps, FX swaps or FX forwards became costlier and deviated from the CIP condition. As stated by Akram et al. (2008) and as widely taught, the deviation from CIP was not arbitraged away.

After the GFC, it was observed that clients increased the cash holdings on their bank accounts (Levy, 2011). Treasury departments in banks and other financial institutions became aware of the deviation in CIP and deployed the foreign cash reserves to take advantage of these deviations. As Du et al. (2017) have pointed out in their study, the extend of the deviation, dubbed as basis, fluctuated significantly over the analyzed time horizon. The possibility to anticipate these deviations would allow banks and financial institutions to time their arbitrage transactions. Up to now, the published researched focused primarily on the US dollar basis against foreign currencies. This study will focus on CIP violations of the foreign currency bases against Swiss franc and whether these deviations could be anticipated using implied FX volatilities of the underlying currency pairs.

The paper has two main aims. First of all, to analyze whether violations from CIP have occurred for foreign currency bases against Swiss franc. The foreign currencies are determined as US dollar, Euro and British sterling. Secondly, whether the deviations could have been anticipated with implied FX volatilities. The focus will be laid on negative CIP deviations since they offer arbitrage opportunities, that can be exploited by borrowing foreign currency and hedge against this currency risk with a FX swap transaction.

To analyze the US dollar, Euro and British sterling basis against Swiss franc, the one-, two-, three- and six-month tenor will be considered. For the calculation of the foreign currency basis, the equation and procedure of Du et al. (2017, pp.8) will be consulted and adapted. Transaction costs will be taken into consideration. To do so, FX swaps will be evaluated at the prevailing bid-ask prices. Concerning the risk-free rates, the LIBID and LIBOR rates will be considered. This procedure offers the advantage of being close to market.

The findings may allow banks and financial institutions based in Switzerland to take advantage of arbitrage opportunities arising from violations of the CIP condition. Should they already be engaged in such arbitrage transactions, the possibility to anticipate changes in the basis would allow them to plan their trades in greater detail and increase their profitability. An increase of banks entering into arbitrage transactions can also be seen in the interest of hedgers of foreign currency, as an increasing number of banks diminishes CIP violations and reduces the incurred hedging costs.

The following chapters will start with a theoretical background section, which aims to explain CIP, FX swap and forwards as well as interest rate swaps (IRS) and cross currency swaps in greater detail. This section will be closed by a quick overview of the capital and leverage ratio requirements under Basel III. Secondly, the literature review will cover a selection of recent studies conducted about CIP deviations. Furthermore, the methodology will be elaborated in greater detail. In a next step, the results are going to be presented, starting with existence of CIP violations over the analyzed data sample and their corresponding implied FX volatilities. In a second step, the changes in basis and implied FX volatilities will be scatter plotted against each other. This should allow to discern whether changes in the basis can be anticipated with changes in FX implied volatilities. The results will afterwards be discussed and the conclusion will aim to tie everything together and provide a recommendation.

2. Theoretical Framework

2.1. Theoretical Background

This section aims to introduce frequently used terms and to delimit IRS, cross currency swap and the FX swap from each other as these terms tend to be confused.

2.1.1. Covered interest rate parity

The covered interest rate parity (CIP) is a non-arbitrage condition. It states that the interest rate of two assets with the same risk specifics should be equal in their return, once the currency risk is hedged (Sushko et al., 2016. p. 7). The textbook relationship between risk free interest rates, FX spot and FX forward rates should therefore be as follows:

$$Fwd = S\left(\frac{1 + r_F}{1 + r_D}\right)$$

Equation 1: Non-arbitrage condition for FX forwards. Adapted from Sushko et al. (2016, p.7)

In equation 1, Fwd is the FX forward rate, quoted as units of domestic currency for one unit of foreign currency. S refers to the FX spot rate, quoted as units of domestic currency for one unit of foreign currency. r_F signifies the foreign risk free interest rate, while r_D is the prevailing domestic risk free rate. If equation 1 does not hold, the CIP fails and arbitrage possibilities are theoretically possible (Du et al., 2017, p. 9).

$$P = \frac{FXS}{S} * \frac{D}{t}$$

Equation 2: Forward premium. Adapted from Finance Trainer International (n.d.-a, p.40)

To allow for comparability, the interest rate differential between the two currencies involved in a FX swap or FX forward is annualized and named premium (P). As stated in equation 2, FXS stands for the FX swap points, expressed in pips of the domestic currency. D signifies the day count convention of the currency lent at risk free while t refers to the duration of the FX forward or FX swap contract.

The cross-currency basis (basis) describes the deviation from the non-arbitrage condition. It compares the difference between a direct investment in foreign currency interest rate instruments to the synthetic foreign currency interest rate with use of FX swap or FX forward.

$$x = r_F - (r_D + P)$$

Equation 3: Cross-currency basis. Adapted from Du et al. (2017)

In equation 3, x stands for cross currency basis and P for the forward premium. The forward premium is the annualized interest rate differential between the two currencies. The basis is expressed in annualized basis points (bps) of the foreign currency. As an example, a basis of -30 bps would signify, that the synthetic foreign currency rate is 30 bps higher than with the direct investment.

2.1.1.1. Opportunities arising for Swiss banks from CIP violations

In the chapters to follow, the focus will be on Swiss banks that hold foreign cash reserves but report in Swiss francs. Therefore, the foreign currency basis of the US dollar, Euro and British sterling will be investigated against the Swiss franc. Violations from the CIP condition would open up additional income possibilities for Swiss banks and financial institutions. The arbitrage opportunities could be exploited with FX swaps and LIBOR rates.

This raises the question, whether the credit risk on these two instruments can assumed to be similar. Under Credit Support Annex (CSA) of the International Swap and Derivatives Association (ISDA) the counterparty risk can be ruled out, as initial margin is deposited as collateral and variation margins are exchanged on a daily basis to account for the positive and negative replacement value of the FX forwards and FX swaps (Du et al., 2017, p.15). Counterparty risk arising from interbank instruments is a legitimate concern. Du et al. (2017, pp. 14) have conducted a regression for changes in the LIBOR basis on the mean changes in the credit default swaps (CDS) for banks active in the interbank market. They concluded that the coefficient of CDS spreads to changes in the LIBOR basis are mostly negligible. In cases where the slope coefficient was negative, the R^2 does not exceed 0.023 (Du et al., 2017, p. 16). In the following chapters, LIBOR is therefore considered as being risk free. Transaction costs are taken into consideration to the extent that banks can borrow at LIBOR and lend at LIBID and FX transactions are transacted at the prevailing bid-ask rate.

Some Swiss banks and financial institutions may hold substantial foreign cash reserves from their clients or own positions. These banks may invest their foreign currency cash reserves in the interbank market to earn interest. A negative foreign currency basis would signify that the interest earned out of a FX lender swap is greater than the interest rate earned from a money market transaction. Instead of having to borrow foreign currency at LIBOR, banks could use their foreign currency cash reserves to enter into a FX lender swap. Moreover, Swiss banks are obliged to maintain a sight deposit account, denominated in Swiss franc, with the Swiss National Bank (SNB) to satisfy the minimum reserve requirements (Swiss National Bank, 2017). The negative interest rate charged on these accounts is lower than the prevailing Swiss franc LIBOR rate. Considering these circumstances, negative CIP violations open up a way to increase the earnings on foreign currency cash holdings. That being said, raising foreign currency from clients, conducting FX lender swaps and placing the Swiss francs at the SNB cannot be considered risk free. Different to the LIBOR contracts, the negative interest rate on the sight deposit account with SNB cannot be fixed. This exposes the bank to an interest rate risk on the Swiss franc deposit.

CIP violations offer risk-free arbitrage opportunities. For Swiss banks, negative deviations might be particularly interesting, as they could be used to increase the interest rate earnings on foreign currency cash holdings.

2.1.2. FX forwards and FX swaps

In the foreign exchange market, one currency is exchanged against another. The first currency denominated in a currency pair is referred to as base currency, the second currency as quote currency. In the interbank market, one unit of the base currency is shown as units of quote currency. For most currency pairs, the forth decimal is referred to as “pip” (Lehman Brothers, n.d., p.13).

FX spot transactions normally settle within two business days. Any FX transaction with a settlement date beyond this point is called a FX forward. They are either traded over-the-counter (OTC) or as FX futures listed on exchanges (Bloss, Ernst, Häcker and Sörensen, 2011, p.273). The OTC proportion of the overall FX forward market is estimated to be around 95% (Bloss et al., 2011, p.278).

A FX swap is the combination of a FX spot and a FX forward. When entering into a FX swap transaction, both parties agree to exchange one currency against another in the spot market while simultaneously converting the amounts back at a predefined point in the future. The currencies involved may have a different interest rate environment, which should be considered when pricing these contracts. Instead of exchanging interest rate payments, the interest rate differential is included in the price of the FX forward and FX swap transactions.

Bid Side Swap Points = S * (E2-E1) * (T/360) * 100

S = Spot Rate
E1 = Base Currency Lending (Offered) Rate of Interest
E2 = Terms Currency Borrowing (Bid) Rate of Interest
T = Number of Days to Maturity

Ask Side Swap Points = S * (E2-E1) * (T/360) * 100

S = Spot Rate
E1 = Base Currency Borrowing (Bid) Rate of Interest
E2 = Terms Currency Lending (Offered) Rate of Interest
T = Number of Days to Maturity

Figure 1: Calculating swap points (Lehman Brothers, n.d., p.84)

The formulas in figure 1 can be used to price FX forwards as well as FX swaps. For FX forwards, the FX swap points, expressed in pips of the quote currency, are directly added or subtracted to the current spot price, resulting in the FX forward price. When trading FX swaps, the market participants quote the FX swap points, which are then added or subtracted from the current FX spot mid-price. The FX swap and forward market show the highest liquidity for tenors up to one year (BIS, 2008) and FX swap markets tend to provide a higher liquidity than FX forward markets.

As an example, the USD/CHF FX swap points from 21 April 2017 at 16:00h CET are shown in figure 2. *Pts Bid* stands for the FX swap bid points, *Pts Ask* for the FX swap ask points and *SP* for the current USD/CHF spot rate. FX swaps always consist of two transactions. The first transaction usually settles with value date spot, whereas the second transaction has a value date at some point in the future. Whether to use bid points or the ask points, depends on the second transaction of the FX swap. A sale of US dollars on the second transaction would imply that the bid points have to be used. A purchase on the other hand, means that the ask points have to be considered.

Assuming a client is selling one million US dollar against Swiss franc with value spot, and simultaneously buying the US dollar back in one month. To price this FX swap, the current mid-market rate is retrieved. In figure 2, that is the average of the values right to *SP*, 0.9984 and 0.9985. The mid-market rate is therefore 0.99845, which is the price for the first transaction. For the second transaction, the FX swap ask points are subtracted from the mid-market rate, subsequently leading to a price of 0.996658. In this particular example, the client would sell one million US dollars and receive a counter value of 998’450 Swiss francs for the first transaction, while having to pay 996’658 Swiss francs on the second transaction to buy the US dollars back.

A similar procedure applies for the pricing of FX forwards. But as FX forwards only consist of one transaction, the current FX spot bid or ask rate is considered. In a second step, the FX swap bid or ask points are subtracted. Assuming a client would like to buy one million US dollar against Swiss franc in one month: In a first step, the current USD/CHF FX spot ask price being 0.9985 is retrieved and subsequently, the FX swap ask points for one month, standing at -17.92, are subtracted. The client could therefore buy one million US dollars in one-month at a price of 0.996708 Swiss franc per US dollar.

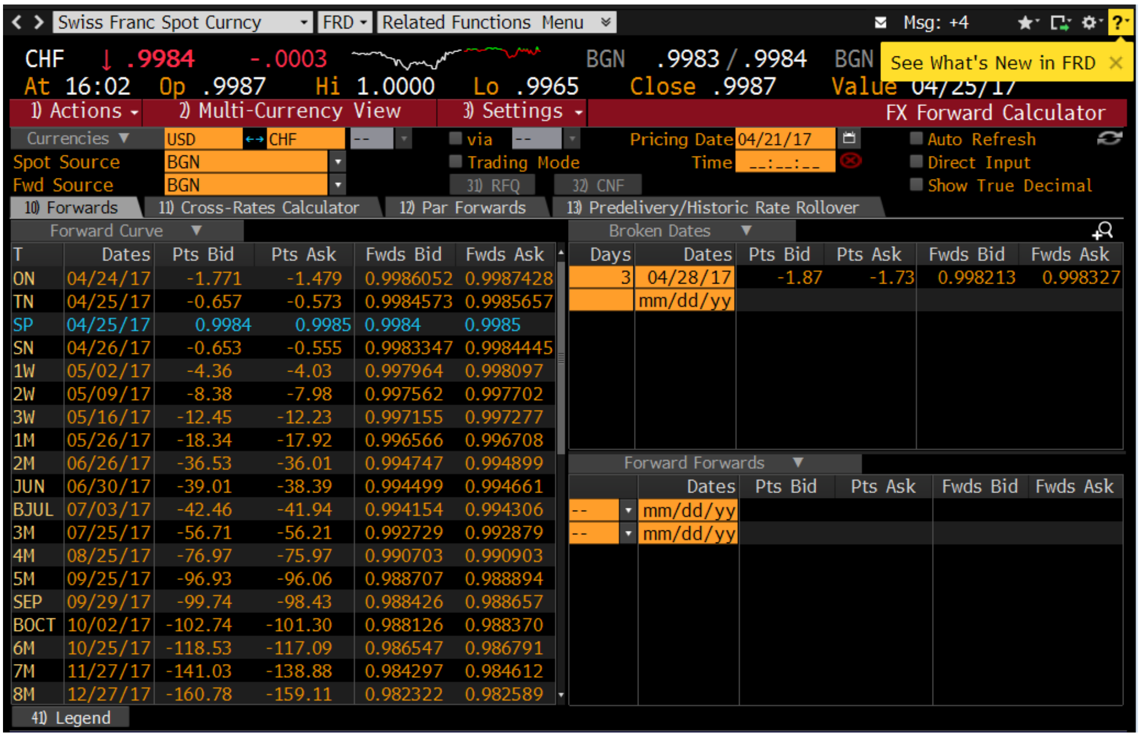

Figure 2:USD/CHF FX swap and FX forward points. Screenshot of FRD function in Bloomberg

FX forwards and FX swaps can be used to increase or decrease the length of maturities. In addition, they can be employed to hedge against currency risk. Assuming a Swiss franc based investor has bought an US dollar denominated stock: To hedge against a depreciation of the US dollar, the investor can sell the US dollar exposure with a FX forward. Should the US dollar deprecate, the currency losses occurred on the stock investments will be compensated with the profits from the FX forward. Furthermore, FX swaps and FX forwards can be used as instruments of liquidity management in banks and treasury departments, as they allow the funding and lending of money (BIS, 2008). Only FX forwards, but not FX swaps, can be used to speculate on currency movements (Bloss et al., 2011, p.278). Moreover, FX swaps and FX forwards can be used to take advantage of CIP violations.

A FX swap contract fixes the underlying interest rate environment and exchange rates. This may lead to an opportunity loss, as the participants no longer profit from upside or downside moves in the exchange rate. Another risk with FX swaps and FX forwards is the counterparty risk. In case of default of a counterparty, the position might has to be covered at current market rates. The counterparty risk can be mitigated almost exclusively with the International Swap and Derivatives Association (ISDA)'s Credit Support Annex (CSA). Under the CSA, the counterparties deposit initial collateral and agree to exchange daily variation margin for negative and positive replacement values resulting from open FX contracts (Du et al., 2017, p.16).

In the chapters to follow, FX swaps in which the second transaction consist of a purchase will be referred to as FX lender swaps. With the sell and purchase of foreign currency, the FX lender swap is the synthetic replication of a foreign currency deposit. Conversely, FX swaps, in which the second transaction consists of a sale of foreign currency, will be dubbed FX borrower swap. They imply a synthetic borrowing of foreign currency.

In the following chapters, there will be a focus on the FX lender swaps, with which the bank sells and purchases foreign currency against Swiss franc, signifying a synthetic replication of a foreign currency deposit in the interbank market.

2.1.3. Cross Currency Swaps

Cross currency swaps consist of the exchange of principals and interest payments from one currency into another. The principals in the respective currencies are fixed at trade date and the corresponding interest payments have to be made yearly (Hull, p.165). The interest rates can be fixed at trade date and stay the same for the whole term, referred to as "fixed against fixed" (Finance Trainer International, n.d.-a, p.25), change periodically in accordance with a reference interest rate, known as "floating against floating" (Finance Trainer, n.d.-a, p.26) or consist of one interest rate being fixed while the other may change according to an underlying reference interest rate, named "fixed against floating" (Finance Trainer, n.d.-a, p.26). The principal amounts in each currency are defined at trade date and take the prevailing FX rate into consideration (Hull, p.165). The tenor of cross currency swaps is usually greater than one year and is, among others, being used to transform borrowings of one currency into another (Hull, p. 166) or take advantage of comparative advantages (Hull, pp. 166). According to Hull (2012), comparative advantages is a situation where the domestic counterparty can borrow at lower interest in their home currency than foreign counterparties could. Hull (2012) cites tax reasons as a possible explanation for this phenomenon. It can be assumed that other factors like perceived creditworthiness and publicity of a counterparty have an influence as well. Furthermore, cross currency swaps can be applied to take advantage of CIP violations.

Figure 3 is a simplified illustration of a "fixed against fixed" (Finance Trainer International, n.d.-a, p. 25) cross currency swap. The first transaction involves the Bank A lending US dollar to Bank B, while Bank B lends Swiss francs to Bank A. Once a year, Bank A and B have to pay interest on the funds they hold. At maturity, Bank A returns the Swiss franc funds including interests to Bank B and Bank B returns the US dollar funds to Bank A including interest.

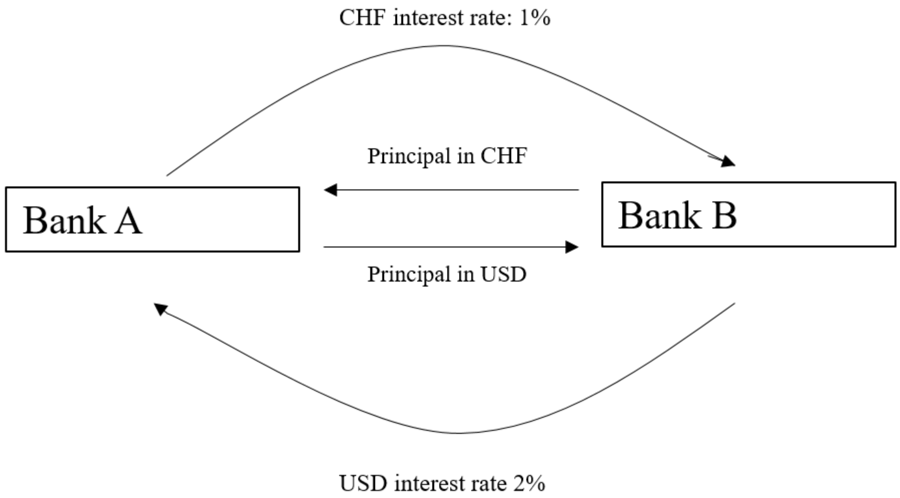

Figure 3:Illustration of cross currency swap. Adapted from Hull (2012, p. 166)

To sum it up, cross currency swaps show similarities to FX swaps, as both instruments consist of two transactions, one at the beginning and one at the end of the contract. Both can be used to hedge currency risk. While FX swaps tend to be used to hedge currency exposure with a maturity up to one year, cross currency swaps usually have tenors greater than one year. Moreover, cross currency swaps involve interest payments for the principal held, whereas the interest rate differential in FX swaps is expressed by FX swap points added or subtracted to the forward rate.

2.1.4. Interest Rate Swaps

In its basic form, an interest rate swap consists of exchanging a fixed against a floating interest rate. The currency denomination of the principal is the same and not exchanged between the counterparties (Hull, 2012, p.150). Interest rate swaps are primarily used to transform assets and liabilities or to make use of comparative advantages (Hull, 2012, pp. 151).

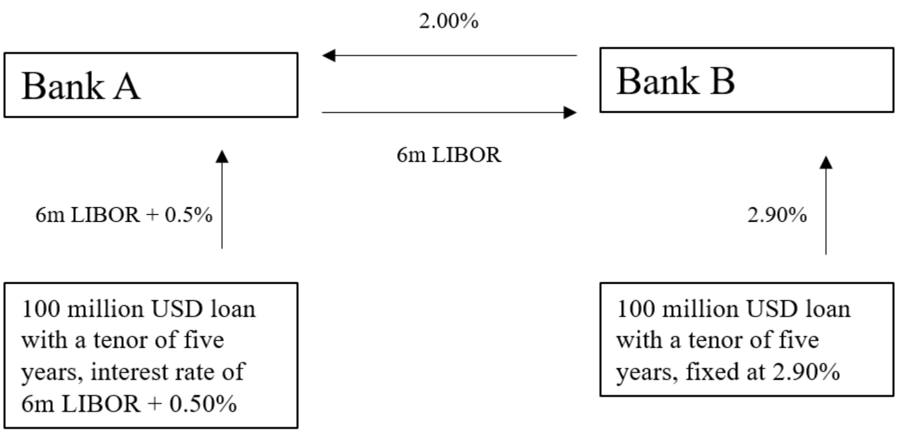

Figure 4: Example for transformation of assets with an IRS. Adapted from Hull (2012, p.151)

As illustrated in figure 4, Bank A has given out a loan, for which it receives the six-month LIBOR rate plus 50 basis points. Bank B on the other hand as an outstanding loan for which it receives 2.90%, irrespective of the prevailing LIBOR rate. Bank A expects falling interest rates and would like to exchange the floating nature of its outstanding loan into a fixed one. Assuming Bank B has the opposite market view, they can enter into an IRS transaction where Bank A receives fixed and pays the floating rate. Bank B is the "fixed-rate payer" (Hull, 2012, p.149) and receives the floating rate from Bank A. The interest is paid semiannually and the principal of 100 million US dollars is not exchanged, it is solely used as reference for the interest rate calculations. With the IRS shown in figure 4, Bank A has effectively hedged against falling interest rates.

Even as they may sound similar, interest rate swaps shall not be confused with cross currency swaps or FX swaps. IRS are used to hedge interest rate risks, transform assets and liabilities or make use of comparative advantages. Whereas cross currency swaps can be used to hedge currency risks and consist of an exchange of the underlying principal.

2.1.5. Capital and leverage ratio requirements under Basel III

In the aftermath of the GFC, the Basel Committee on Banking Supervision decided to reform the current regulatory framework, referred to as Basel II, with the aim to strengthen the global capital and liquidity rules of banks (BIS; 2011, p.1). The resilience of the global banking sector should be increased and prevent future turmoil and spillover effects on the real economy (BIS, 2011, p.1). The committee argued that one of the main reasons for the severity of the GFC were the substantial on- and off-balance sheet exposures of banks and the lack to capture the corresponding risk correctly (BIS, 2011, p.1). Furthermore, different definitions of the capital base combined with insufficient disclosures were hindering market participants to assess the capital quality between the different banks (BIS, 2011, p.2). The introduced reform package, dubbed "Basel III" (BIS, 2011, p.10) brought along, among others, substantial changes to the capital requirements (BIS, 2011). The definition of capital was standardized and capital requirements were increased for positions held in a bank's trading book and for OTC derivatives (BIS, 2011, p.8). The initiation of a leverage ratio intends to prevent banks from building-up excessive on- and off-balance sheet positions (BIS, 2011, p.61). During the transitional period, lasting until end of December 2018 (BIS, 2013), the capital requirements will increase incrementally until a Minimum Total Capital, including conservation buffer, of 10.5% has to be reached. In some jurisdictions, like Switzerland, national regulators have introduced legislation which surpasses the Basel III regulatory framework (FINMA, 2011, p.10).

The leverage ratio is non-risk adjusted and calculated by dividing the capital measure, which constitutes of Tier 1 capital, by the exposure measure which is the on- and off-balance sheet exposure of a bank (BIS, 2014). As of 2018, the regulator will demand a leverage ratio of greater than three percent (BIS, 2014). Depending on the jurisdiction and the systematic relevance, some banks may face higher requirements. Taking Switzerland as an example, systematic relevant banks are required to fulfill a leverage ratio of greater than five percent (FINMA, 2015). As the leverage ratio does not take the underlying risk of a balance sheet position into consideration, a money market transaction leads to the same capital requirement as a riskier consumer credit of the same amount. This may encourage banks to refrain from money market transactions, which generally incorporate high denominations but low counterparty risk. A study conducted by Bindseil and Nelson (2015) concluded that the Basel III regulation "may result in a reduction of the ease, and therefore in the amount, of certain types of arbitrage activity across financial markets" (p.36). Furthermore, a study conducted by Deloitte (2014, p.12), estimates that the changes in regulatory requirements have led to an increase of 2.15 basis points for uncleared FX derivatives including FX swaps and cross currency swaps and 1 basis point for uncleared interest rate swaps.

In the chapters to follow, the focus will be on CIP deviations. The replication of a FX lender swap will be undertaken with LIBOR and LIBID rates. The leverage ratio seems to be a substantial cost driver when entering into an arbitrage transaction. Even though the underlying transactions are of short duration and incorporate relatively low risk, they increase a bank's balance sheet due to their high denomination. As Du et al. (2017, p.26) pointed out, the benefit of entering into an arbitrage transaction must be bigger than the required capital costs to make the transaction economically viable. This could mean that certain arbitrage opportunities are not being exploited, as the true associated balance sheet costs are higher than the risk-free profits resulting from it.

2.2. Literature Review

The purpose of this section is to review and analyze the current state of research conducted for deviations of covered interest rate parity (CIP). The focus will be on the papers from Sushko, Borio, McCauley and McGuire (2016), Du, Tepper and Verdelhan (2017) and Pinnington and Shamloo (2016).

Sushko et al. (2016) analyzed, whether the hedging demand has an influence on the CIP deviation and its persistence since the GFC can be explained by increased balance sheet costs. The authors focused primarily on long-term CIP deviations.

For the measurement of hedging demand, Sushko et al. (2016) citied McGuire and von Peters' (2012) approach, which they augmented by including FX hedging demand from institutional investors and corporate bond issuances. To measure the balance sheet costs, Sushko et al. (2016) relied on the counterparty risk, derived from the LIBOR-OIS-spreads and the market risk, measured by the implied FX volatility. They argue that the approach for pricing FX derivatives has changed since the GFC. Until the GFC, FX derivatives were priced marked-to-market and the increase in market share was considered one of the top priorities for banks. This allowed banks to increase their balance sheet virtually unrestrictedly in response to volumes demanded by the market and conducted by the swap trading desks (Sushko et al.,2016). According to Sushko et al. (2016) this altered in the period following the 2008-2011 crisis. Banks changed to a more cost sensitive approach of FX derivatives pricing, including counterparty risk at all times. The increase in balance sheet costs refrained banks to conduct arbitrage that would have brought the CIP deviations back into balance. Sushko et al. (2016) focused their research on the JPY/USD basis, which has shown the biggest CIP deviation since the GFC. They conclude that the variation in the JPY/USD basis can be explained by two factors, the first being the aggregated hedging demand. The bigger the hedging demand of Japanese companies and banks, the bigger the variation in the JPY/USD basis. The second factor is the funding condition in the repo market. Arbitrageurs can take the opposite positon of hedgers by raising US dollar fund over repo transactions and enter into FX swap transactions. A tightening of the repo market led to an increase in funding costs for entering into arbitrage transactions. Sushko et al. (2016) claimed that neglecting the hedging demand, the short-term basis is almost exclusively determined by LIBOR-OIS spreads, repo spreads and market liquidity. They are more volatile and have a tendency to widen in stressed situations. The long-term basis is primarily driven by demand shocks from hedging transactions. Sushko et al. (2016) found the same effects of hedging demands on the basis for other freely convertible currencies, among others the Australian dollar, Canadian dollar, Swiss franc Euro and the British sterling.

The implication of funding gaps on the respective currency basis was convincingly laid out by Sushko et al. (2016). For the measurement of the balance sheet costs, the paper relied on market and counterparty risk. The market risk arises from the default of the counterparty and the resulting market risk of covering the outstanding transaction at current market rates. Sushko et al. (2016) claim that changes in pricing of the FX derivatives increased the balance sheet costs. The International Swaps and Derivatives Association (ISDA), founded in 1985 (ISDA, 2013), issued the ISDA Master agreement. It aims to standardize the over-the-counter (OTC) derivatives business by providing legal frameworks and prewritten contracts. The credit support annex (CSA) defines, among others, the risk mitigation between counterparties for outstanding OTC derivatives (ISDA, 2013b, p.8). Initial collateral is deposited between counterparties when entering into an OTC derivative transaction and daily variation margin is exchanged to account for negative and positive replacement values (Du et al., 2017, p.16). These measures should therefore reduce market and credit risk substantially. Counterparties entering into a FX swap or cross currency swap with each other, both having signed the ISDA Master agreement as well as the CSA, should therefore be able to reduce or eliminate the counterparty and market risk in the pricing of FX derivatives.

The claim of Sushko et al. (2016), that balance sheet costs are a reason for the absence of arbitrageurs to close the currency basis, seems legitimate. However, the question arises if counterparty risk and market risk are the appropriate ways to measure them.

Similar to Sushko et al. (2016), Du, Tepper and Verdelhan (2017) focused on deviations from covered interest rate parity but demonstrated that credit risk cannot explain the persistent CIP deviations. Their sample included the most liquid currencies, dubbed G10 currencies, between 2010 and 2016. Counterparty risk was analyzed using the credit default swap (CDS) spreads of banks between 2010 and 2016. The counterparty risk arose from the unsecured LIBOR lending. The FX forward or FX swap transactions on the other hand, were sufficiently secured under the CSA agreement. Du et al. (2017) have found no significant influence of the CDS spreads on the deviations from CIP. To demonstrate that the CIP deviations are persistent, even in the absence of credit risk, Du et al. (2017) examined the currency basis using repo transactions for tenors up to one year and Kreditanstalt für Wiederaufbau (KfW) bonds in different currencies, for tenor greater than one year. They chose KfW bonds because KfW is an AAA-rated German bank with its liabilities fully backed by the German Government (Du et al., 2017, p.20) and issues substantial amounts of bonds denominated in different currencies. Du et al. (2017) found a persistent negative basis against Japanese yen, Swiss franc and Danish krona based on repo transactions and a persistently negative basis for the Euro, Japanese yen, Swiss franc and Danish krona when based on KfW bonds and taking transaction costs into consideration. The annualized arbitrage opportunities ranged from 9 basis points to 20 basis points with a substantial variation over the time series and a standard deviation of 5 to 23 basis points (Du et al., 2017, p.4). As these investments were to have a conditional volatility of 0, the sharp ration would be infinite (Du et al., 2017, p. 4). After Du et al. (2017) had identified persistent arbitrage opportunities, they sought possible explanations.

They formed the hypothesis that the persistent CIP deviation can be explained by the increased costs of financial intermediation since the GFC and imbalances in the international investment demand and supply across different currencies. The higher financial intermediation costs seem to have spillover effects to other potential arbitrageurs such as hedge funds, money market funds, reserve managers and corporate issuers, as they rely on funding and leverage from regulated entities to make their strategies attractive (Du et al., 2017, p.28). Du et al. (2017) found four main characteristics to prove the CIP deviations: First, the basis increased towards quarter ends. The tighter balance sheet regulation and quarterly reporting requirements seemed to have an influence on the currency basis. The one-month contract increased substantially exactly one month before the end of the quarter (Du et al., 2017, p. 4). A similar increase was observed by Du et al. (2017) for the one-week contract exactly one week before the end of the quarter. No substantial increases were observed for three-month contracts, as they most likely always appear on the banks' balance sheet over quarter end. This led Du et al. (2017) to the conclusion that financial regulation has a casual impact on asset prices. Secondly, Du et al. (2017) demonstrated that one third to one half of the CIP deviation can be explained by analyzing the Interest Rate on Excess Reserves (IOER) and the Fed Funds or LIBOR rate as proxy for the balance sheet costs. The authors elaborated that in absence of any balance sheet constraints, banks would borrow at LIBOR or Fed Funds rate and place the funds risk free at the IOER. They interpret the spread between the Fed Funds rate and the IOER as the "shadow cost of leverage" (Du et al., 2017, p. 5). Furthermore, Du et al. (2017) demonstrated that the cross-currency basis is correlated with the nominal interest rates. Taking the US dollar as the base currency, high nominal interest rates lead to a positive basis and low nominal interest rates to a negative basis. An arbitrageur would therefore borrow in currencies with high nominal interest rates like the Australian dollar or the New Zealand dollar and lend in currencies with a low nominal interest rate. Contradictory to the classical carry trade, where investors fund in low yielding currencies and invest in high nominal interest rate currencies. Du et al. (2017) have shown that the currency basis is affected by interest rate shocks. To measure this claim, they analyzed the currency basis during the European Central Bank (ECB) interest rate decisions, starting with the interest rate announcement until the end of the press conference. Lastly, Du et al. (2017) found that the currency basis is correlated with other liquidity spreads, especially the LIBOR tenor basis and the KfW – German Bund basis.

Du et al. (2017) demonstrated that persistent deviations in CIP cannot be explained by credit risk. For their analysis, Du et al. (2017) have focused on the US dollar as base currency for the basis. This raises the question, what effects could be observed, if the basis of not only the US dollar but the Euro and the British sterling would be analyzed. Instead of studying the basis of the latter against a wide basket of currencies, only the Swiss franc could be considered. Especially, as the US dollar exhibited a negative basis against Swiss franc of on average -20 bps (Du et al, 2017, p.11). According to Du et al. (2017), the basis is affected by interest rate shocks. The Swiss franc exhibited a sudden reduction of the interest environment after the discontinuation of the minimum exchange rate in January 2015 (SNB, 2015). It would therefore be interesting to analyze, whether CIP deviations for other major currencies could be observed against Swiss francs. Furthermore, whether changes in the basis could be anticipated by studying other measures of increased uncertainty and prevailing risk sentiment, such as implied volatilities.

Pinnington and Shamloo (2016) focused on the CIP deviations for Swiss franc crosses in the first half of 2015, when the Swiss National Bank abolished the minimum exchange rate between the Euro and the Swiss franc. They claim that reduced liquidity is responsible for the deviation in CIP and not funding difficulties. The uncertainty succeeding the abolishment of the minimum exchange rate led to higher implied volatilities and increased currency hedging demand by non-financials, investors and corporates (Pinnington and Shamloo, 2016, p.2). These elements, combined with the reduced leverage capabilities of FX swap market makers, widened the bid-ask spreads for FX forwards and FX swaps. A condition, which according to Pinnington and Shamloo (2016) persisted until the end of their sample in mid-2015. To prove their claim, Pinnington and Shamloo (2016) decomposed the CIP deviation into three components: First, the market distortions, measured by the mispricing of FX forwards and FX swaps, secondly the interbank market distortions, analyzed based on the funding pressures between two currencies and lastly the transaction costs, identified by the bid-ask spreads. Pinnington and Shamloo (2016) concluded that FX forward mispricing only played a role in the days following 15 January 2015. But the biggest impact on the deviations in the first half of 2015 can be attributed to an increase in transaction costs. Pinnington and Shamloo (2016) found that CIP deviations could be observed in non-Swiss franc currency pairs as well. Pointing to the fact that distortions following the SNB's 15 January decision had a wide-ranging impact on CIP deviations. Generally, the deviations were more severe for the 30-day basis than for the 90-day. The authors briefly analyzed the impact on the currency basis for cross currency swaps. They argue that the long-term deviations are affected mostly by funding problems resulting from increased central bank liquidity. The increased monetary base in the eurozone has pushed yields down, attracting US-based firms to issue debt in EUR and hedge the currency risk with cross currency swaps, putting pressure on the currency basis. The deviations in the long-term currency basis were already observed prior to the abolishment of the Euro against Swiss franc minimum exchange rate in January 2015 (Pinnington and Shamloo, 2016, p.10). Pinnington and

Shamloo (2016) conclude that short term deviations were mostly driven by wide bid-ask spreads whereas longer-term deviations resulted from funding imbalances between two currencies.

In Pinnington and Shampoo's (2016) analysis, it can be seen that the 30-day CIP deviations for EUR/CHF as well as USD/CHF were more volatile than for the 90-day horizon. Considering the research conducted by Du et al. (2017), this could prove the fact that 30-day FX swap contracts are subject to the "quarter-end effects" (Du et al., 2017, p.34), increasing the standard deviation of the latter. Pinnington and Shamloo (2016) have argued that increased implied volatilities have led to wider bid-ask spreads, resulting in persisting CIP deviations. This raises the question, to what extend deviations could be anticipated by analyzing implied FX volatilities.

2.3. Methodology

Violations from CIP have been observed, among others, in the studies from Sushko et al. (2016), Pinnington and Shamloo (2016) and Du et al. (2017). Different explanations were stated for the CIP deviations. Sushko et al. (2016) and Du et. al (2017) based their research on the US dollar as reporting currency. Pinnington and Shamloo (2016) focused on Swiss franc crosses but primarily on the deviations in the first half of 2015. In research conducted by Du et al. (2017) the US dollar basis against Swiss franc was persistently negative, pointing to arbitrage opportunities that could be exploited with a FX lender swap.

The following chapters will therefore focus on arbitrage opportunities for banks and financial institutions with reporting currency Swiss franc. The time horizon spans from the first trading day of 2011, 4 January, until 30 December, the last trading day of 2016. It covers FX lender swaps in US dollar, British sterling and Euro. The chosen time span covers different political and regulatory events as well as the introduction and abolishment of the minimum exchange rate between the Euro and the Swiss franc. Furthermore, it will investigate whether deviation from CIP can be anticipated by using the implied volatility of the underlying currency pair.

To answer the research question, a data set containing the FX swap ask points, FX spot rates and implied volatilities for the one-month, two-month, three-month and six-month tenor of the underlying currency pairs USD/CHF, GBP/CHF and EUR/CHF was retrieved from Bloomberg. Bloomberg aggregates quotes from different liquidity providers into the

Bloomberg Composite (Bloomberg, 2017), which gives a representative level of prevailing market prices. For reasons of consistency, the last price of the trading day at 23:00h Central European time (CET) was considered. As a reference for the risk-free rate, the corresponding LIBOR rates for US dollar, British sterling, Euro and Swiss franc were retrieved. The LIBOR rate is widely known and was therefore chosen over the Overnight Index Swap (OIS) rate as reference rate. Due to bank holidays in the United Kingdom, LIBOR rates may not be fixed for every trading day in the FX market. To allow the comparability of the data, the CIP deviations were only analyzed on days when a LIBOR fixing took place.

The day count in the FX and money market is mostly either the actual days divided by 360 or actual days divided by 365. The actual days may differ from the standard tenor due to holidays or in February due to the shortened month. As an example, the one-month maturity is usually 30 days, but should the expiry fall on a holiday, the contract expires on the next trading day, which could lead to a one-month contract incorporating 31 or more days. To account for these deviations, every day in the data set was assigned with the corresponding maturity using the Bloomberg functionality in Excel shown in equation 4:

```
= BDP("EUR1M BGN CURNCY"; "DAYS_TO_MTY";"REFERENCE_DATE";TEXT(CELL;JJJJMMTTT"))
```

Equation 4: Bloomberg day count functionality in Excel.

EUR1M BGN CURNCY stands for the one-month EUR/USD FX swap contract. The tenor can be changed by adjusting 1*M*. The term *DAYS_TO_MTY* stands for the duration a EUR/USD FX swap contract had at *REFERENCE_DATE* defined in *CELL*. For simplicity, the duration of the EUR/USD FX swap contract was taken as reference for the calculation of the annualized forward premium.

In a next step, the annualized forward premium (*P)* was calculated and from there on, the corresponding cross currency basis (x) is determined. To account for transaction costs, foreign currency has to be borrowed at LIBOR whereas domestic currency can be lent at LIBID. LIBID is calculated by subtracting 0.125% from the prevailing LIBOR rate. For FX swaps, the calculation is based on the current mid-market rate of the underlying currency pair. Transaction costs were taken into consideration by deployment of the FX swap ask points which trade at a spread over the FX swap mid-points. The following example illustrates the calculation of the basis:

USD/CHF FX swap Ask points (FXS_{Ask})	-20.52
USD/CHF spot rate mid (S_{Mid})	0.97635
LIBOR CHF	-79.9 bps
LIBID CHF (rD)	-92.4 bps
LIBOR USD (rF)	77.167 bps
Duration (t)	31
Day count convention (D)	360

Table 1: Calculation of foreign currency basis with market data as of 30 December 2016 09:00h CET. Market data retrieved from Bloomberg.

To start with, the annualized forward premium (P) had to be calculated, by using equation 5. In equation 6, the values from table 1 have been inputted and a negative basis of -244 bps has resulted. The USD/CHF FX swap ask points in the numerator have to be divided by 10’000, as they are quoted in pips of the quote currency.

$$P = \frac{FXS_{Ask}}{S_{Mid}} * \frac{D}{t}$$

Equation 5: Forward premium, adapted from Du et al. (2017) and Finance Trainer.

$$-244\ bps = \frac{-0.002052}{0.97635} * \frac{360}{31}$$

Equation 6: Annualized forward premium USD/CHF as of 30 December 2016 09:00h CET.

The negative basis of -244 bps stands for the interest rate differential between the US dollar and the Swiss franc arising from a FX lender swap. To allow the existence of arbitrage opportunities, the implied interest rate from the FX lender swap must be greater than the interest rate paid resulting from borrowing US dollars and lending Swiss francs for the same duration. To check the existence thereof, the basis (x) in equation 7 must be different from zero.

$$x = LIBOR_F - (LIBID_D - \left(\frac{FXS_{Ask}}{S_{Mid}} * \frac{D}{t}\right))$$

Equation 7: Foreign currency basis, adapted from Du et al. (2017).

As depicted in equation 8, the basis is -74.43 bps annualized. This points to an arbitrage opportunity that could be exploited with a FX lender swap.

$$\text{-74.43 bps} = 77.167bps - (-92.4bps - -244\ bps)$$

Equation 8: US dollar basis against Swiss franc as of 30 December 2016 09:00h CET.

To illustrate the arbitrage potential, a FX lender swap with a notional of 50 million US dollars and a tenor of one-month is assumed. The annualized negative basis of -74.433 bps would result in a profit of 32’047.34 US dollars for the one-month contract.

If markets were efficient, such a deviation would not occur or only for a short period of time. Assuming foreign and domestic risk free rates were to stay constant on a particular day, market participants would substantially increase their demand for FX lender swaps. The increased demand would drive the FX swap points up to less negative values. This procedure will be repeated until the interest rate differential between the risk-free rates is equal to the forward Premium.

In the example shown above, the interest rate differential in the risk-free rates stands at -169.569 bps (-92.4 bps – 77.167 bps). As shown in equation 9, for the basis to reach zero, the FX swap Ask points would have to increase until -14.217 pips.

$$-169.569\ bps = \frac{FX\ Swap\ Ask\ points}{0.97365} * \frac{360}{31}$$

Equation 9: Interest rate differential between risk-free rates. Data as of 30 December 2016 09:00h CET.

In circumstances where the basis is above zero, the CIP violation could be exploited with a FX borrower swap. A positive basis exhibits that the risk-free rates are higher than the synthetic interest rate over a FX swap. Market participants could therefore borrow foreign currency with a FX swap, place the foreign currency at the LIBID rate while funding the FX borrower swap with Swiss francs at LIBOR. Equation 10 differs slightly to equation 7. This originates from the transaction costs taken into consideration.

$$x = LIBOR_D - (LIBID_F - \left(\frac{FXS_{Bid}}{S_{Mid}} * \frac{D}{t}\right))$$

Equation 10: Positive basis formula including transaction costs. Adapted from Du et al. (2017).

The paper will focus on negative deviations. Any positive deviations in the results will show minor differences, as the calculation is based on transactions costs occurring from FX lender swaps.

As the CIP condition is hardly ever zero, a CIP trading range of 20 bps will be applied. Only breaches above positive 10 bps or negative 10 bps are considered as substantial breaches of the CIP condition. The CIP trading range should filter out minor deviations of the CIP condition and aims to give a clearer view of substantial breaches.

The calculation procedure as shown in table 1 will be repeated for all tenors and currencies analyzed. This should allow to reason, whether CIP violations have occurred for the analyzed currency pairs.

In a next step, the implied FX volatilities of the three currency pairs and their respective tenors will be analyzed and included in the graph to depict whether an increase in implied volatility comes along with an increase of deviation in CIP. Moreover, the intraday course of the US dollar basis against Swiss franc will be examined for the 15 January 2015, the day the Swiss National Bank abolished the minimum exchange rate (SNB, 2015), 24 June 2016 the day after the United Kingdom decided the leave the European union (Brexit referendum) and 30 December 2016, which signifies quarter- and year-end and the last trading day before a capital increase under Basel III (BIS, 2013). The US dollar basis was chosen as the currency pair, as it was not directly affected by the abolishment of the minimum exchange rate policy of the SNB or the Brexit referendum. For this investigation, Bloomberg Fixing prices will be used as other intraday data was not available in a reliable manner. Bloomberg fixes the FX rates and FX swap points every full- and half hour. These fixing rates are calculated as the time-weighted average of the prevailing prices of a currency pair or FX swap ask point, 5 minutes before and 6 seconds after the fixing time (Bloomberg, 2016).

Finally, changes in implied FX volatility will be scatter plotted against changes in the foreign currency basis. There will be a time lag of one day applied to the change of the basis. This should allow to depict, whether changes in implied volatility can anticipate changes in the basis. Furthermore, the same procedure will be repeated with a moving average of two days over the changes of the basis and implied FX volatility. This should allow to smoothen out extremes and give a clearer picture of the trend.

To sum up, the sample data set starts on 4 January 2011 and ends on 30 December 2016. This leads to each currency pair and tenor having a sample size of n=1515. The data set was retrieved from Bloomberg using Bloomberg Composite prices as of 23:00h CET for any particular trading day. The direct transaction costs are taken into account by including bid-ask rates for the risk-free rates and for the FX swap points.

3. Results

3.1. Findings

3.1.1. US dollar basis against Swiss franc

The following chapter will start with analyzing the CIP violation for the US dollar basis against Swiss franc for the different maturities including their corresponding implied FX volatility. Thereafter, the day to day changes in basis and implied FX volatility will be scatter plotted against each other. In a first step with a time lag of one day on the basis, secondly with a moving average over the last two days to smoothen out extremes. Lastly, the intraday change of the basis on 15 January 2015, the day of the abolishment of the minimum exchange rate between the Swiss franc and the Euro (SNB, 2015), 24 June, the day after the Brexit referendum (BBC, 2016) and the 30 December 2016, the last trading day of 2016 and also the last trading day before an increase in the capital conservation buffer under Basel III, will be analyzed.

3.1.1.1. CIP violations and implied volatility

In the following graphs, the US dollar basis is analyzed for any deviation from the CIP condition. Bases below zero can be arbitraged out with a FX lender swap, while bases above zero can be arbitraged out with a FX borrower swap. Any positive or negative breaches of the CIP trading range are pointing to substantial arbitrage opportunities. Moreover, the graphs will display the implied USD/CHF volatility.

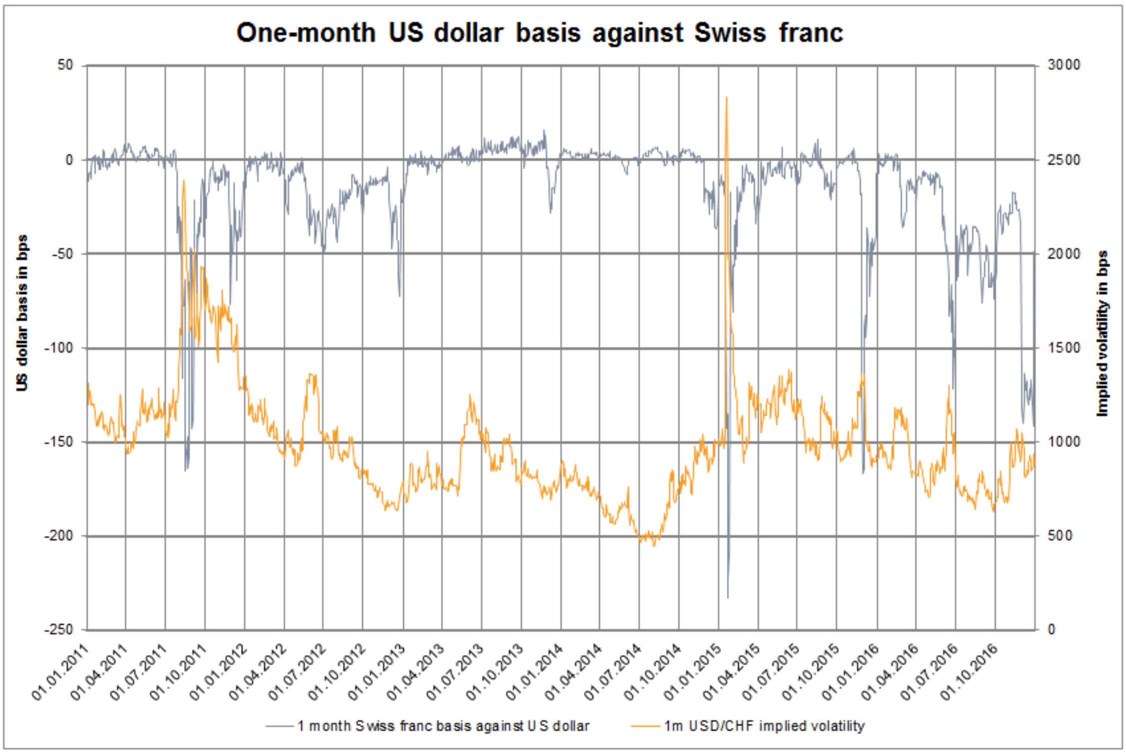

Figure 5: One-month US dollar basis against Swiss franc. Market data retrieved from Bloomberg.

As can be seen in figure 5, the CIP condition has been violated several times between 4 January 2011 and 30 December 2016. From a total of 1515 trading days, the US dollar basis was below zero on 980 days and above zero on 535 days. In addition, the US dollar basis was trading outside the CIP trading range on a total of 586 days. Thereof, negative breaches of the CIP trading range added up to 569 days, while positive breaches occurred on 17 days. The highest US dollar basis occurred on 22 November 2013 with 16bps, the lowest appeared on 21 January 2015 with -233 bps.

Analyzing the quarter- and year-end effect in greater detail, one can observe that its first occurrence was in November of 2011. On 24 November, the US dollar basis stood at -6 bps. In the following days, it started to decrease and reached a low of -76 bps on 29 November. In December of 2011, the basis started to gently recover and on the last trading day of the year, the US basis stood at -11 bps. In the second quarter of 2012, the US dollar basis decreased from -9.5 bps on 21 May to -48.5 bps on 4 July. In the months to follow, the US basis smoothly recovered and returned to the CIP trading range by the beginning of September. Similar to 2011, the US dollar basis begun to decrease in the end of November. From -4 bps on 26 November, it corrected to -72.6 bps on 24 December. Thereafter, the basis recovered and returned to the CIP trading range by 8 January 2013. In 2013, the only negative quarter-end deviation could be observed in November. The US dollar basis stood at 1 bps on 29 November 2013. In the following days, it corrected to a low of -28.5 bps on 6 December 2013. Thereafter, the basis recovered to the CIP trading range by 20 December. In 2014, there were minor negative deviations of 8 bps towards the second quarter and 5 bps towards the third quarter. The biggest negative deviation of the year occurred in the end of November. While the US dollar basis stood at 0.5 bps on 26 November, it decreased by 19 bps on the next day. In the following days, the basis retreated further until it bottomed out on 24 December.

In the aftermath of the discontinuation of the minimum exchange rate policy (SNB, 2015), the US dollar basis plummeted. While on 15 January, the day of the announcement, the US dollar basis stood at -12.5 bps, it retreated to -232.5 bps by 21 January. From there on, the US dollar basis started to slowly recover and returned to the CIP trading range by the beginning of March. Towards the end of the first, second and third quarter, the basis decreased by 20 bps. Comparable to the other year-ends, the US dollar basis started to decrease from -6 bps on 20. November to -166.5 bps on 30 November. From there on, the basis recovered and was within the CIP trading range by 30 December.

Towards the first quarter of 2016, the US dollar basis decreased by 37 bps to -35 bps on 29 February. In the second quarter of 2016, the basis started to decline on 27 May until it bottomed out 24 June 2016 at -122 bps. The latter coincides with the Brexit referendum. Unlike other negative deviations observed, the US dollar basis was not able to recover to the CIP trading range after the Brexit referendum (BBC, 2016). The basis decreased from -26 bps on 24 November to -141.5 bps on 28 December. Different to 2013 and 2015, the lowest year-end basis in 2016 was not reached in the beginning of December, but towards the end of December.

To conclude, since April 2016, the basis has consistently and substantially been negative. Furthermore, sharp decreases in the US dollar basis coincident with increases in implied volatility. The “quarter-end effects” cited by Du et al. (2017, p.34) were observable. This refers to the behavior of banks to reduce their engagement in financial instruments that stay on their balance sheet over the quarter ends, which coincide with the publication of regulatory requirements (Du et al., 2017). The negative deviations were particularly pronounced towards year-ends. Negative deviations in the aftermath of risk events recovered quickly with the exception of the Brexit referendum. Thereafter, the one-month US dollar basis was not able to recover to levels seen before.

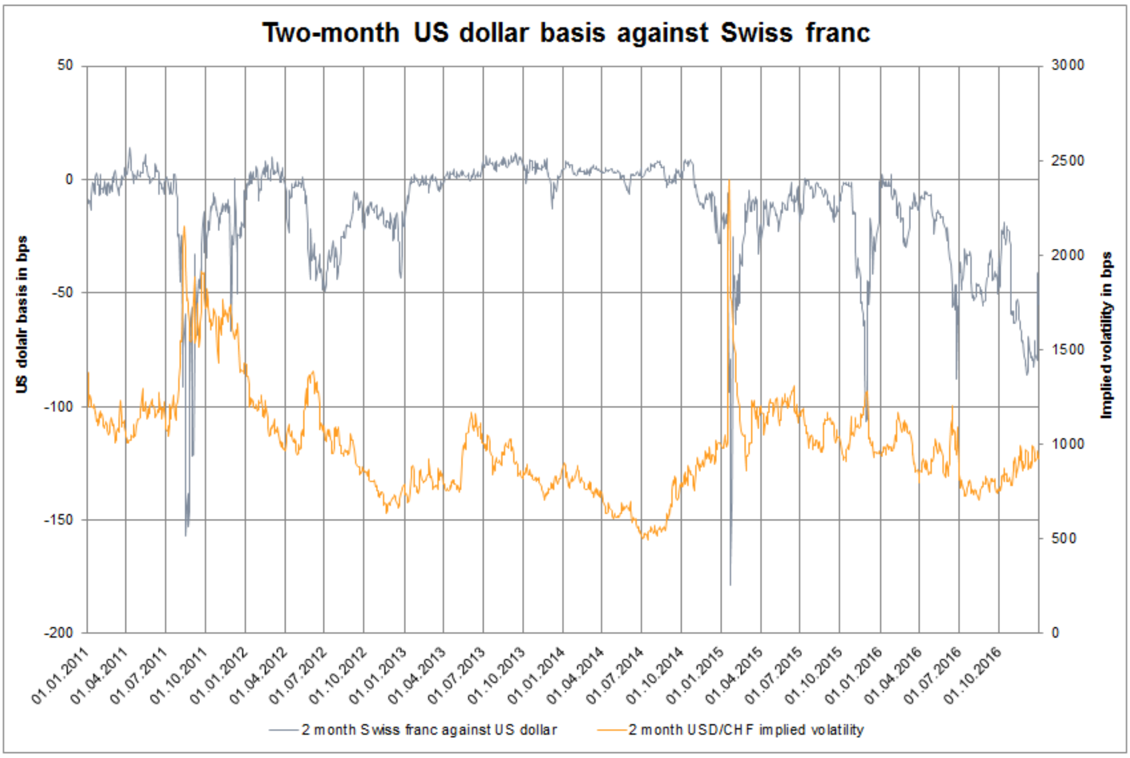

Figure 6: Two-month US dollar basis against Swiss franc. Market data retrieved from Bloomberg.

As seen in figure 6, the overall trend of the two-month US dollar basis showed similarities to the one-month. Differences occurred in the magnitude of violations, where the two-month basis reacted less severe than the one-month.

From January 2011 until December 2016, the basis was trading below zero on 1022 days and positive on 493 days. While it traded above the CIP trading range on 8 days, it stood below it on 649 days. Comparable to the one-month, the lowest basis was observed on 21 January 2015, when it plummeted to -179 bps. The highest positive deviation occurred on 11 April 2011 with 14 bps. In contrast to the one-month, the two-month exhibited a prolonged negative basis since November 2014. From the remaining 547 trading days, the basis was below zero on 542 and below the CIP trading range on 256.

To be in accordance with the quarter-end claim expressed by Du et al. (2017), the negative deviations should decrease further into negative territory two months before the end of the quarter. While in 2011, no such effect was observable, the basis decreased towards the third quarter of 2012. On 19 July, the basis stood at -31 bps. In the following days, the basis started to decrease until it reached -44 bps on 31 July. Thereafter, the basis started to recover and returned to -31 bps by 7 August. In the following years, no "quarter-end effects" (Du et al.,2017, p.34) could be observed. Instead, the basis started to decrease around one month before year end. This effect was observed for all end-of-years. With exception of 2012 and 2014, the lowest point of the year-end correction occurred between the end of November and the beginning of December.

Similar to the one-month US dollar basis, the two-month US dollar basis dipped heavily around the analyzed risk events. The one- and two-month basis behaved analogously around the introduction of the EUR/CHF currency peg in 2011. After the discontinuation of the latter in 2015, the two-month US dollar basis needed 39 days, while the one-month basis needed 29 days to recover to levels seen before the event. Comparable to the one-month, the Brexit referendum made the basis decrease to levels it was not able to recover from afterwards.

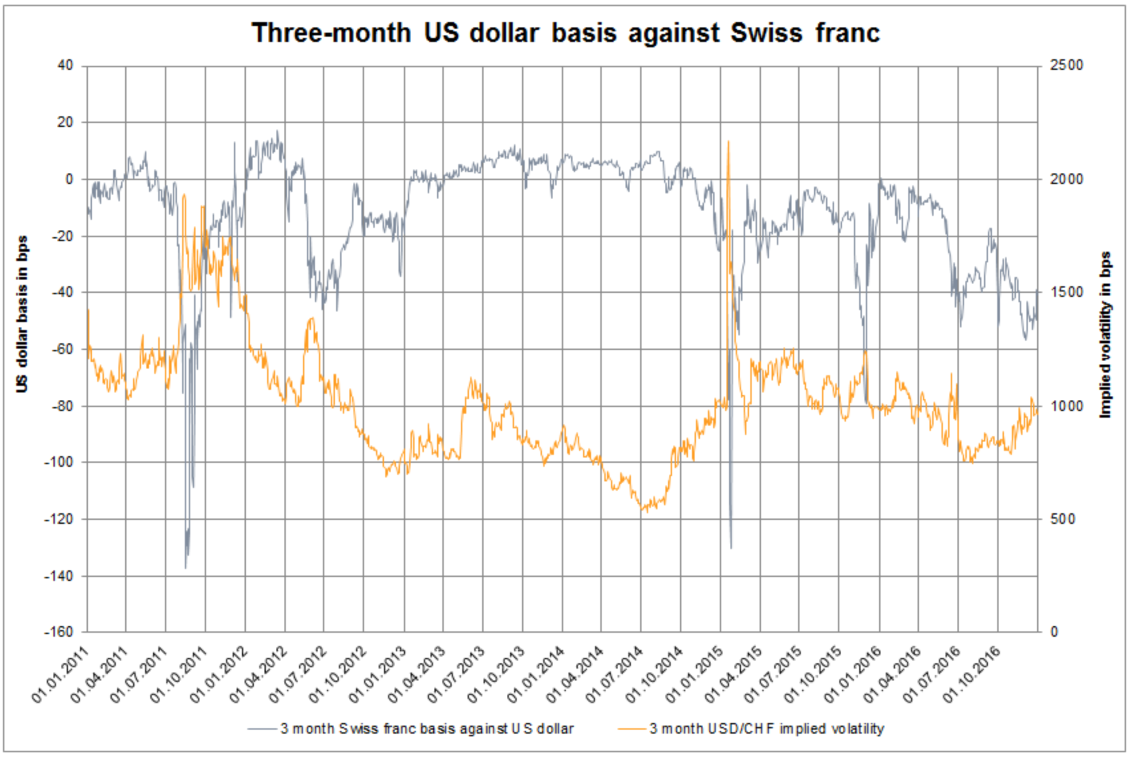

Figure 7: Three-month US dollar basis against Swiss franc. Market data retrieved from Bloomberg.

Different to the one- and two-month, the three-month US dollar basis exhibited a positive deviation in the first quarter of 2012 as well as from April 2013 until September 2014, as can be seen in figure 7.

The three-month US dollar basis stood above the CIP trading range on 35 days, compared to 17 days in the one- and 8 in the two-month. The lowest basis occurred on 17 August 2011 with -137 bps, whereas the highest basis was observed on 15 March 2012 with 17 bps. This stands in contrast to the shorter time frames, where the low occurred in January 2015.

Similar to the shorter US dollar tenors, the basis started to decrease around one month before year-end. Except for 2012 and 2014, the basis reached a low around the period of end of November to beginning of December. This observation is similar to the one- and two-month US dollar basis.

Comparable to the other time frames analyzed, the basis has been persistently negative since November 2014. From the remaining 547 trading days, the basis was negative on 545, exhibiting the most pronounced negative period of all analyzed time frames. But with 236 trading days below -10 bps, the strength of the deviation was less pronounced than the one seen in the shorter time frames.

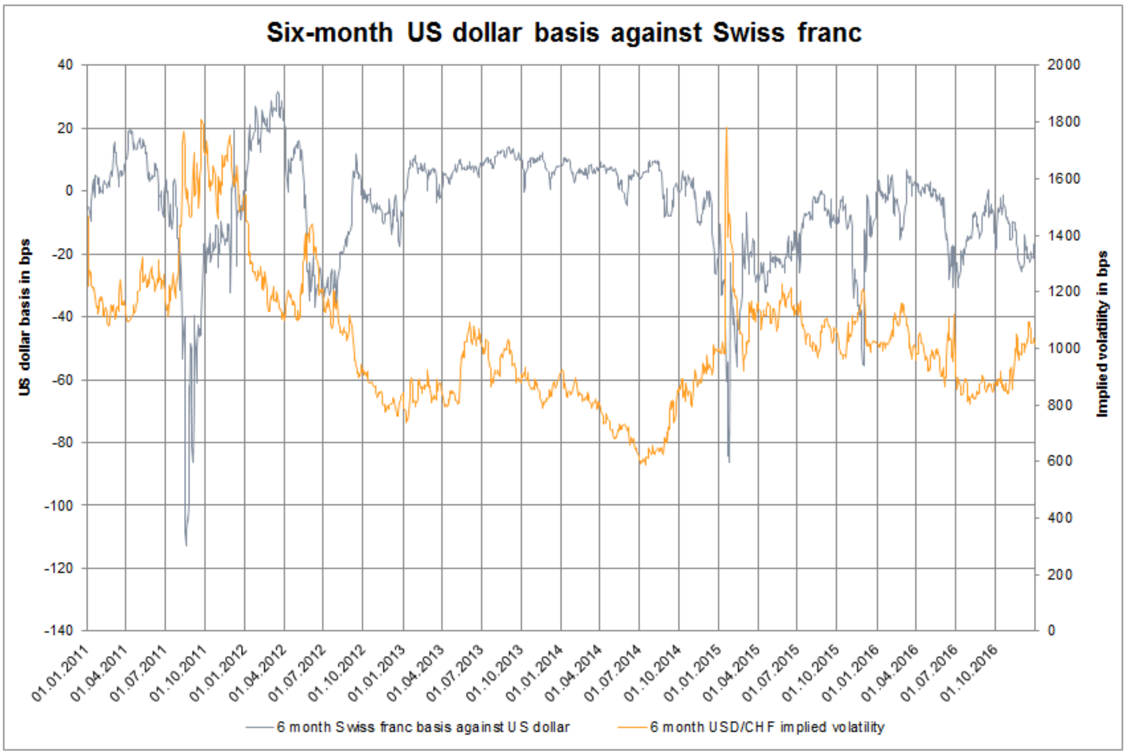

Figure 8: Six-month US dollar basis against Swiss franc. Market data retrieved from Bloomberg.

Similar to the three-month, the six-month exhibited a prolonged period of positive basis, as can be seen in figure 8. With one exception, the basis was trading in positive territory from 30 December 2011 until 17 May 2012. During this period, it reached a high of 32 bps, which also marked the highest value of all analyzed US dollar bases. From a total of 1515 trading days, the basis was above zero on 703 and negative on 812. The six-month US dollar basis showed 188 positive breaches of the CIP trading range, the highest of all analyzed US dollar bases. On the other hand, it exhibited the least breaches of the CIP trading range with a total of 457 days. Similar to the three-month, the lowest value was observed in August 2011, whereas the highest six-month US dollar basis occurred in March 2012.

Corrections were observed around one-month before the end of the year. But different to the shorter US dollar bases analyzed, they were less pronounced. The reaction after stress events was similar to the shorter ones. After the SNB announcement in January 2015, it required 30 days to recover. After the Brexit referendum, the six-month basis was the only US dollar basis that was able to retreat to levels seen before the event.

To conclude, CIP violations did occur over the analyzed time span. The one-month contracts showed the biggest deviations and reacted most sensitively. Market stress events led to a decrease in the US dollar basis over all maturities analyzed, but the biggest deviations were observed in the one-month contract. Arbitrage opportunities from negative US dollar bases arose for all time frames, but the most values below -10 bps could be observed in the two-month tenor. Furthermore, the bases tended to decrease around a month before the end of the year.

3.1.1.2. Scatterplot of daily changes in basis and implied volatility

To analyze the relation between changes in the US dollar basis to changes in implied USD/CHF volatility, the two data points were included in a scatterplot. In a first step, a time leg of one day was applied on the changes of the US dollar basis and plotted against the change of the implied USD/CHF volatility. In a second step, a moving average of two days was applied over the US dollar bases and the implied USD/CHF volatility, to smoothen out extremes along the time span and provide a clearer picture of the trend. In order to anticipate changes in the basis through changes in implied volatility, the data points would have to appear either below the horizontal and right of the vertical axis, or above the horizontal but left of the vertical axis. If this circumstance occurred, the significance would have to be tested with a hypothesis test.

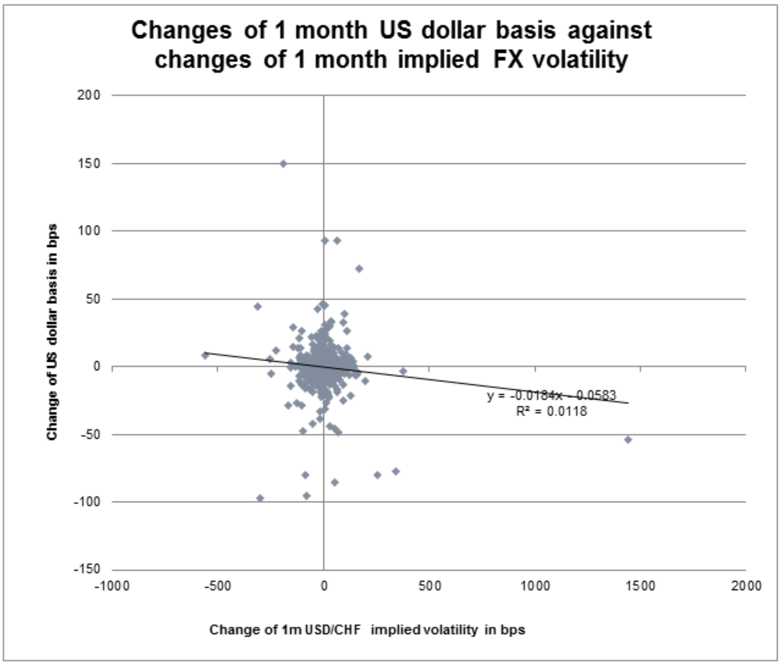

Figure 9: Change of 1 month US dollar basis against changes of 1 month USD/CHF implied volatility, with a time lag of one day. Market data retrieved from Bloomberg.

For the scatterplot of the one-month US dollar basis changes against the changes of the implied one-month USD/CHF volatility, the R^2 stood at 0.0118 and the slop of the regression line was slightly negative at -0.0184. No clear trend could be derived, as can be seen in figure 9.

The R^2 and the slope of the regression lines only changed marginally for the remaining US dollar scatter plots under analysis, as can be seen in table 2:

	One-month	**two-month**	**three-month**	**six-month**
R2	0.0118	0.0179	0.019	0.0069
Slope of regression line	-0.0184	-0.0206	-0.0195	-0.0121

Table 2: Summary of US dollar basis scatter plots without moving average.

The remaining US dollar scatter plots can be found in the appendix 4, 5 and 6.

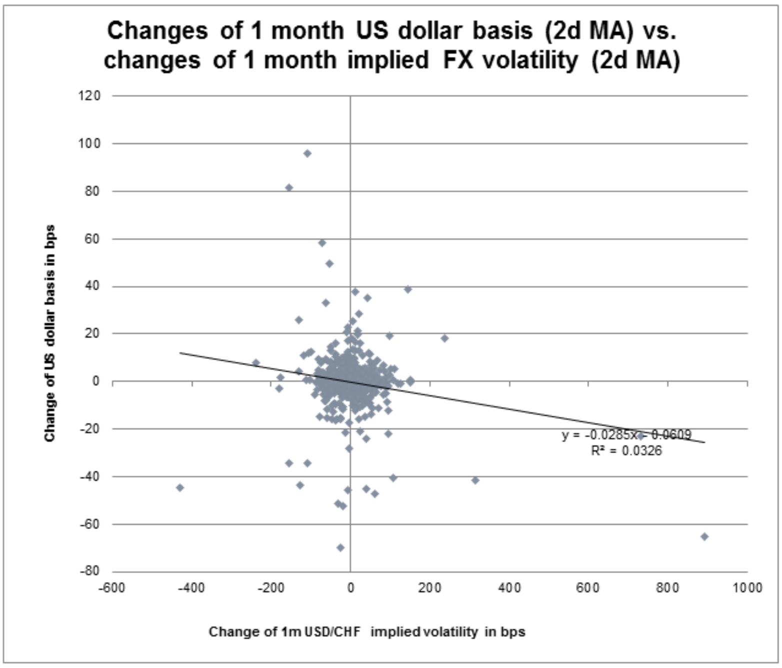

Figure 10: Changes of 1 month US dollar basis against changes of 1 month implied USD/CHF volatility. Time lag of one-day and two-day moving average over the changes was applied. Market data retrieved from Bloomberg.

In a second step, a two-day average of the changes in the US dollar basis against the changes in the implied USD/CHF volatility was applied. This aimed at smoothening out extremes and provide a clearer picture of the overall trend. As can be seen in figure 10, the R^2 increased by the factor 2.76 compared to the prior analysis. The slope of the regression line decreased by the factor 1.55, but was not able to exhibit a clear trend. Similar to the scatter plots without moving average, the R^2 and slope of the regression line did not change notably for the other tenors. The R^2 and slope of the regression lines are summarized in table 3.

	One-month	**two-month**	**three-month**	**six-month**
R^2	0.0326	0.0291	0.0324	0.0225
Slope of regression line	-0.0285	-0.0246	-0.0233	-0.0203

Table 3: Summary of US dollar basis scatter plots with moving average.

The remaining scatter plots can be found in the appendix 1, 2 and 3.

To sum up, no clear pattern was extrapolated that would point to the fact that changes in the US dollar basis could be anticipated by changes in the implied USD/CHF volatility. The slope of the regression line for all analyzed maturities was only marginally negative and the R^2 were not significant.

3.1.1.3. Intraday changes of the one-month US dollar basis

It could be observed that the US dollar basis decreases substantially around particular political stress events, central bank decisions or year-ends. To analyze these deviations of CIP, the intraday movements of the one-month US dollar basis were studied in further detail.

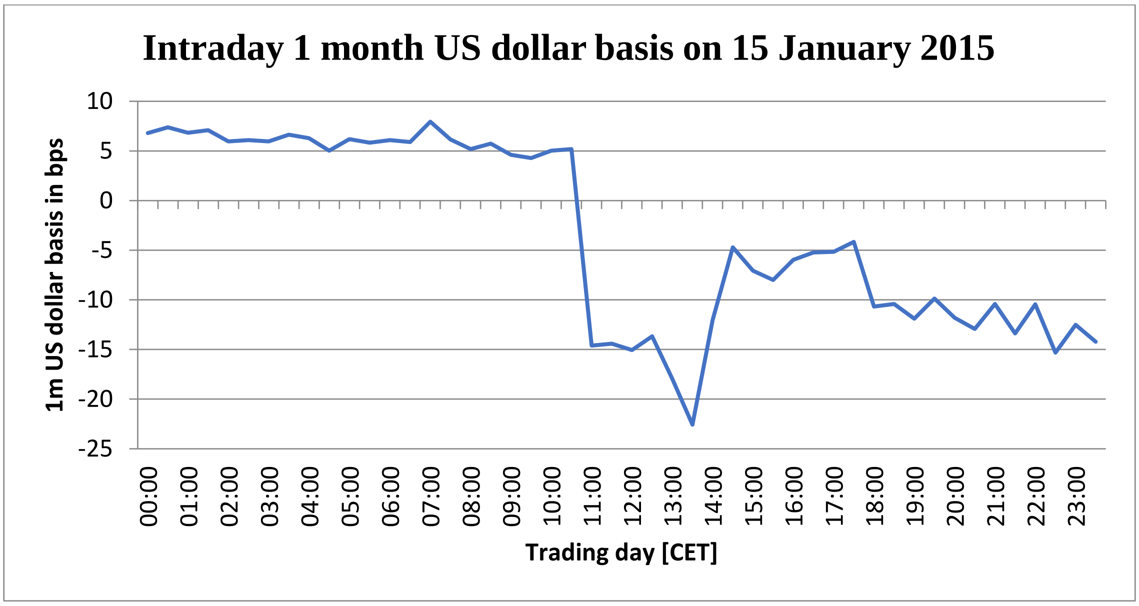

Figure 11: Intraday 1 month US dollar basis on 15 January 2015. Market data retrieved from Bloomberg.

On 15 January 2015 at 10:30h CET, the SNB declared, that the minimum exchange rate between the Swiss franc and the Euro is abolished with immediate effect (SNB, 2015). Moreover, the interest rate on sight deposits was decreased by 50 basis points to -75bps (SNB, 2015).

As can be seen in figure 11, the basis was above 0 before the announcement of the SNB at 10:30h CET. It then reversed into negative territory and reached a low of -22.53 basis points at 13:30h. The basis did recover in the early afternoon but retreated again after the European trading session ended at 18:00h CET. The decrease of the US dollar basis further amplified in the following trading days and led to a one-month basis of -232bps on 21 January 2015.

It could be observed that the basis reacted instantly to the changes in monetary policy but the whole extend was only felt 6 days after the announcement.

On 23 June 2016, the citizens of the United Kingdom went to the polls, to decide whether to leave the European Union (BBC, 2016). In the end of May 2016, the one-month US dollar basis started to retreat from -10 bps to -74bps on 23 June. In figure 12, the intraday one-month US dollar basis on 24 June, the day after the Brexit referendum, is shown. At 05:30h CET, the basis decreased by 96 bps in 30 minutes. With the exception of a quick recovery around 10:30h CET, it stayed below -100bps for the rest of the trading day.

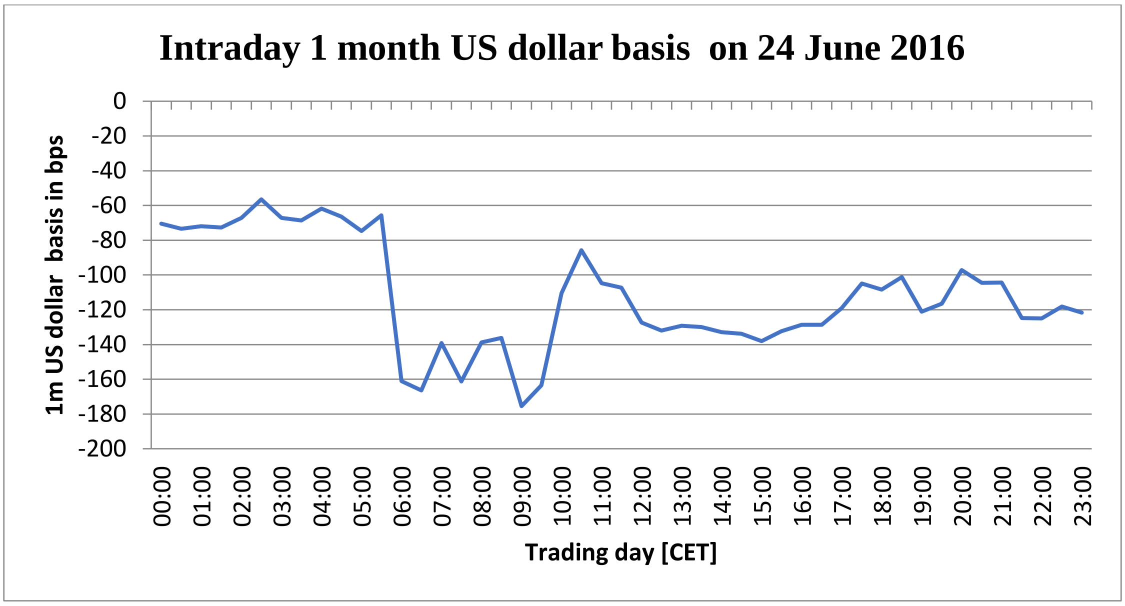

Figure 12: Intraday 1 month US dollar basis on 24 June 2016. Market data retrieved from Bloomberg.

The referendum had a lasting effect on the one-month US dollar basis. Different to 15 January 2015, the one-month US dollar basis was not able to recover to levels seen before the referendum.

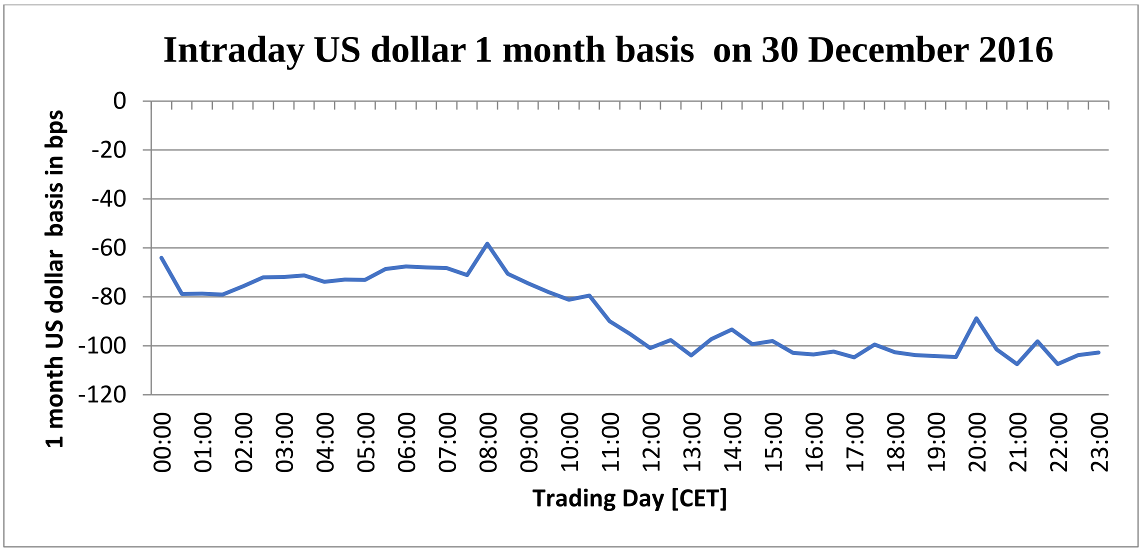

Figure 13: Intraday 1 month US dollar basis on 30 December 2016. Market data retrieved from Bloomberg.

Figure 13 exhibits 30 December 2016, the last trading day of the year. Until 08:00h CET, the basis was trading between -60bps and -80bps. Thereafter, it started to retreat and breached below -100bps around 12:00h CET. In the afternoon, the basis was not able to recover to the levels seen in the morning and reached a low of -107 bps at 21:00h CET.

To sum up, it can be said that CIP violations were observable for all analyzed US dollar basis tenors. The basis moved further into negative territory before perceived political uncertainty, around one-month before year-end or after influential central bank decisions. The deviations from CIP were most pronounced in the one-month contract. The scatter plot analysis of the change in basis and change in implied volatility did not show a clear trend between the two variables.

3.1.2. Euro basis against Swiss franc

In the following section, the Euro basis against Swiss franc is analyzed for any deviation from the CIP condition. Any bases below zero point to an arbitrage opportunity that could be exploited with a FX lender swap, while bases above zero can be arbitraged out with a FX borrower swap. Similar to the US dollar basis, any positive or negative breaches of the CIP trading range are pointing to substantial arbitrage opportunities. The following graphs will display the Euro basis as well as the implied EUR/CHF volatility.

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3.1.2.1. CIP violations and implied EUR/CHF volatility

For the CIP condition to hold, the basis has to be around zero. Substantial violations were defined as values below or above 10 bps from zero. Theoretically, any deviation thereof points to arbitrage opportunities. Deviations that lead to a negative basis can be exploited with a FX lender swap, positive deviations with a FX borrower swap. The focus was laid on negative deviations.

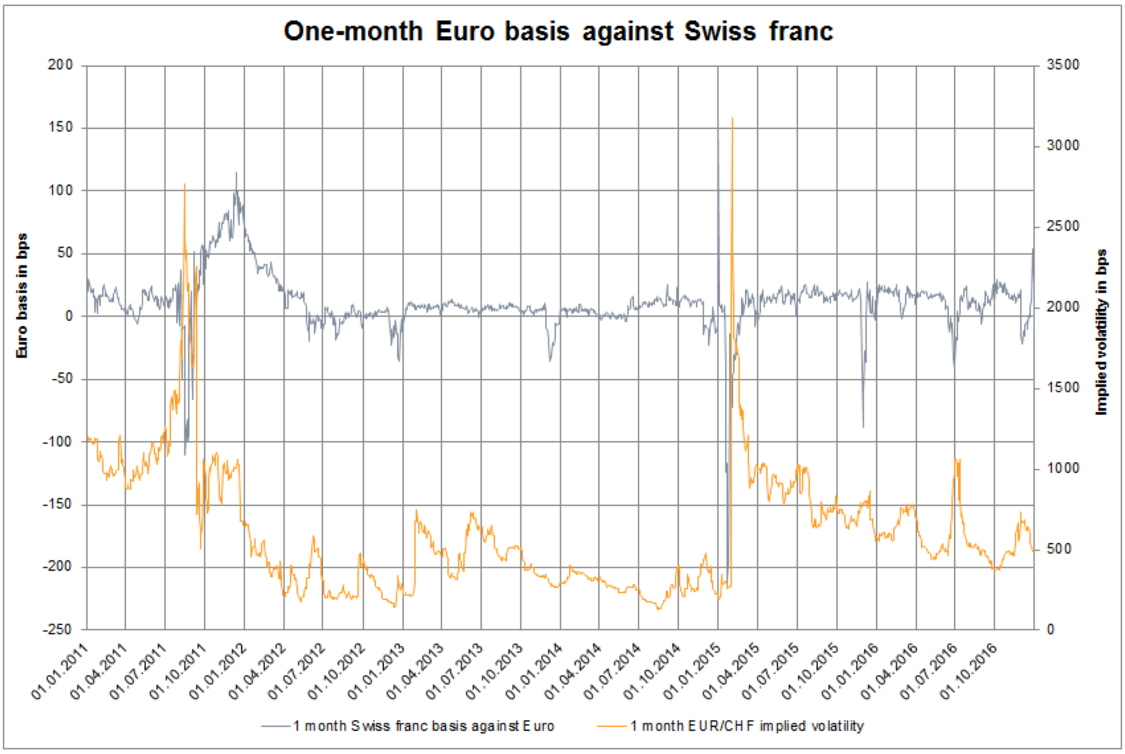
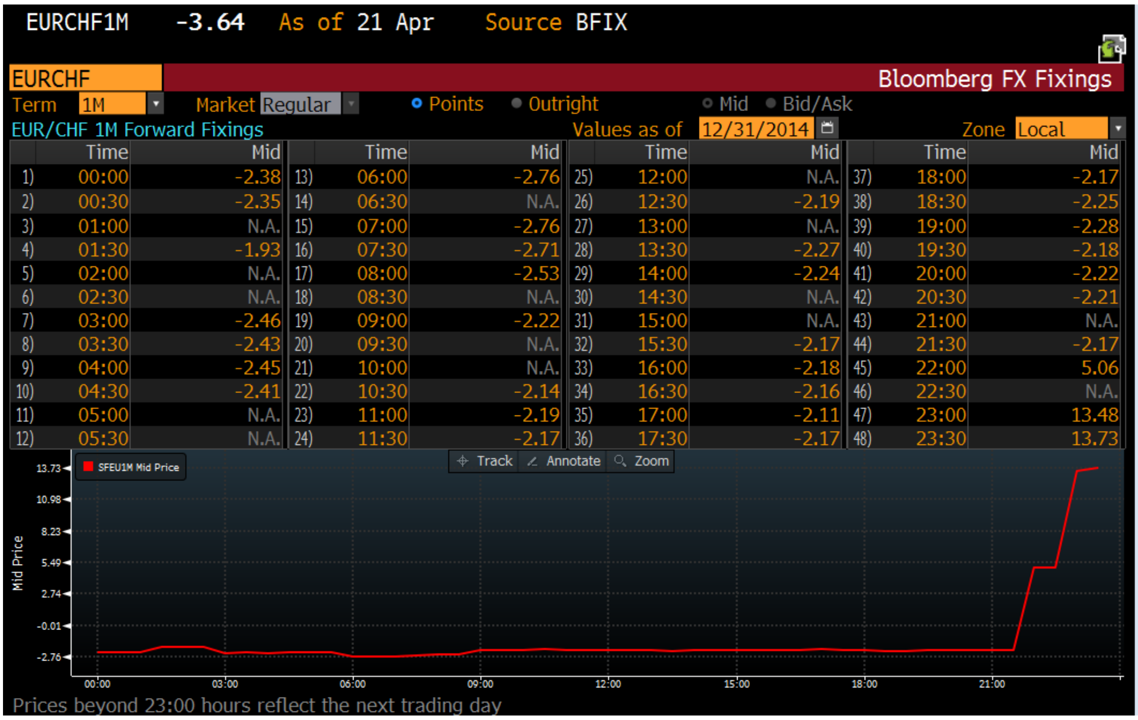


Figure 14: One-month Euro basis against Swiss franc. Market data retrieved from Bloomberg.

As can be seen in figure 14, the one-month Euro basis against Swiss franc has been trading around zero with several outliers between 4 January 2011 and 30 December 2016. Out of the 1515 observed trading days, the basis was positive on 1277 and negative on 238. Furthermore, the basis breached the defined CIP trading range 859 times, whereof 756 deviations were positive and 103 negative. From January 2011 until 20 April 2011 the basis was exclusively trading in positive territory. In addition, it could be observed that the basis reversed from 37 bps on 9 August 2011 to -110 bps on 17 August 2011. This move was accompanied by an increase in implied volatility, pointing to stressed market conditions. In the aftermath of the introduction of the minimum exchange rate between the Euro and the Swiss franc on 6 September 2011 (SNB, 2011), the basis started to gradually increase from 6.5 bps on 6 September to 115 bps on 13 December 2011.

Thereafter, it started to decrease and touched zero on 24 May 2012. This period was accompanied by a substantial decrease in implied volatility.

A negative deviation from CIP could be observed, among others, before the year-end 2012, when the basis decreased from -16 bps to -54 bps. The negative deviation started to fade in the last trading days of 2012 so that it stood at -11 bps on 31 December. On the first trading day in January 2013, the basis recovered and by 7 January 2013, it was trading above zero. A similar move was observed in December 2013 and to a lesser extend in December 2014. On the last trading day of 2014, the Euro basis spiked to 158 basis points. In fact, a closer analysis of the intraday FX swap points on 31 December 2014 exhibited a significant increase from 21:30h CET onwards as can be seen in figure 15. If the FX swap points from 21:00h were applied for the calculation of the basis, the result would have been in proximity to the EUR basis seen on 29 December 2014.


EURCHF1M -3.64 As of 21 Apr Source BFIX

EURCHF — Bloomberg FX Fixings

Term 1M — Market Regular — Points — Outright — Mid — Bid/Ask

EUR/CHF 1M Forward Fixings — Values as of 12/31/2014 — Zone Local

	Time	Mid		Time	Mid		Time	Mid		Time	Mid
1)	00:00	-2.38	13)	06:00	-2.76	25)	12:00	N.A.	37)	18:00	-2.17
2)	00:30	-2.35	14)	06:30	N.A.	26)	12:30	-2.19	38)	18:30	-2.25
3)	01:00	N.A.	15)	07:00	-2.76	27)	13:00	N.A.	39)	19:00	-2.28
4)	01:30	-1.93	16)	07:30	-2.71	28)	13:30	-2.27	40)	19:30	-2.18
5)	02:00	N.A.	17)	08:00	-2.53	29)	14:00	-2.24	41)	20:00	-2.22
6)	02:30	N.A.	18)	08:30	N.A.	30)	14:30	N.A.	42)	20:30	-2.21
7)	03:00	-2.46	19)	09:00	-2.22	31)	15:00	N.A.	43)	21:00	N.A.
8)	03:30	-2.43	20)	09:30	N.A.	32)	15:30	-2.17	44)	21:30	-2.17
9)	04:00	-2.45	21)	10:00	N.A.	33)	16:00	-2.18	45)	22:00	5.06
10)	04:30	-2.41	22)	10:30	-2.14	34)	16:30	-2.16	46)	22:30	N.A.
11)	05:00	N.A.	23)	11:00	-2.19	35)	17:00	-2.11	47)	23:00	13.48
12)	05:30	N.A.	24)	11:30	-2.17	36)	17:30	-2.17	48)	23:30	13.73

Figure 15: EUR/CHF 1 month FX swap points as of 30 December 2014. Screenshot of BFIX function in Bloomberg.

On 15 January 2015, the day when the SNB abandoned the minimum exchange policy (SNB, 2015), the one-month Euro basis stood at 9 bps. It then started to substantially decrease in the following days and reached a low of -216 bps on 21. January 2015. But pronounced negative deviation of the CIP condition was only of limited duration. The basis recovered quickly and stood within the CIP trading range by 19 February 2015.

Similar to 2012 and 2014, a deviation of the basis into negative territory could be seen in December 2015. The magnitude was more pronounced than in the years before, with the basis having plummeted from 13 bps on 24 November 2015 to a low of -87 bps on 30 November 2015. In contrast to the previous years, the basis recovered earlier and was within the CIP trading range by 9 December 2015. The Brexit referendum led to a decrease of the basis from -5 bps on 23 June 2016 to -41 bps on 28 June 2016. This drop was accompanied by an increase of the implied volatility from 570 bps, in the beginning of June 2016, to a peak of 1050 bps on 24 June 2016. But similar to other observed stressed market conditions, the Brexit referendum did not result in a lasting negative basis. The year-end of 2016 was no different from the other year-ends analyzed in the data sample. The basis dipped into negative territory on 29 November 2016. Comparable to 2015, it was within the CIP trading range by 8 December. Between 24 and 29 December, the basis spiked into positive territory when it marked a high of 55 bps.

The investigation of the implied one-month EUR/CHF volatility showed that, with exception of 2014, the implied one-month EUR/CHF volatility decreased towards the end of the year. Stressed market conditions have brought along a negative basis that was significantly below zero but did not last for an extended period of time. Different to the one-month US dollar basis, the one-month Euro basis was able to recover after the Brexit referendum.

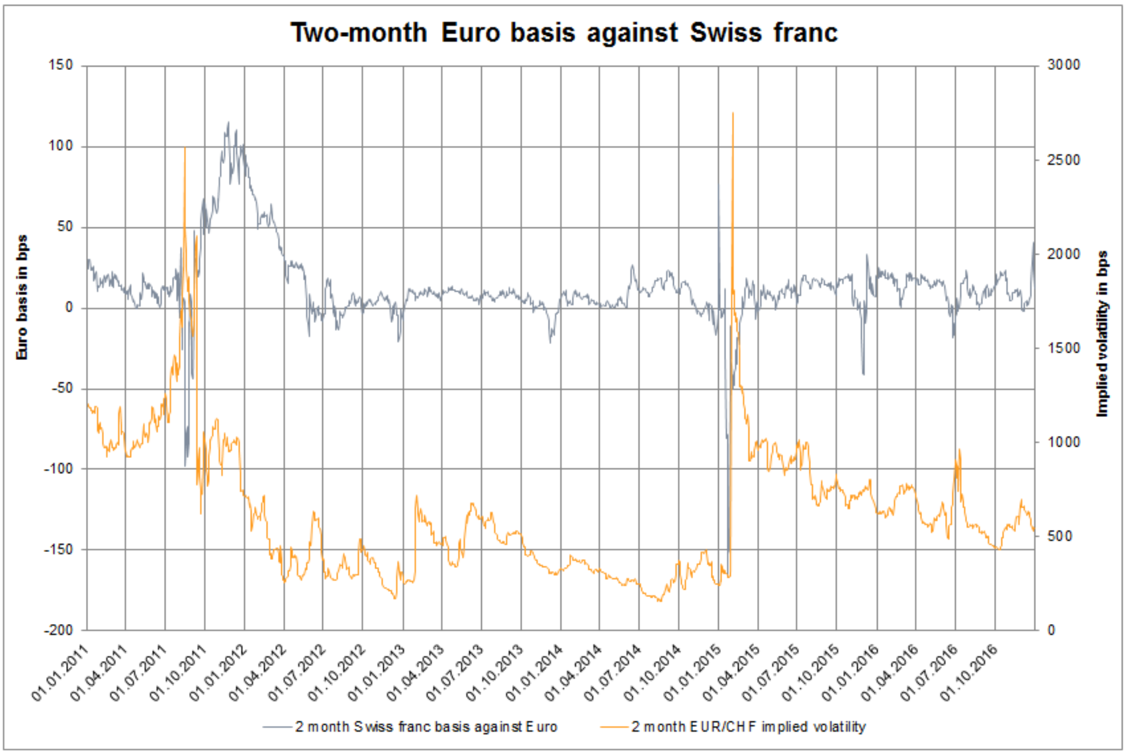


Figure 16: Two-month Euro basis against Swiss franc. Market data retrieved from Bloomberg.

Turning to the two-month basis, the overall trend looks comparable to the one-month, as can be seen in figure 16. From a total of 1515 trading days, the basis was positive on 1312 and negative on 203. The CIP trading range was breached on a total of 799 days, whereof 737 were positive breaches and 62 negative ones. To confirm the observations of the "year-end effect", found by Du et al. (2017, p.34), a correction of the basis should be observable two months before the end of the year. In the two-month analysis, there was no evidence to fortify this claim. But similar to the one-month basis, a year-end correction around the end of November was observable. These corrections were less pronounced than for the one-month maturity. For the year of 2012, the basis corrected from 5 bps on 30 November 2012 to – 21 bps on 21 December. But by 28 December 2012, the basis recovered back to the CIP trading range. Similar moves were observed towards the year-end of 2013 and 2014. On the last trading day of 2014, the two-month Euro basis jumped by 80 bps. As depicted in figure 17, the FX swap points started to increase from 21:30h CET onwards.

Figure 17: EUR/CHF 2m FX swap points as of 30 December 2014. Screenshot of BFIX function in Bloomberg.

If the FX swap points from 21:00h CET were used instead of the ones at 23:00h CET, the Euro basis would have been similar to the previous days.

In 2015, the basis corrected from 4 bps on 23 November to -41 bps on 1 December 2015. In contrast to the one-month basis, there was no year-end deviation detectable in 2016. The two-month basis started to increase in December and reached a high of 41 bps on 28 December 2016

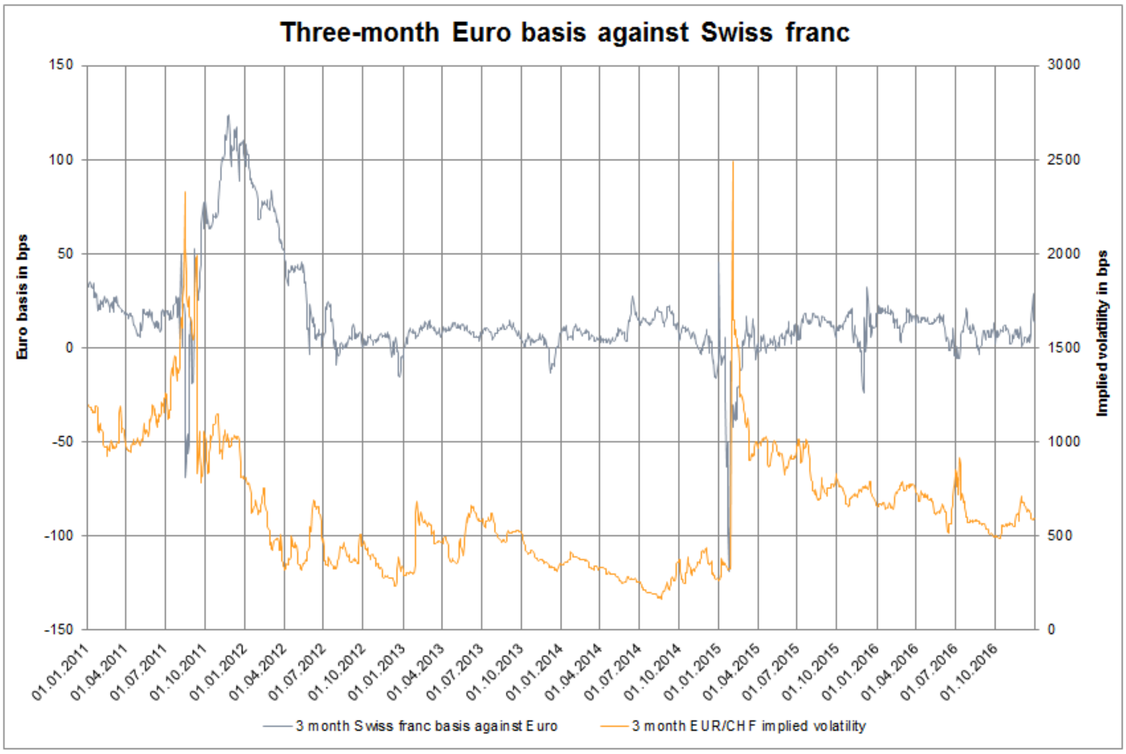


Figure 18: Three-month Euro basis against Swiss franc. Market data retrieved from Bloomberg.

When analyzing the overall trend in figure 18, it can be observed that negative CIP violations occurred less often and in a less distinctive manner for the three-month Euro basis than for the one- and two-month. From the sample set of 1515 days, the basis was in positive territory on 1379 and negative on 136. From a total of 819 breaches of the CIP trading range, 770 were positive while 49 were negative. The three-month basis was exhibiting a substantial positive CIP violation from 7 September 2011 to 25 May 2012, when it rose to a high of 124 bps. Similar to the shorter maturities analyzed, negative CIP deviations were observed towards year-ends.

In 2012, there was a minor correction of the Euro basis at the beginning of December. In 2013, the basis started to decrease from 29 November onwards and reached a low of -11 bps on 10 December. Different to the previous two years, the basis started to decrease around the mid of December in 2014. The year-end move of 2015 was observed earlier than in the previous months and more distinct. From 23 November 2015 on, the Euro basis decreased from 4 bps to -23 bps on 1 December. Thereafter, it retraced and from 8 December on, it stayed above zero for the remaining days of the year. In 2016, no negative deviations were observed in November or December.

Similar to the shorter maturities, a sharp spike occurred on 31 December 2014. It can be seen in figure 19, that the corresponding FX swap points spiked from 21:30h CET onwards. If the FX swap points as of 21:30h were considered, the basis would have stood at -13 bps, insignificantly different to the preceding days.

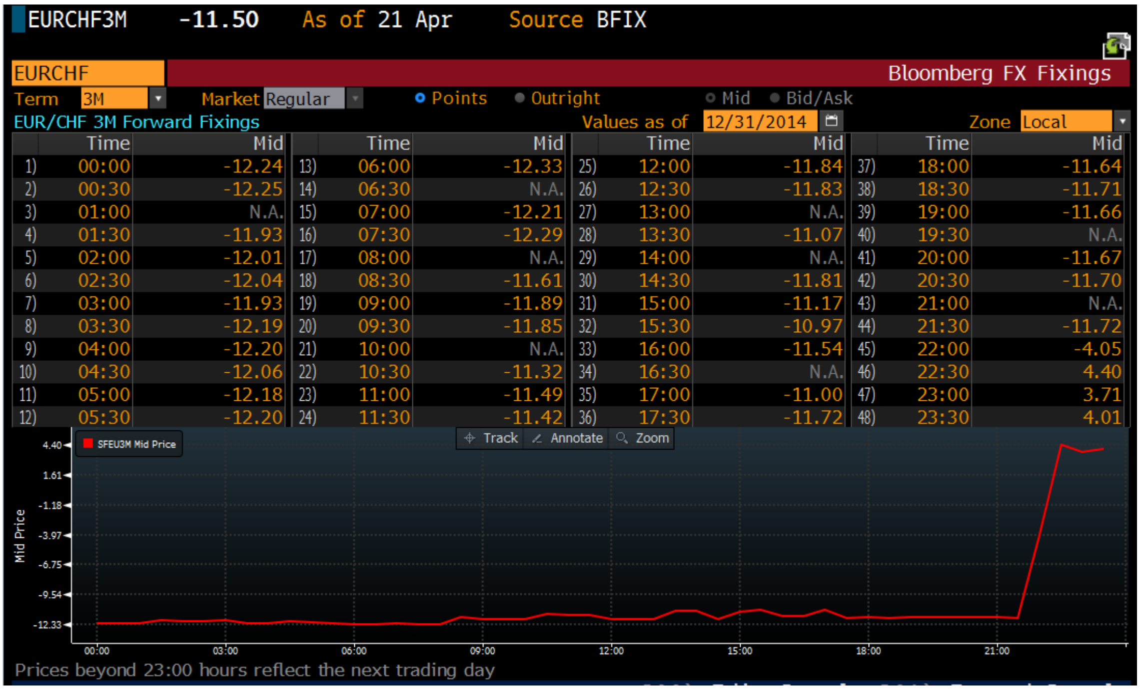


Figure 19: EUR/CHF 3m FX swap points as of 30 December 2014. Screenshot of BFIX function in Bloomberg.

To sum up, the negative CIP deviations for the three-month basis occurred less pronounced than in the shorter tenors. Conversely, positive deviations from CIP were more pronounced in the three-month basis than in the shorter tenors.

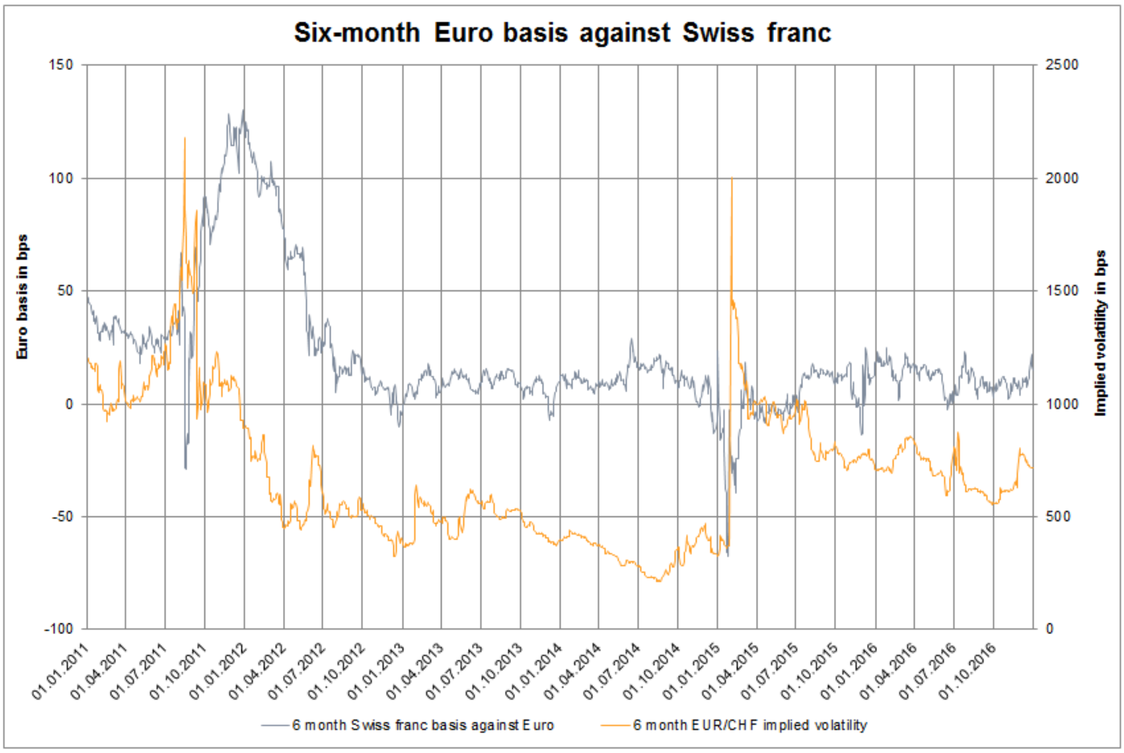


Figure 20: Six-month Euro basis against Swiss franc. Market data retrieved from Bloomberg.

The six-month Euro basis, as shown in figure 20, breached the defined CIP trading range on a total of 997 days. Thereof 953 deviations were above 10 basis points while 44 were lower than -10 basis points. It showed the strongest positive deviation from the CIP condition over all analyzed bases and maturities. Different to the shorter tenors, the implied six-month EUR/CHF volatility peaked in August 2011, whereas the one- two- and three-month implied EUR/CHF volatilities peaked on 16 January 2016. Similar to the other maturities observed, the basis was in positive territory from 25 August 2011 until 4 December 2012, with a high of 130 bps points on 28 December 2011. In contrast to the other durations analyzed, a negative correction of the basis towards year-end has not been discovered. Similar to the one-, two- and three-month tenor, negative deviations from CIP have been observed in stressed market conditions, but they reversed to the CIP condition within several days.

To sum up, the Euro bases exhibited only limited arbitrage opportunities that could have been exploited with a FX lender swap. Conversely, the Euro basis showed more days with a positive basis than with a negative one, pointing to the fact, that arbitrage profits could have been made with a FX borrower swap, rather than a FX lender swap. A negative correction of the basis towards year-end in the one-, two- and three-month tenor was observed. These deviations were strongest in magnitude for the one-month basis.

3.1.2.2. Scatter plot of daily changes in basis and implied volatility

Similar to the US dollar basis, the changes in the Euro basis were scatter plotted against changes of the implied EUR/CHF volatility. In a first step, the changes were analyzed without application of a two-day average, in a second step with the usage of the latter.

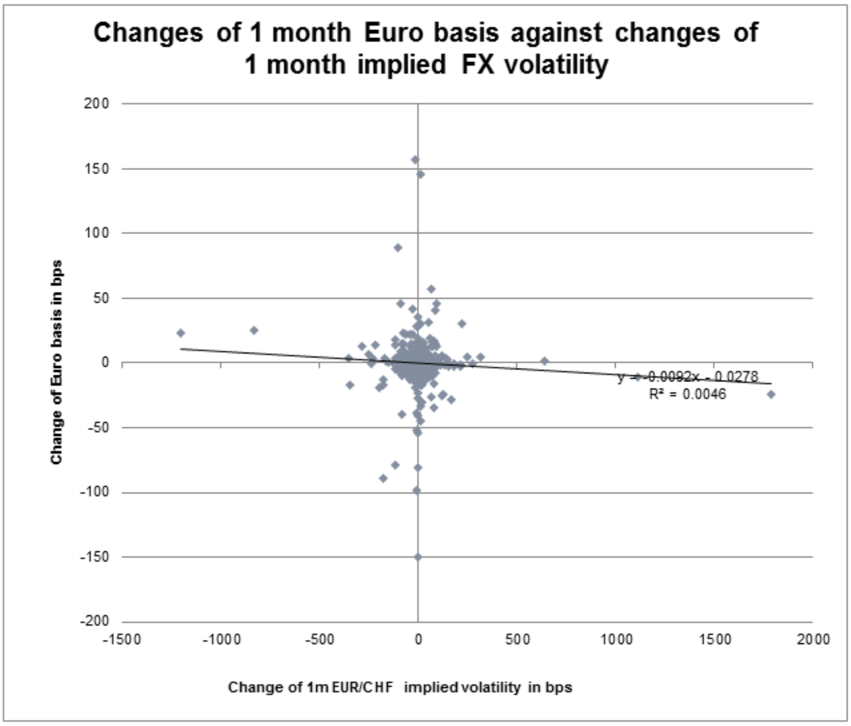


Figure 21: Changes of one-month Euro basis against changes of one-month implied EUR/CHF volatility, with time lag of one day. Market data retrieved from Bloomberg.

As can be seen in figure 21, a slightly negative slope of the regression line and a R^2 of 0.0046 resulted for the one-month analysis. Given the low R^2 value of 0.0046, no clear trend can be extrapolated from the graph. A similar outcome can be seen in the two-month analysis, as shown in table 4. The increase of the duration has led to a R^2 of 0.0004, which is lower than the R^2 observed in the one-month.

	One-month	two-month	three-month	six-month
R^2	0.046	0.0004	0.00005	0.000001
Slope of regression line	-0.0092	-0.0024	-0.0007	-0.0001

Table 4: Summary of Euro basis scatter plots without moving average.

The further the duration was extended, the more the R^2 decreased. Turning to the slope of the regression line, the further the maturities were extended, the less negative the slope became.

The scatter plots for the two-, three- and six-month tenor can be found in the appendix 7, 8 and 10.

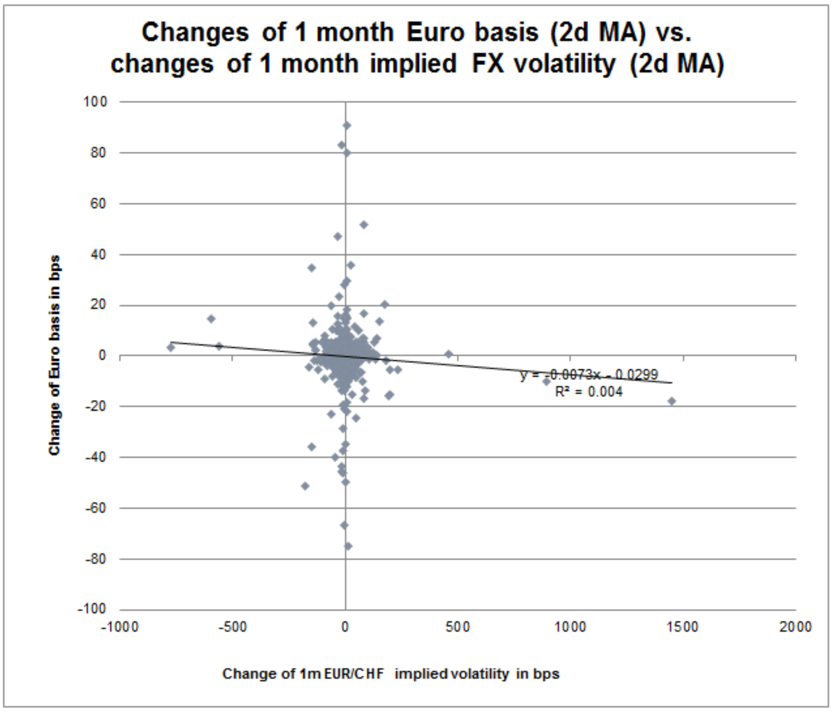


Figure 22: Changes of one-month Euro basis against changes of one-month implied EUR/CHF volatility. Time lag of one-day and two-day moving average over the changes was applied. Market data retrieved from Bloomberg.

In a next step, a two-day moving average over the changes in the Euro basis and implied EUR/CHF volatility was applied. Figure 22 exhibited a R^2 of 0.004 for the one-month tenor and a negative slope of -0.0073. As can be seen in table 5, the R^2 did not change notably for the other maturities. The slope of the regression line tended to increase when the tenor of the basis and implied volatility were raised. The slope stood above zero for the three – and six-month.

	One-month	two-month	three-month	six-month
R2	0.004	0.0002	0.0002	0.0013
Slope of regression line	-0.0073	-0.0014	0.0012	0.0031

Table 5:Summary of Euro basis scatter plots with moving average.

The two-, three- and six-month scatter plots can be found in the appendix 9, 11 and 12.

To sum up, there was no evidence, that a change of the Euro basis could have been anticipated by a change of the implied EUR/CHF volatility.

3.1.3. British sterling basis against Swiss franc

Similar to the previous sections, the foreign currency basis will be analyzed against Swiss franc for any violation from the CIP condition. Any bases that are different from zero point to arbitrage opportunity that could be exploited with a FX lender or FX borrower swap. Similar to previous analysis of the foreign currency basis, any deviations greater or smaller than 10 bps from zero are revealing substantial arbitrage opportunities. The following graphs will display the British sterling basis as well as the implied GBP/CHF volatility.

3.1.3.1. CIP violations and implied volatility

Figure 23 exhibits, that violations from the CIP condition were observable in the one-month British sterling basis against Swiss franc. From an analyzed 1515 trading days, the basis stood above zero on 1067 days and was in negative territory on 448 day. A persisting positive basis was witnessed, with the most pronounced one from 28 December 2011 to 5 April 2012. Negative deviations from the CIP condition did occur less often than positive ones, but were more pronounced. The defined CIP trading range was breached 554 times, whereof 250 were positive breaches and 204 negative. Stress events like the abolishment of the minimum exchange between the Swiss franc and the Euro did result in the basis peaking at negative -229 bps. Even though these deviations were strong in magnitude, they did not persist and the basis recovered quickly.

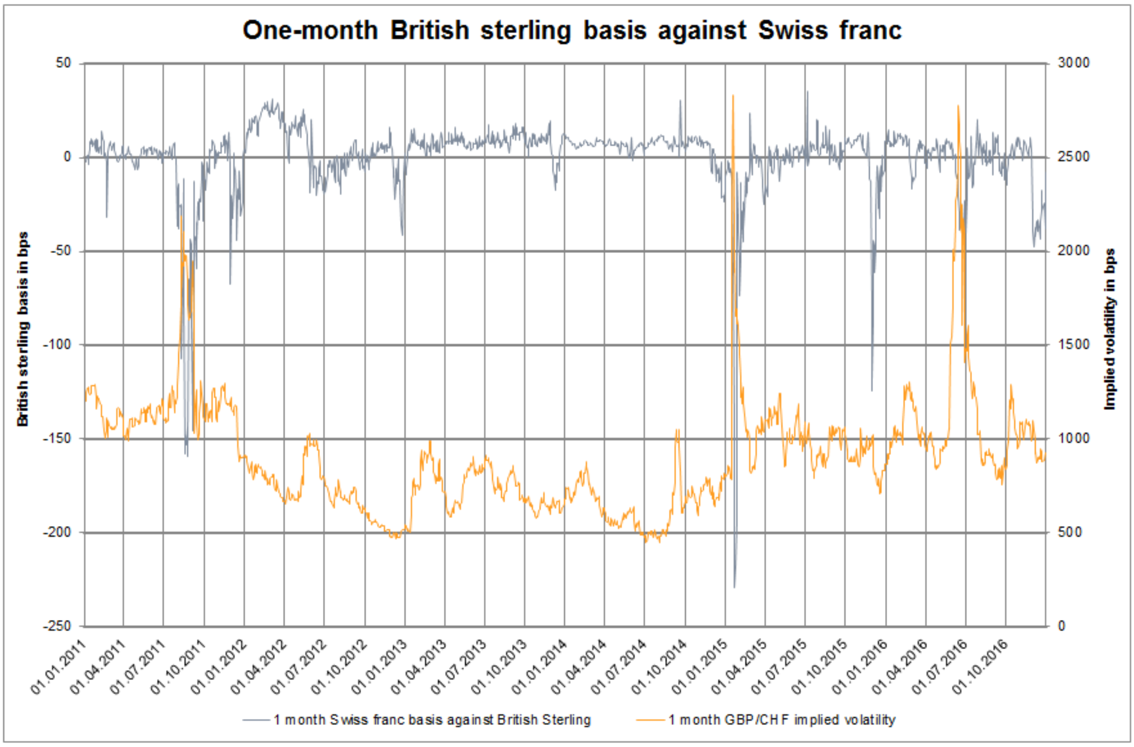


Figure 23: One-month British sterling basis against Swiss franc. Market data retrieved from Bloomberg.

As shown in figure 23, negative deviations towards year-ends have been observed. In 2012, the basis decreased from 7 bps on 29 November 2012 to as low as -41 bps on 24 December 2012. The negative basis recovered towards the end of the year and stood above zero on 4 January 2013. A comparable move was detected in 2014 and 2016. The year-end of 2015, on the other hand, showed a substantial deviation from the CIP condition. On 19 November 2015, the basis was trading at 2 bps but decreased sharply over the coming weeks to a low of -124 bps on 30 November 2015. But the negative basis did not persist. As per 30 December, the basis recovered to positive territory. In 2013, a decrease of the basis was accompanied by an increase of the implied one-month GBP/CHF volatility, whereas in 2012, 2015 and 2016 the implied volatilities decreased during the last trading weeks of the year. "Quarter-end effects" (Du et al, 2017, p.34) were observed in the second quarter of 2012, in the first quarter of 2015, as well as in the second quarter of 2016. The decrease of the basis in the latter may rather be attributed to the Brexit referendum than the quarter-end. Compared to the year-end deviations, quarter-end effects tended to be less distinct.

Similar to the US dollar and Euro basis, stressed market conditions resulted in a significant decrease from the CIP condition which was accompanied by a spike in implied

GBP/CHF volatility. This was observable in September 2011, when the SNB introduced the minimum exchange rate policy (SNB, 2011), January 2015, the abolishment of the latter (SNB,2015) as well as in June 2016, when the Brexit referendum was accepted (BBC, 2016). Different to the observations made in the US dollar basis, the British sterling basis was able to recover from the correction seen around the time of the Brexit referendum.

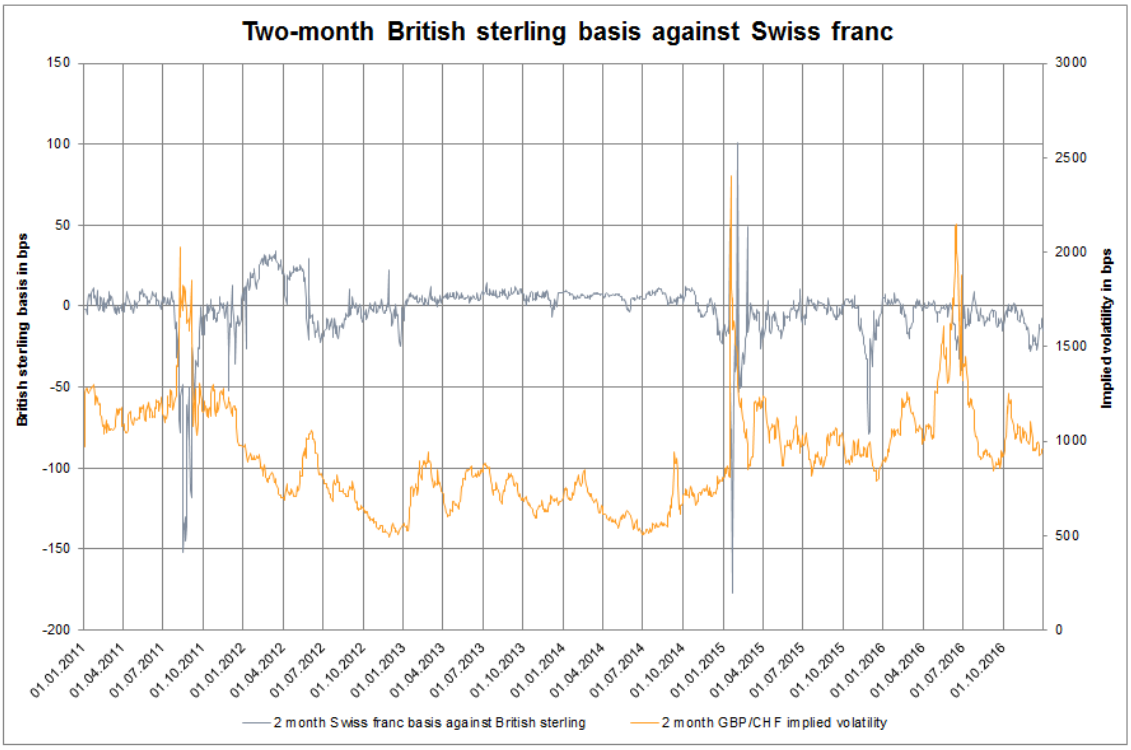


Figure 24: Two-month British sterling basis against Swiss franc. Market data retrieved from Bloomberg.

The overall course of the two-month basis, as depicted in figure 24, looked similar to the one-month tenor. From a total of 1515 trading days, it was in positive territory on 829 and negative on 686. A low was reached on 21 January 2015 with -177 bps, while the highest basis occurred 8 trading days later, on 2 February 2015, when it peaked at 101 bps. In contrast to the one-month tenor, negatives breaches of the CIP trading range outnumbered positive ones. With 276 negative breaches, the two-month basis showed the highest number of all British sterling observations. While there were no significant negative quarter-end deviations from CIP observable, several year-end corrections occurred. In 2012, 2014 and 2016 a negative basis in the area of -25 bps was observed. In these years, the lowest point of the basis was reached between 16 December to 29

December. The implied two-month GBP/CHF volatility behaved differently in these three years. While it did not change towards the year-end of 2012, it increased in 2014 and decreased in 2016.

In 2011 and 2015, the corrections of the two-month basis were stronger in magnitude with -52 bps and -78 bps respectively. In both years, the lowest British sterling basis was observed in the last days of November and the implied two-month GBP/CHF volatility decreased towards year-end.

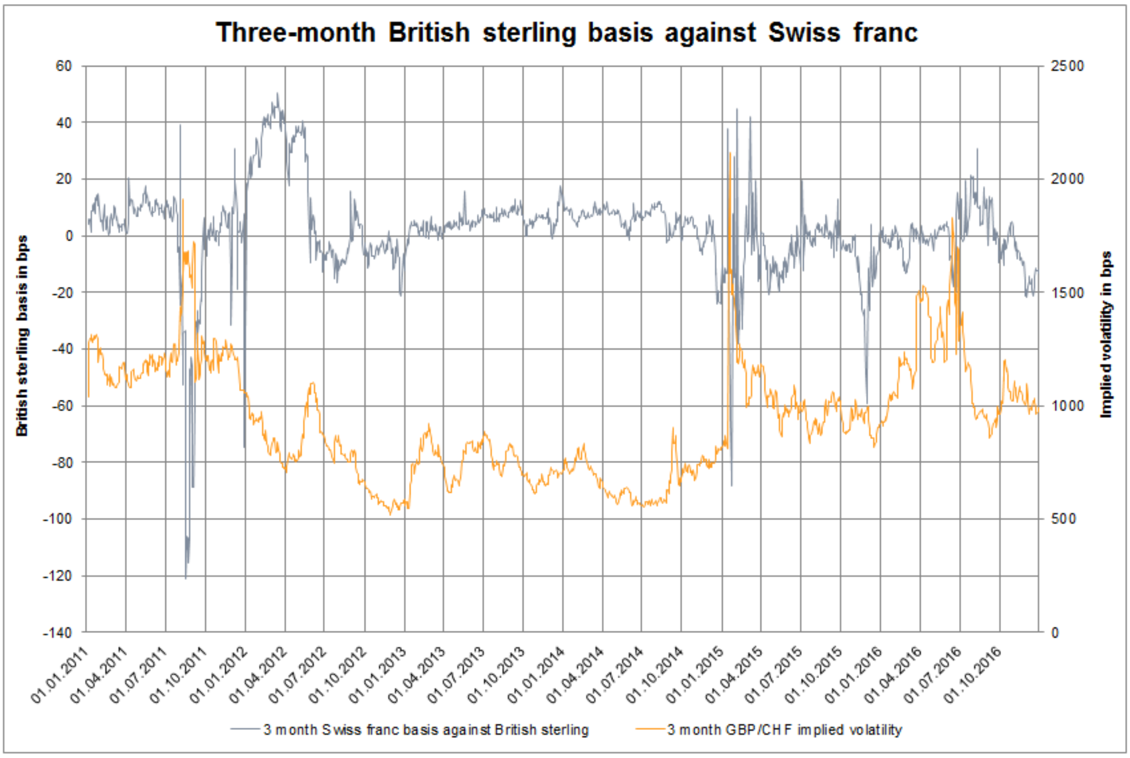


Figure 25: Three-month British sterling basis against Swiss franc. Market data retrieved from Bloomberg.

Turning to the three-month basis, it can be seen in figure 25 that the overall course was similar to the one-month. Difference between the two arose from the magnitude of the outliers. Generally, these were less pronounced for the three-month basis. Furthermore, the latter showed it lowest deviation from CIP on 17 August 2014 at -121 bps, whereas the one- and two-month basis reached their respective lows on 21 January 2015. The negative deviation in January 2015 did occur, but less pronounced. From a total of 1515 trading days, the basis was below zero on 561 days and above it on 954. The basis stood outside the CIP trading range on a total of 436 days, whereof 242 were above and 194 below. Similar to the two-month basis, year-end corrections from CIP did occur.

In the years 2012, 2014 and 2016 a deviation of the magnitude between -21 and -24 bps occurred, while in 2015, deviation stood at -59 bps. Furthermore, the deviation in 2015 was most pronounced at the end of November, whereas 2012, 2014 and 2016 showed the biggest deviations around mid-December. The overall course of the implied three-month GBP/CHF volatility was comparable to the one- and two-month tenors, with the difference that the three-month was less pronounced.

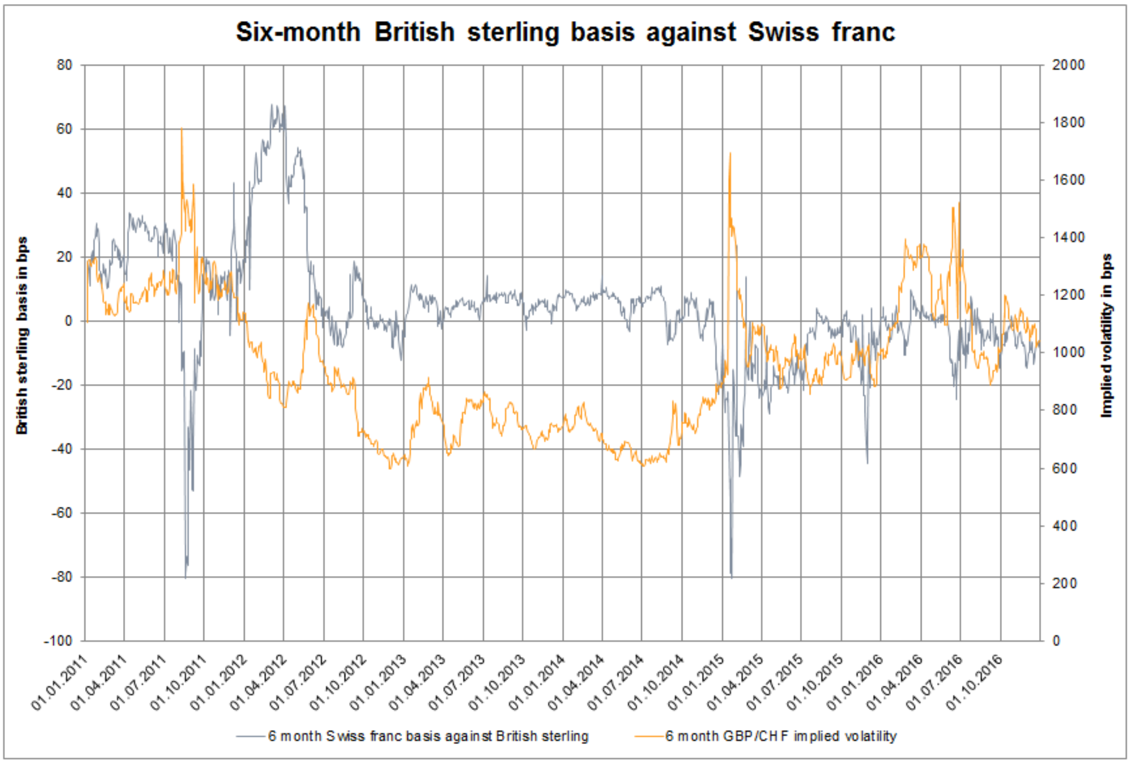


Figure 26: Six-month British Sterling basis against Swiss franc. Market data retrieved from Bloomberg.

The six-month basis showed the strongest positive deviations from all analyzed British sterling bases. From a total of 550 days outside the CIP trading range, 341 were positive, marking the highest number of breaches of all analyzed British sterling bases. Similar to the three-month, the lowest basis occurred after the introduction of the minimum exchange rate policy by the SNB in 2011 (SNB, 2011), when the basis plummeted to -80 bps. As can be seen in figure 26, the negative deviation was of approximately equal magnitude as in January 2015, when it reached -80 bps as well. A negative deviation from the CIP condition was observable towards the year-ends of 2014, 2015 and 2016. In 2014 and 2016, the deviation reached -23 bps and -15 bps in mid-December of the corresponding years. Similar to the other tenors observed, the highest year-end deviation did occur in 2015, with a six-month basis of -45 bps on 1 December 2015.

To conclude, negative deviations from the CIP condition were observed in the British sterling basis against Swiss franc. But they did not persist for an extended period of time and were mostly a result of either stressed market conditions or year- and quarter-ends. With regard to the negative deviations, the longer the tenor, the less pronounced they were. The positive deviations on the other hand, appeared to be more pronounced the longer the maturity was. Furthermore, over all analyzed maturities, the period from January 2012 to July 2011 exhibited a persistent positive basis.

3.1.3.2. Scatter plot of daily changes in basis and implied volatility

Similar to the previous scatter plots, changes in the foreign currency basis were plotted against changes of the corresponding GBP/CHF implied volatility. In a first step, without application of a two-day average, in a second step with the usage of the latter.

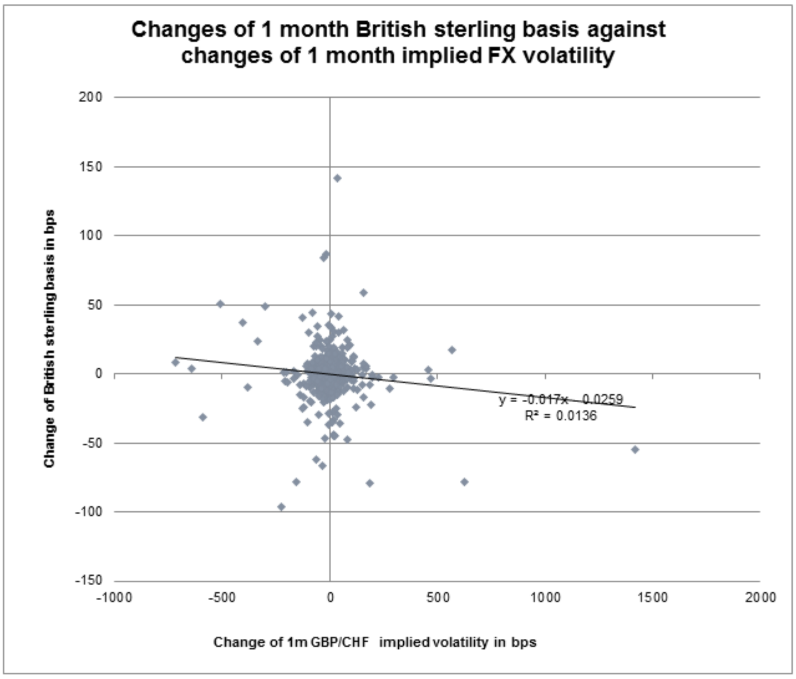


Figure 27: Changes of one-month British sterling basis against changes of one-month implied GBP/CHF volatility. Time lag of one-day on the basis. Market data retrieved from Bloomberg.

The remaining scatterplots can be found in appendix 13, 14 and 16.

As shown in figure 27, the regression line of the scatter plot had a slightly negative slope and a R^2 of 0.0136. For the changes in two-month basis against the changes in the implied two-month GBP/CHF volatility, the R^2 increased slightly while the slope of the regression line decreased from -0.017 to -0.0288, which was the lowest value of the analyzed British sterling scatter plots.

As shown in table 6, the three-month horizon exhibited the biggest R^2, but with a value of 0.0216 it was not significant. The six-month scatter plot showed the lowest R^2 with a value of 0.0012 and the highest slope with -0.0052.

	One-month	**two-month**	**three-month**	**six-month**
R^2	0.0136	0.022	0.0216	0.0012
Slope of regression line	-0.017	-0.0288	-0.0265	-0.0053

Table 6: Summary of British sterling basis scatter plots without moving average.

There was no clear trend observable allowing changes in the British sterling basis to be anticipated by changes in the implied GBP/CHF volatility.

The application of a moving average over the changes generally increased the R^2 of the scatter plots over all tenors, as can be seen in table 7. Comparing the one-month in figure 28 with figure 27, it can be observed that the R^2 increased by the factor 4.3. The slope of the regression line decreased by the factor 2. Even though the R^2 are higher than in the previous analysis, the scatter plots lack to show a clear trend between the change in implied GBP/CHF volatility and the change in basis.

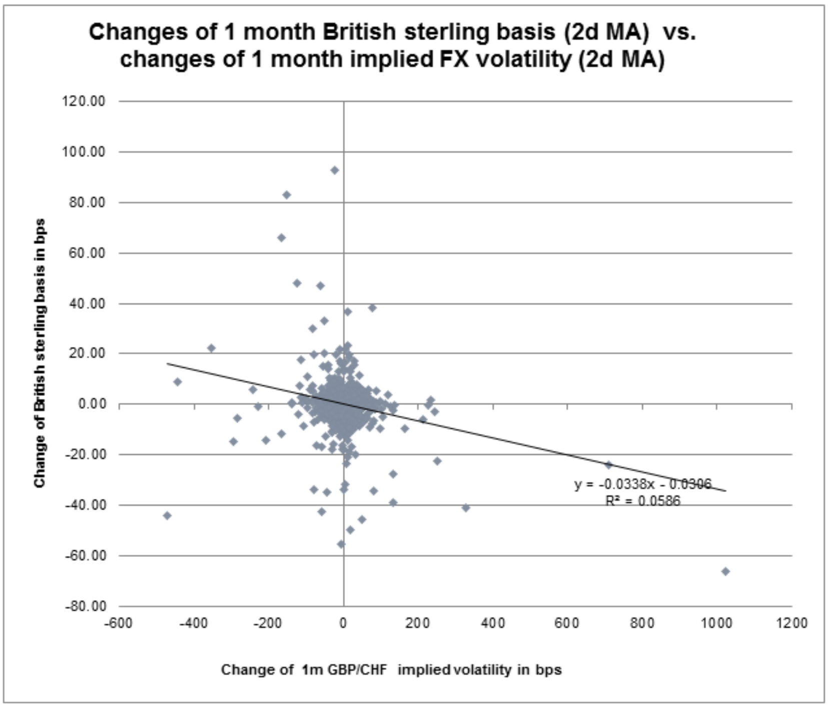


Figure 28: Changes of one-month British sterling basis against changes of one-month implied GBP/CHF volatility. Time lag of one-day on the basis and two-day moving average on the changes. Market data retrieved from Bloomberg.

The remaining scatter plots can be found in appendix 15, 17 and 18.

	One-month	two-month	three-month	six-month
R^2	0.0586	0.0485	0.0462	0.0139
Slope of regression line	-0.0338	-0.0331	-0.0301	-0.0165

Table 7: Summary of British sterling basis scatter plots with moving average.

Comparable to US dollar and Euro scatter plots, no clear evidence was found that changes in the basis could be anticipated by changes in the implied FX volatility.

3.2. Discussion

The US dollar basis against Swiss franc exhibited the highest negative deviation from CIP of all analyzed currency pairs. Within the US dollar basis, the one- and two-month showed the most negative deviations outside the CIP trading range. Since November 2014, their basis was mostly negative and the respective one-month basis was persistently negative since April 2016. The Euro basis against Swiss franc exhibited more positive than negative deviations from CIP, whereas in British sterling basis the positive and negative deviations were about equal.

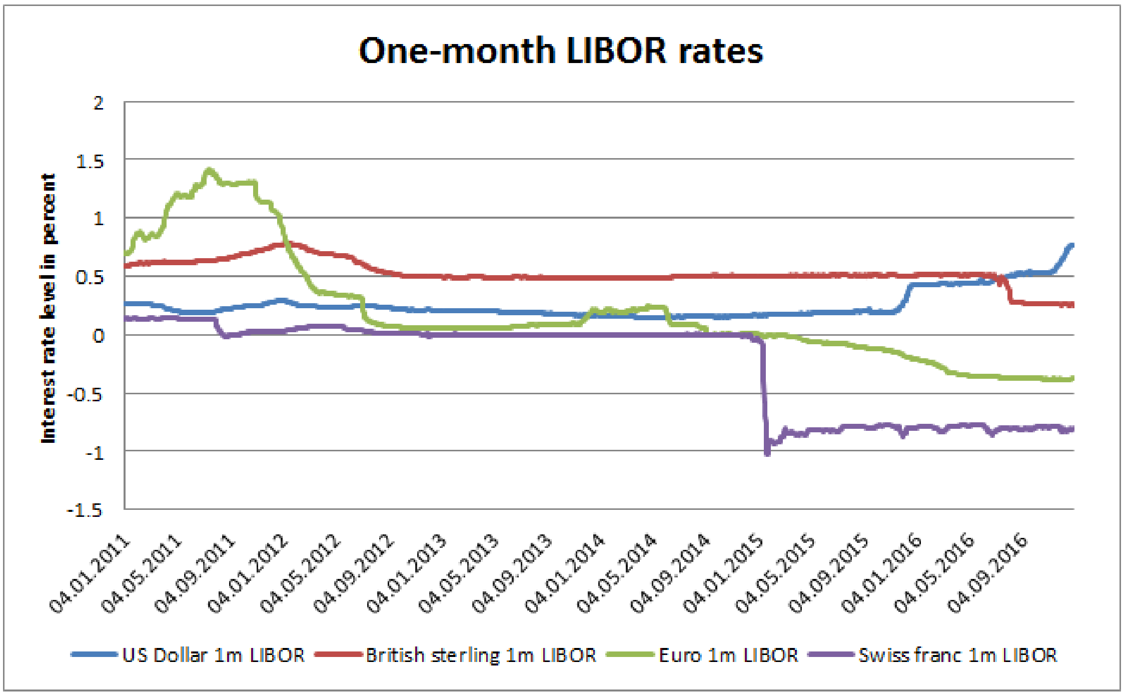


Figure 29: Interest rate differential of the one-month LIBOR rates. Market data retrieved from Bloomberg.

As can be seen in figure 29, the interest rate differential was most pronounced between Swiss franc and US dollar for the analyzed time horizon. The differential started to widen further, ever since the Federal Reserve started to hike interest rates in December 2015 (Federal Reserve, 2015) while the European Central Bank (European Central Bank, 2015) and the Bank of England (Bank of England, 2016) reduced their respective interest rates and increased the money base through asset purchase programs.

The fact that a higher interest rate differential between the Swiss franc and the analyzed currencies led to a higher negative basis is similar to the observations made by Du et al. (2017). Conversely to the carry-trade, where one borrows in a low interest rate currency and lends the funds out in a high interest rate currency, CIP arbitrage opportunities arise from borrowing in the high interest rate currency and lend the proceedings in a low interest rate currency. Possible reasons were elaborated by Sushko et al. (2015). High interest rate currencies attract money inflows originating from outside the respective currency zone. These investors may wish to hedge their currency exposure and turn to the FX swap market. As the hedging demand may outweigh the supply, a pressure on the FX swap points may result, leading to further negative deviations from the CIP condition.

The basis in all analyzed currency pairs decreased after stress events, while the shorter tenors reacted more sensitively. Over the analyzed time horizon, the introduction (SNB,

2011) and abolishment (SNB, 2015) of the minimum exchange rate policy by the SNB and the Brexit referendum (BBC, 2016) were determined as the most severe stress events. The increase in implied FX volatility around the time of these events fortified this claim. While the SNB announcements as well as the Brexit referendum led to a sharp negative deviation of the CIP, the courses after the respective event were different. On the trading day after the Brexit referendum, the basis reached a low point but started to recover afterwards. The Euro and British sterling bases were able to recover to levels seen before the referendum, whereas the US dollar bases, with exception of the six-month basis, were not able to retreat to pre-June 2016 levels.

This stands in contrast to the SNB announcements, when the lowest basis was observed around 10 days thereafter. Possible explanations can be derived from Pinnington and Shamloo (2015). They claim that increased hedging demand combined with lower liquidity and widening bid-ask spreads are responsible for the deviations. It can be assumed that the SNB announcement on 15 January affected the Swiss franc market more severely than the Brexit referendum. The market turmoil in Switzerland on and following 15 January 2015 might have resulted in banks being more reluctant in providing quotes in the FX swap markets, given that some might have suffered severe losses on their trading books. The increased hedging demand in the aftermath of the announcements combined with the reduced liquidity might be one of the reason why the basis further decreased into negative territory.

A negative deviation from CIP towards year-ends could be observed over most time horizons and currencies analyzed. But different to Du et al. (2017), the low point of the deviation occurred in the end of November or beginning of December, irrespective of the tenor of the basis. This stands in contrast to the claim by Du et al. (2017), where only the one-month bases should show the low point of the deviation one month before the end of the year. Year-end hedging demand might explain some of the deviation but does not clarify why the basis started to recover towards year-end. Another explanation could be the gradual increases in regulatory requirements under Basel III (BIS, 2013). Under the latter, the requirements are increased by January of the respective year. It can therefore be assumed, that banks try to bring their balance sheet in line with the upcoming requirements. Foreign banks that report in US dollar, Euro or British sterling may try to decrease their foreign currency positions by selling those currencies against their reporting currency. To do so, they may enter into FX borrower swap, where they buy US dollar, Euro or British sterling against Swiss franc with value spot and convert the position back at a predefined time in the future. The increased demand for FX borrower swaps combined with year-end hedging demand may put further pressure on the negative CIP basis.

The persistence of a negative CIP deviation of greater than -10bps in the US dollar basis against Swiss franc was striking. As elaborated by Sushko et al. (2015), such deviations were quickly arbitraged away prior to the GFC. The introduction of higher capital requirements under Basel III and especially the leverage ratio seemed to have an influence on the willingness of banks to engage in arbitrage transactions as pointed out by Du et al. (2017). It might be argued that the increase in regulation led to a more stable and sound financial system, but it should be kept in mind, that less market making and risk taking financial institutions lead to wider bid-ask spreads, increasing the costs for clients. Negative deviations in the foreign currency basis against Swiss franc can be cited as an example, as they increase the hedging costs for Swiss franc investors holding foreign assets.

The scatter plot analysis over all time horizons and bases did not show a clear trend between the basis and the implied volatility. It can therefore be concluded unlikely that deviations from CIP can be anticipated by using implied FX volatility.

Turning to the methodology, the defined CIP trading range of 20 bps helped to differentiate minor from substantial deviations and plotted a clearer picture of the CIP violations. The calculation of the basis with LIBOR, LIBID rates and FX swap ask points considered the bid-ask spreads paid and increased the practical relevance for accurately measuring negative CIP violations. The weakness in this approach was that positive CIP deviations were revaluated at the same bid-ask rates as negative ones, leading to a minor distortion in accuracy. Furthermore, the FX swap ask points showed one particular weakness: They were retrieved using the prices from 23:00h CET of any particular trading day. These rates had a tendency to deviate from the FX swap ask points seen around 18:00h CET, especially so before long weekends or bank holidays as less liquidity providers seemed to be available. Retrospectively, FX swap ask points should have been retrieved at 16:00h CET, when London based as well as New York based liquidity providers are quoting.

To conclude, negative deviations from CIP reoccurred towards end of November to beginning of December for most tenors and currencies analyzed. The biggest arbitrage opportunities with a negative basis arose from the one- and two-month tenors in the US dollar against Swiss franc basis. The Euro basis on the other hand, exhibited more positive than negative CIP violations. Generally, stress events can be used to take advantage of CIP deviations, as they tend to recover quickly. Furthermore, the bigger the interest rate differential of the foreign currency to the Swiss franc, the more pronounced and persistent the negative CIP deviations were. On the other hand, there was no evidence found that deviations from CIP could be anticipated using implied volatilities.

4. Conclusion

The aim of the paper was to analyze if violations from the CIP condition have occurred over a time horizon from 4 January 2011 until 30 December 2016 and whether these deviations could be anticipated with implied FX volatilities. The analysis was conducted on the US dollar, Euro and British sterling basis against Swiss franc with a focus on negative deviations. Violations of the CIP condition manifest arbitrage opportunities. Negative bases can be arbitraged out with FX lender swaps, in which the foreign currency is sold with value spot and simultaneously bought back at a predefined price and time in the future. The existence of negative deviations allows Swiss based banks and financial institutions to increase their earnings on foreign currency cash reserves held. A reliable possibility to anticipate deviations from CIP could help banks and financial institutions to time their arbitrage transactions to maximize their returns.

Violations of the CIP condition were found for the analyzed currencies between 4 January 2011 and 30 December 2016. The strongest negative deviations were found in the one- and two-month US dollar basis. For the British sterling bases, positive and negative deviations were observed in about equal quantity, whereas the Euro basis exhibited substantially more positive than negative deviations. There was no clear evidence, that the changes in the foreign currency basis could have been anticipated using implied FX volatilities. On the other hand, a reoccurring negative deviation about one-month before the end of the year was observable for most tenors and bases. Furthermore, stress events led to sharp decreases of the basis into negative territory. They were mostly short-lived and recovered quickly.

The shorter tenors reacted more sensitively and generally showed bigger outlier than the longer dated bases. Further studies might concentrate on this finding and analyze the CIP violations for tenors of shorter than one-month. Attention should be paid to the data stamp of the FX swap ask points. To protect the data set against distortions resulting from reduced liquidity, the market data in the afternoons of the European trading session should be considered. Furthermore, the positive deviations were not analyzed in greater detail. Given their occurrence in the Euro bases, one can conduct further research on this matter. Lastly, the R^2 tended to increase when the two-day moving average was applied. One could therefore expand the moving average to 5 or 10 days and investigate whether the R^2 become significant.

The CIP violations offer arbitrage opportunities for Swiss banks and financial institutions. To maximize the return, these transactions should be timed towards end of November to beginning of December when the negative basis tended to decrease substantially. However, these institutes should consider regulatory requirement first, as capital costs might outweigh potential profits.

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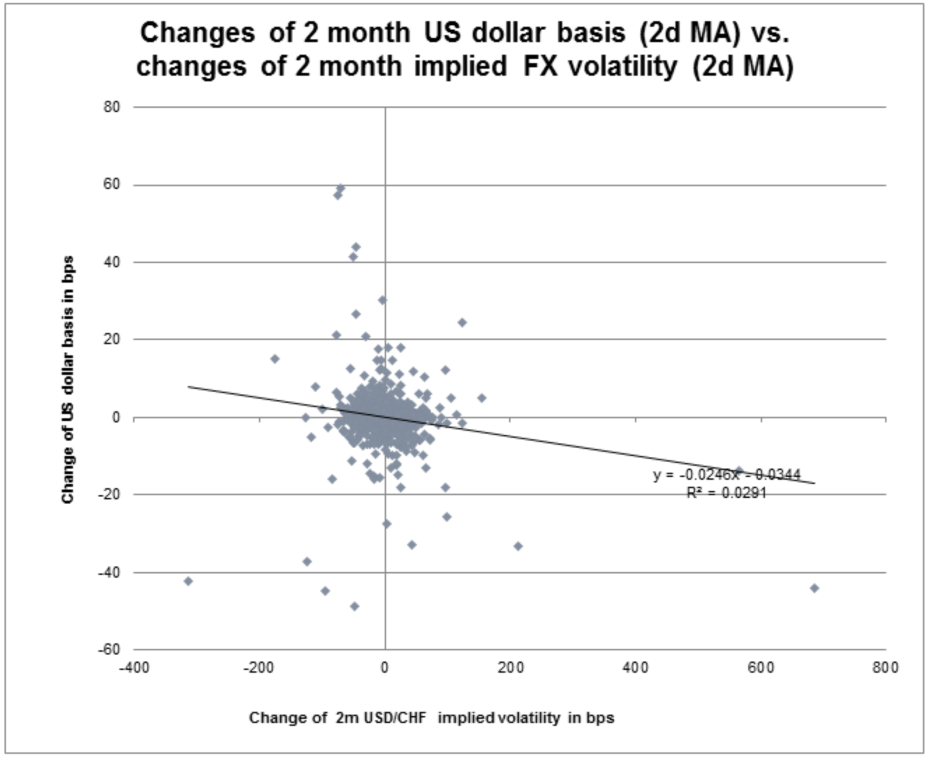
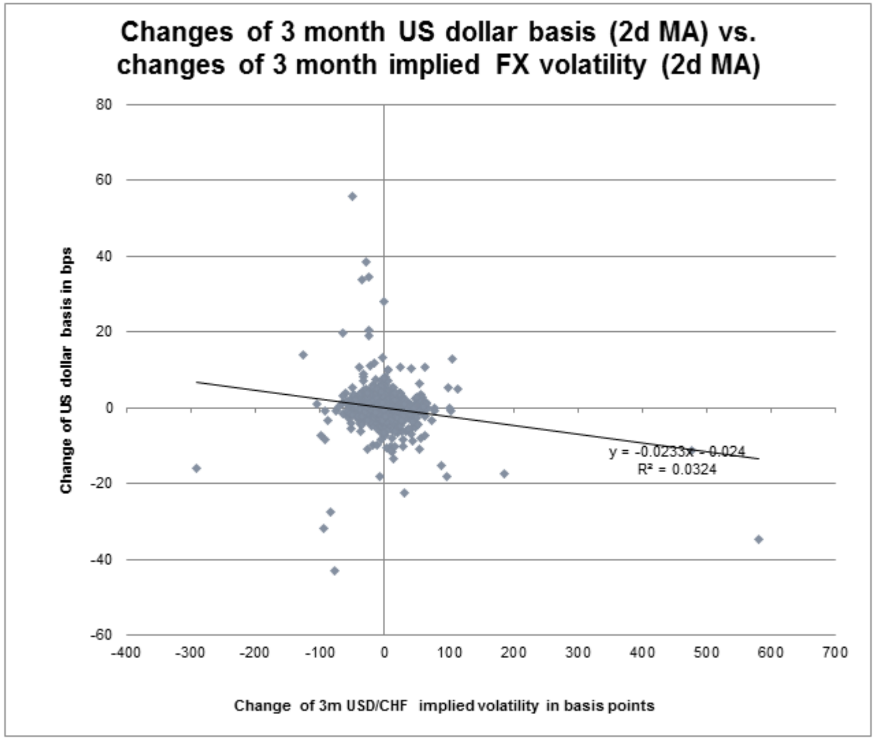
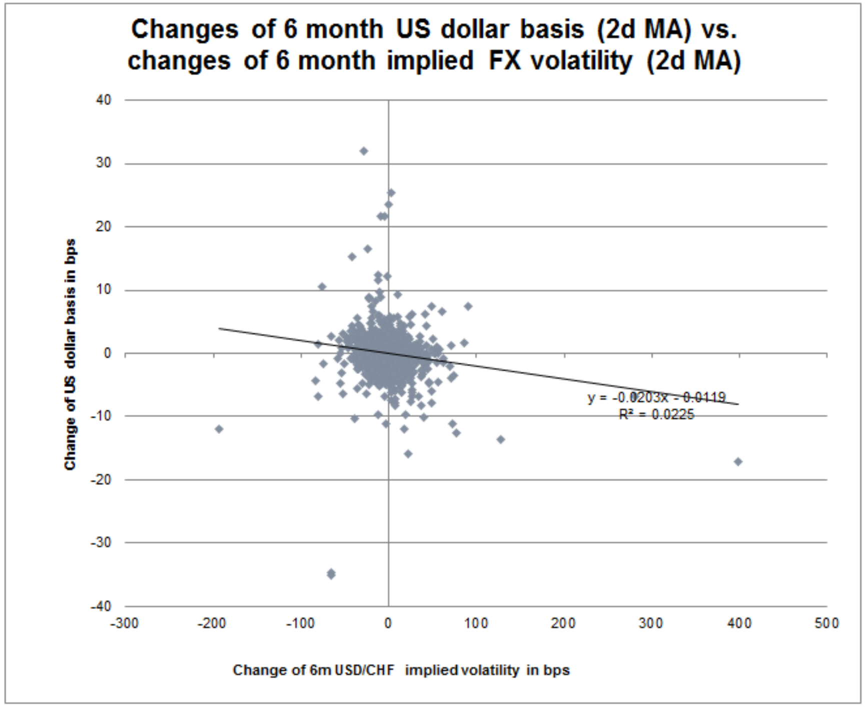
Appendix

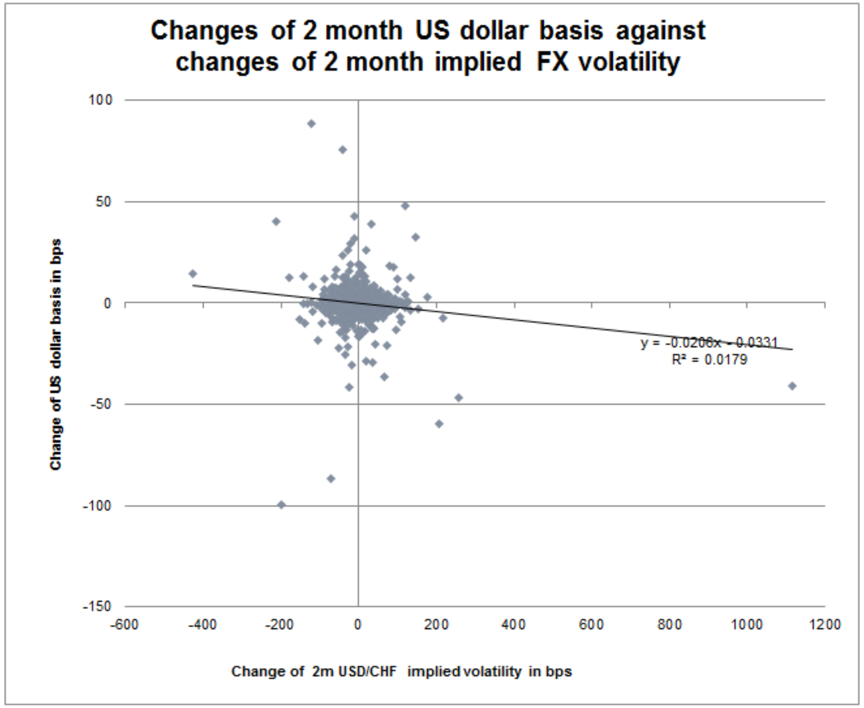


Appendix 1: Changes of two-month US dollar basis against changes of implied volatility. Time lag of one-day and two-day moving average applied. Market data retrieved from Bloomberg.



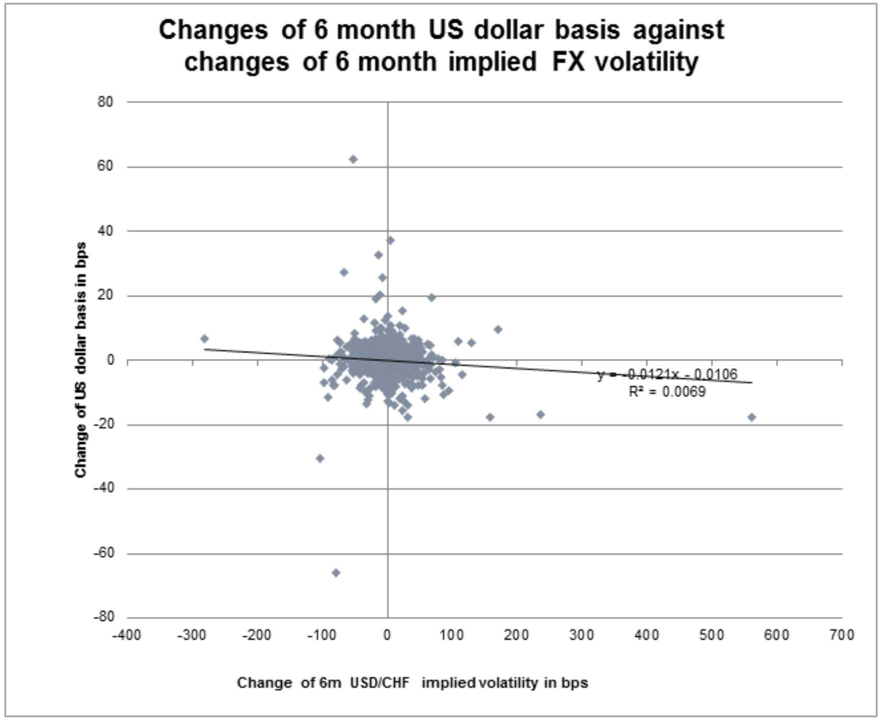
Appendix 2: Changes of three-month US dollar basis against changes of implied volatility. Time lag of one-day and two-day moving average applied. Market data retrieved from Bloomberg.



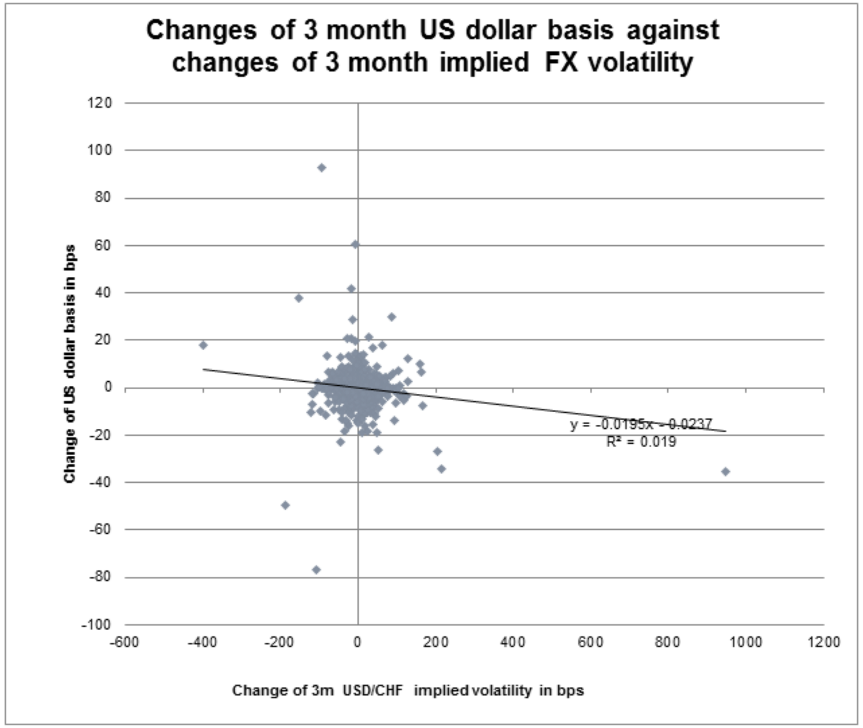


Appendix 3: Changes of six-month US dollar basis against changes of implied volatility Time lag of one-day and two-day moving average applied. Market data retrieved from Bloomberg.

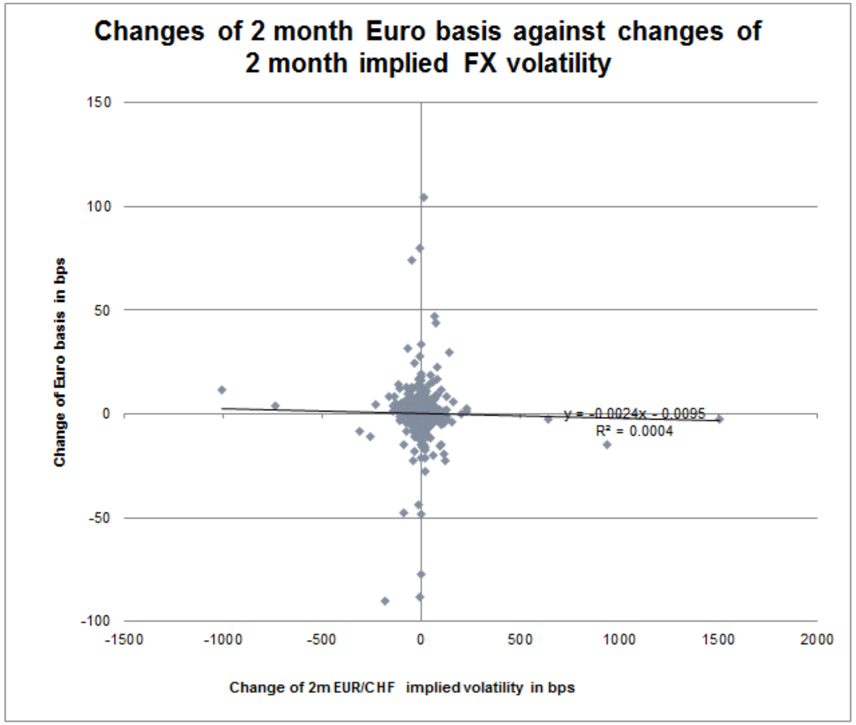
Appendix 4: Changes of two-month US dollar basis against changes of implied volatility. Time lag of one-day applied. Market data retrieved from Bloomberg.



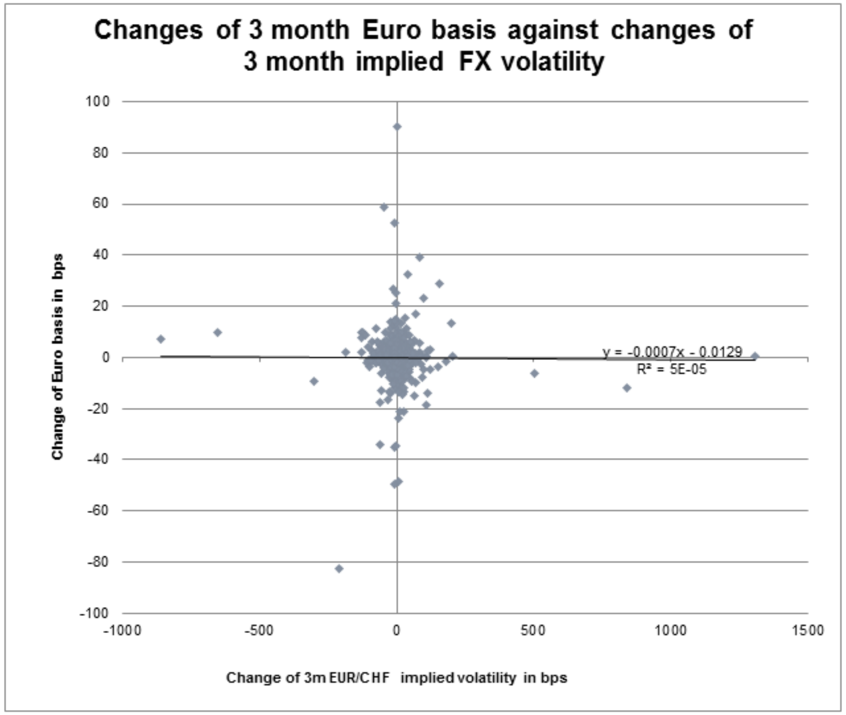
Appendix 5: Changes of six-month US dollar basis against changes of implied volatility. Time lag of one-day applied. Market data retrieved from Bloomberg.



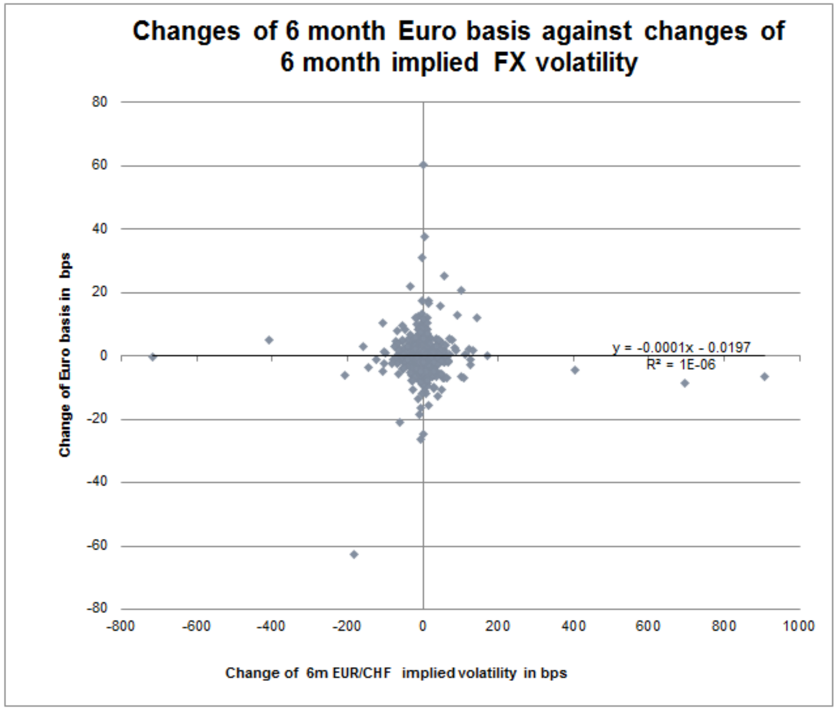
Appendix 6: Changes of three-month US dollar basis against changes of implied volatility Time lag of one-day applied. Market data retrieved from Bloomberg.



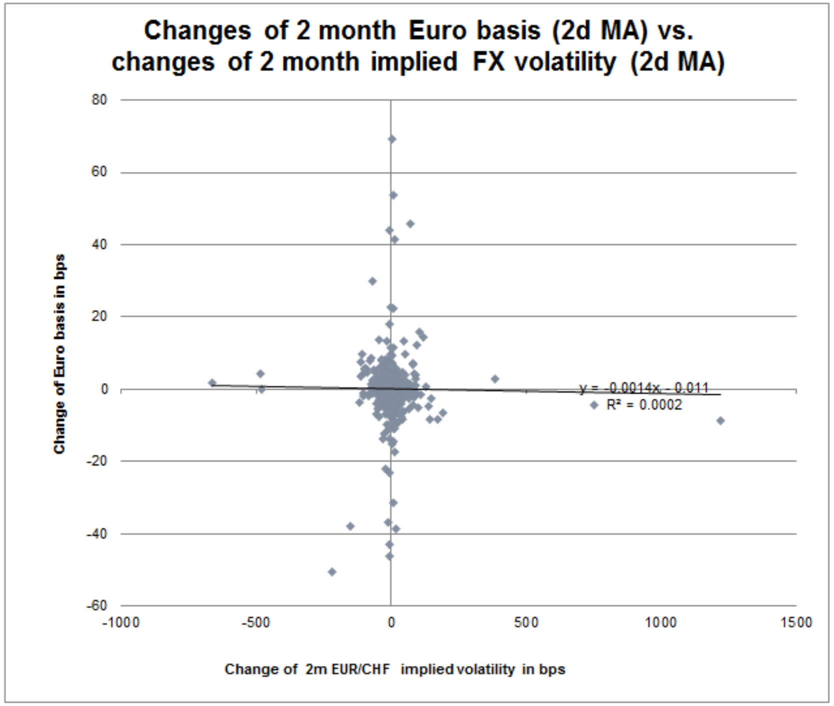
Appendix 7: Changes of two-month Euro basis against changes of implied volatility. Time lag of one-day applied. Market data retrieved from Bloomberg.



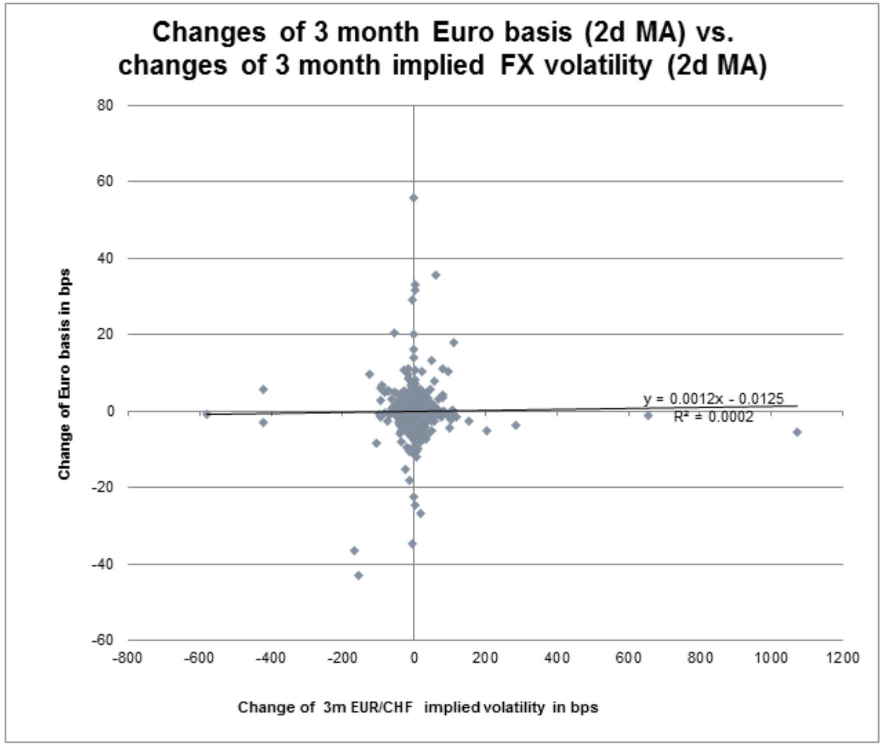
Appendix 8: Changes of three-month Euro basis against changes of implied volatility Time lag of one-day applied. Market data retrieved from Bloomberg.



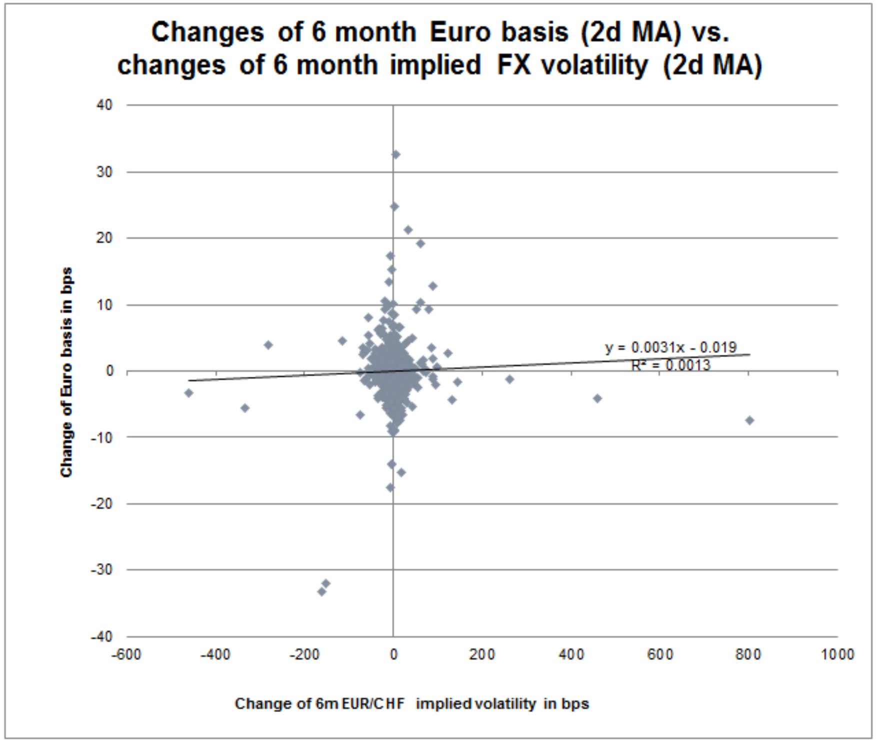
Appendix 10: Changes of six-month Euro basis against changes of implied volatility. Time lag of one-day applied. Market data retrieved from Bloomberg.



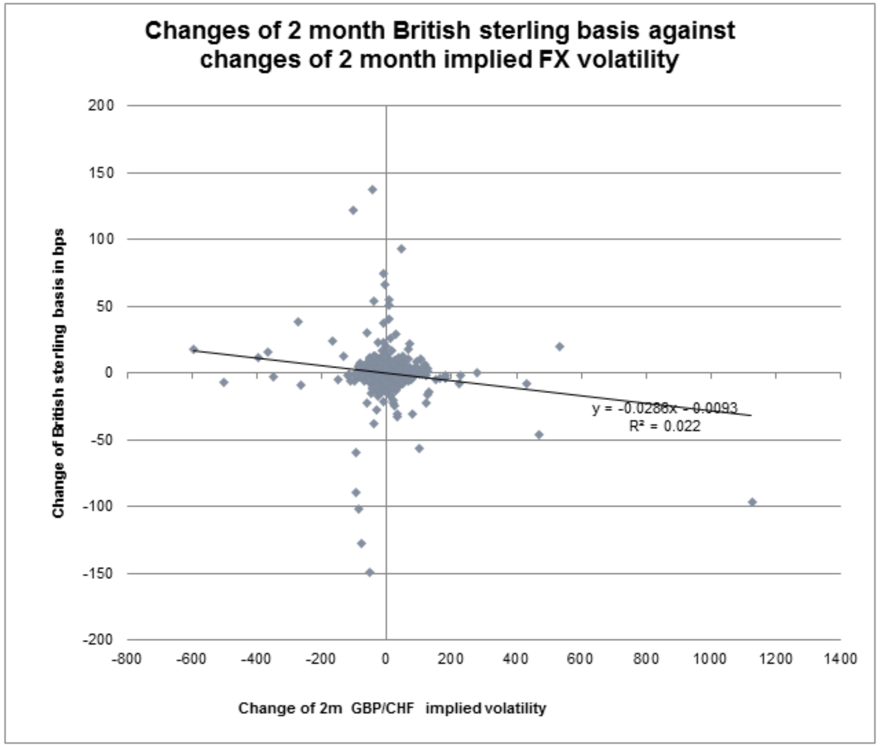
Appendix 9: Changes of six-month Euro basis against changes of implied volatility. Time lag of one-day and two-day moving average applied. Market data retrieved from Bloomberg.



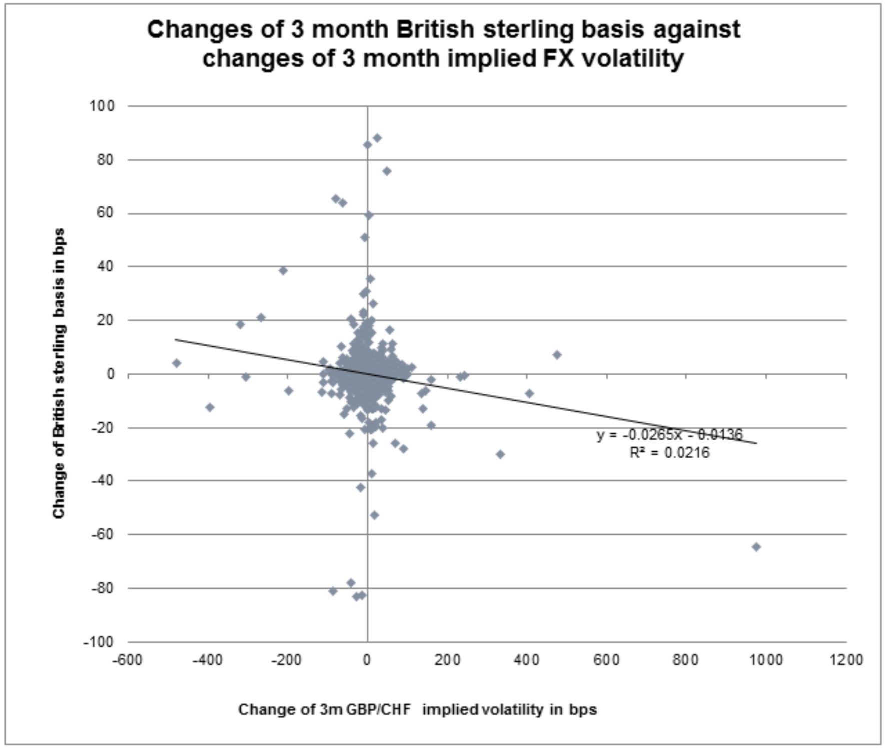
Appendix 12: Changes of three-month Euro basis against changes of implied volatility. Time lag of one-day and two-day moving average applied. Market data retrieved from Bloomberg.



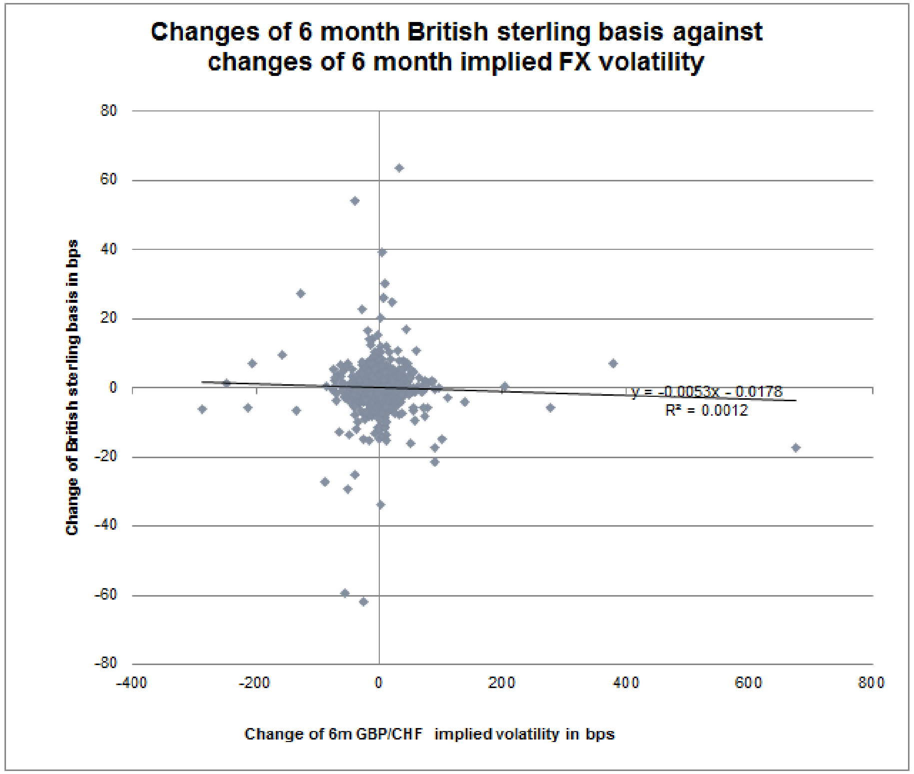
Appendix 11: Changes of six-month Euro basis against changes of implied volatility. Time lag of one-day and two-day moving average applied. Market data retrieved from Bloomberg.



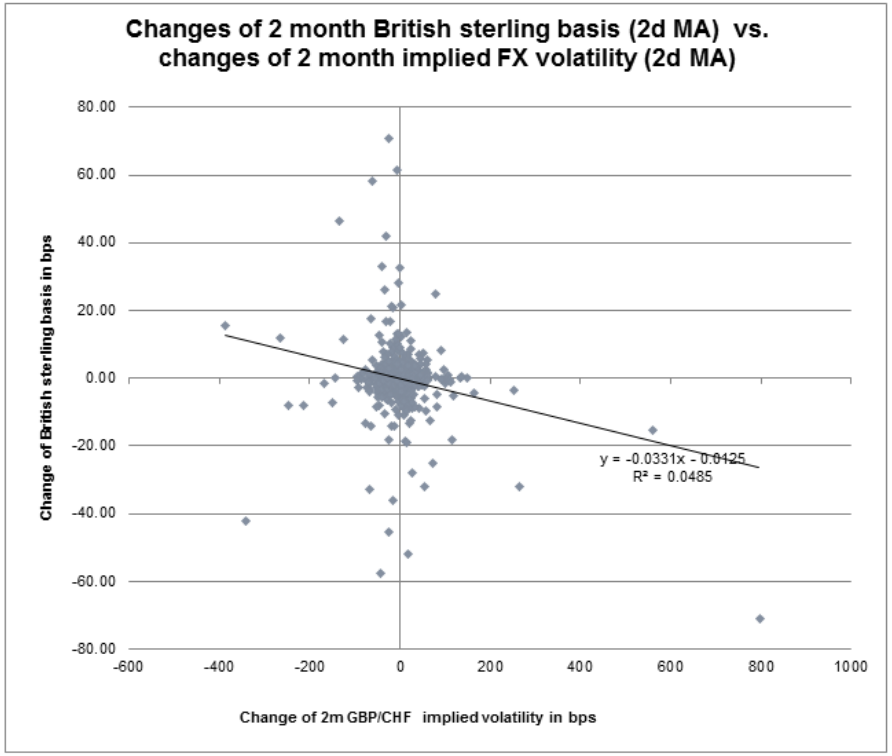
Appendix 14: Changes of two-month British sterling basis against changes of implied volatility. Time lag of one-day applied. Market data retrieved from Bloomberg.



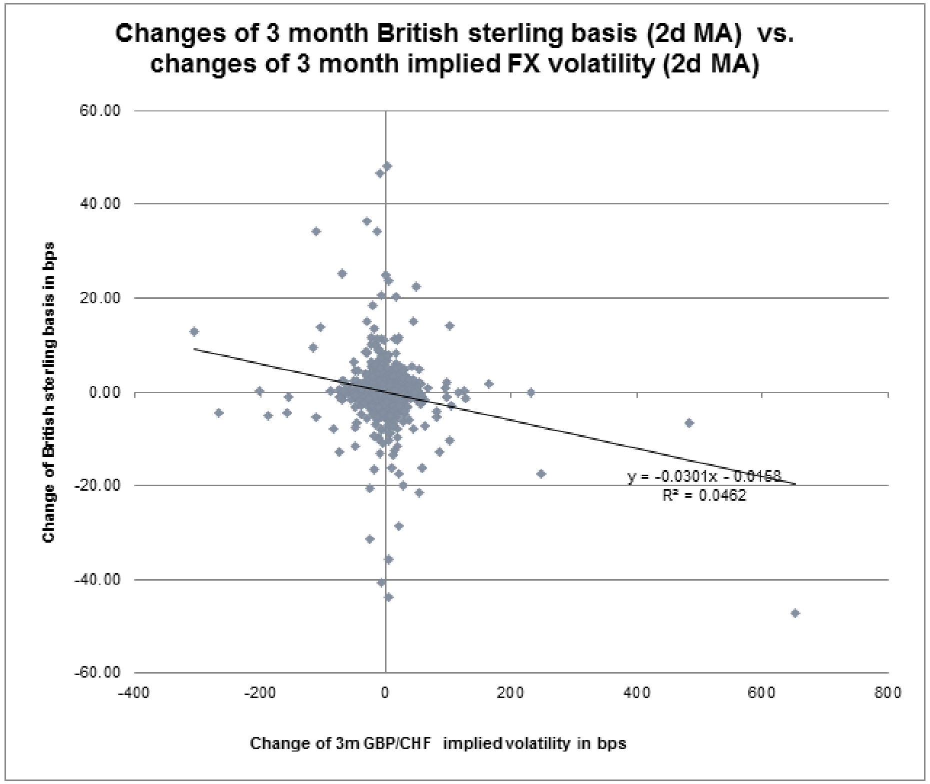
Appendix 13 Changes of three-month British sterling basis against changes of implied volatility. Time lag of one-day applied. Market data retrieved from Bloomberg.



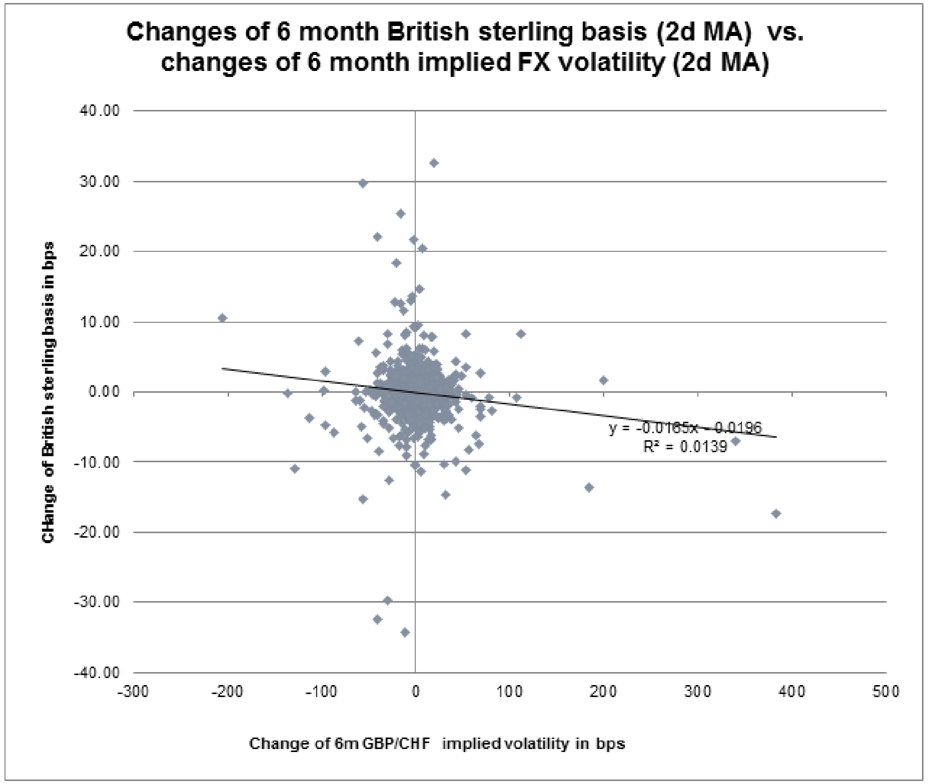
Appendix 16: Changes of six-month British sterling basis against changes of implied volatility. Time lag of one-day applied. Market data retrieved from Bloomberg.



Appendix 15: Changes of two-month British sterling basis against changes of implied volatility. Time lag of one-day and two-day moving average applied. Market data retrieved from Bloomberg.



Appendix 18: Changes of three-month British sterling basis against changes of implied volatility. Time lag of one-day and two-day moving average applied. Market data retrieved from Bloomberg.



Appendix 17: Changes of six-month British sterling basis against changes of implied volatility. Time lag of one-day and two-day moving average applied Market data retrieved from Bloomberg.

	1m		2m		3m		6m	
	pos	neg	pos	neg	pos	neg	pos	neg
British sterling basis	1067	448	829	686	954	561	961	554
US dollar basis	535	980	493	1022	521	994	703	812
Euro basis	1277	238	1312	203	1379	136	1359	156

Appendix 19: Days with positive and negative bases. Market data retrieved from Bloomberg.

	1m		2m		3m		6m	
	high	low	high	low	high	low	high	low
British sterling basis	36	-229	101	-177	50	121	68	-80
US dollar basis	16	-233	14	-179	17	-138	32	-113
Euro basis	158	-216	115	-166	124	-119	130	-68

Appendix 20: High and low of the bases in bps. Market data retrieved from Bloomberg.

	1m		2m		3m		6m	
	> 10	<-10	> 10	<-10	> 10	<-10	> 10	<-10
British sterling basis	250	204	139	276	242	194	341	209
US dollar basis	17	569	8	649	35	635	188	457
Euro basis	756	103	737	62	770	49	953	44

Appendix 21: Days outside the CIP trading range. Market data retrieved from Bloomberg