The Puzzle of Persistent Covered Interest Rate Parity Deviations: does Monetary Policy matter?

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Abstract

One of the seminal puzzles in international finance since the financial crisis in 2007 is the persistence of covered interest rate parity (CIP) deviations. Although initial rises in CIP deviations were attributed to counterparty risk, the cross-currency basis for the Yen, Euro and Swiss Franc with respect to the US dollar have been persistently negative since 2014. This is suggestive of a dollar financing premium for foreign banks, as the synthetic dollar borrowing rate is much higher than in a world where CIP deviations should be arbitraged away. This begs the question, why is this happening? We answer this through the lens of a simple model, where we make predictions regarding the forces that drive the CIP deviations. The relevant forces are (i) limits to arbitrage through capital constraints imposed on arbitrageurs, (ii) monetary shocks by domestic and US central banks and (iii) the inclusion of central bank swap lines. Key insights from the model are that expansionary monetary policies pursued by the ECB and BOJ lead to a widening of CIP deviations, and that the inclusion of central bank swap lines is effective insofar as it reduces counterparty risk. In addition, we provide empirical evidence to confirm our model predictions. To test the effect of monetary policy on CIP deviations, we construct monetary shocks as the surprise change in interest rate futures for the underlying central bank rate around monetary announcements for a set of advanced countries. We find some evidence that expansionary monetary shocks by the Swiss National Bank, Bank of Japan and European Central Bank during the period of negative interest rate policies since 2014 have led to a widening of CIP deviations. Using an event study methodology, we show there is a positive effect of central bank swap lines issued by the Federal Reserve on dampening CIP deviations in the 2008-2011 period.

Keywords: interest rate parity, exchange rates, currency swaps, dollar funding

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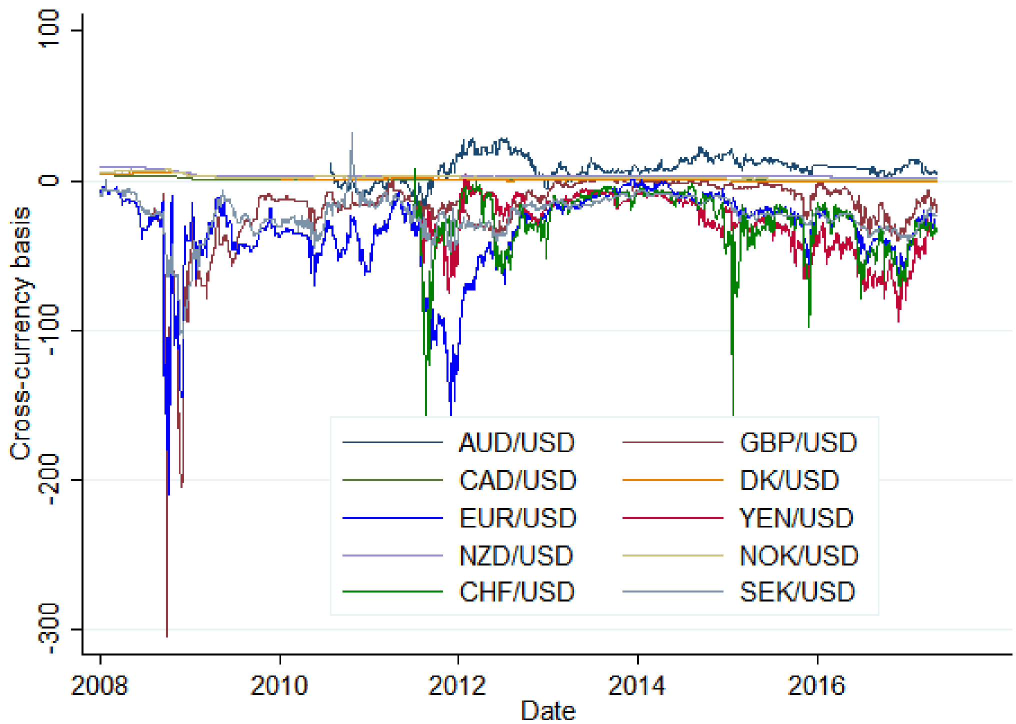
1 Introduction

Figure 1: The puzzle of persistent CIP deviations



Source: Bloomberg

Covered interest rate parity (CIP) is one of the most fundamental laws of international finance. A theory of arbitrage, it states that the rate of return on equivalent[1] domestic and foreign assets should equalize after covering exchange rate changes in the forward market. The use of a forward contract, guaranteeing an exchange rate at the maturity of a contract, should eliminate foreign exchange risk. However, since 2008 CIP deviations have become a regularity (Figure 1), and the cross-currency basis became highly negative for the EUR/USD, YEN/USD and CHF/USD bilateral pairs in the financial crisis of 2008, resurfacing again in 2011 following the Euro Debt crisis. In the absence of financial frictions, the negative cross-currency basis for these pairs means an arbitrageur could make a riskless profit by borrowing US dollars locally and then lending in Euros, Yen and CHF, demanding a sufficiently high forward premium to make the profit equal to the CIP deviation. The initial consensus on CIP deviations in 2008 and 2011 was that it was principally due to a rise in counterparty risk, as many banks faced a decline in credit worthiness

[1]Equivalent meaning having the same maturity, risk characteristics etc.

(Baba and Packer 2009). However, what is really puzzling is that these deviations have persisted, and have widened since 2014, even though the VIX and libor-ois spreads[2] have returned to more normal levels.

From the perspective of a European or Japanese bank, there are two principal ways to obtain dollars. The first is to borrow US dollars directly, either via the interbank market, issuing dollar deposits or dollar denominated debt. The second way, and one that has become increasing popular[3], is to borrow dollars through the foreign exchange swap market. Foreign exchange swaps are instruments used to exchange currencies and hedge exchange rate risk using a forward contract, and have been used by financial institutions, exporters and importers, as well as institutional investors who wish to hedge their positions. Currently the pricing of these contracts are such that non-US banks are paying a premium to borrow dollars in the swap market.

A common explanation for the persistent failure of CIP rests on a limits to arbitrage argument; in the current regulatory environment, arbitrageurs lending dollars in the swap market are capital constrained, and have insufficient liquidity to absorb the demand for dollar funding[4] (Du, Tepper, and Verdelhan 2016). In contrast to the focus on supply side factors, the contribution of this paper is to consider the role of negative interest rate policies of the ECB, BOJ and SNB and the tapering of the US Federal Reserve balance sheet since 2014 as a factor in widening CIP deviations, providing both theoretical mechanisms and empirical evidence. Through a model, we outline the effect of limits to arbitrage due to tightening of arbitrageur balance sheets in the post-crisis period, and secondly, the effect of divergent monetary policies. As motivation for the hypothesis that monetary policy is a causal factor, we note that in the period since 2014, a more negative libor differential for the Euro and the Yen [5] corresponds to a widening of CIP deviations (Figure 2). There is also a sharp correlation between movements in the Federal Reserve balance sheet and the cross-currency basis for the Yen, Euro and Swiss Franc since 2014 (Figure 3). According to Zoltan Parsar of Credit Suisse, *"The difference between key cross-currency bases trading at -100 or -25 bps is an extra \$400 billion of reserves in the system... With every \$100 billion of reserves drained, the \$/¥ basis increases by 10 bps."*. The evidence presented in Figures 2 and 3 is suggestive that divergent monetary policy stances are a factor in widening CIP deviations. As Japan and the Eurozone implement negative interest rates, foreign banks are more likely to increase their dollar lending

[2]The VIX is an index measuring implied volatility of S&P 500. Libor-ois spreads are the difference between the London interbank offer rate (libor) and the overnight index swap rate (ois), and provides a measure of credit risk in interbank markets.

[3]In section 2, we will present stylized facts to support the growing use of foreign exchange swaps by financial institutions.

[4]For example, they find that CIP deviations increase in periods where firms have to report business-end capital ratios and also find some evidence of the increased cost of leverage in the post-crisis period

[5]The libor differential is 3 month libor of a given currency less the 3 month US libor rate.

activities and purchase more US dollar assets[6], creating a dollar funding gap that has been met by a rise in demand for dollars through the swap market to hedge against the currency mismatch of bank balance sheets (Borio, McCauley, McGuire, and Sushko 2016). The excess demand for dollars in the swap market, combined with capital constraints on parties lending dollars in the swap market, translates to the dollar lending premium we see for the bilateral currency pairs of the Euro, Swiss Franc, Yen and Swedish Krona with respect to the US dollar in Figure 1.

The critical assumption underlying this mechanism is that divergent monetary policies have increased the relative rate of return on US dollar assets, generating an excess demand for dollar assets by non-US financial institutions and increased demand for dollar funding via cross-currency swaps. The distortionary effect of negative interest rate policies has led to a recent literature on "risk-reversal" rates, which suggests that negative interest rates can actually have perverse effects on bank lending through squeezing profit margins on domestic currency activities relative to dollar lending (Brunnermeier and Koby 2016). To make qualitative predictions regarding the forces that drive CIP deviations, we build a model of a stylized non-US bank with dollar and domestic currency assets, with dollar borrowing sourced through the debt market or via cross-currency swaps. The demand for swaps they generate is then equated to a limited supply of dollar swaps through a capital constrained arbitrageur. This simple setup lends itself to comparative statics regarding the effect of monetary shocks on the interest rate margin and portfolio choice; shocks that increase the relative interest rate margin on dollar assets lead to a rise in demand for dollars via swaps and a widening of the CIP deviation. In the empirical part of the paper, we show using high frequency identification of monetary announcements by the ECB, SNB and BOJ to support the hypothesis that negative interest rate policies do widen CIP deviations.

Another mechanism we illustrate in an extension of our model is the response of CIP deviations to the expansion of central bank swap lines by the Federal Reserve. This was the predominant policy mechanism used to alleviate dollar funding pressures for foreign banks in select advanced economies in 2008. The arrangements consisted of an agreement to exchange a specified amount of dollars for the foreign currency at a fixed price. The swap lines therefore are subject to zero exchange rate risk and provide indirect dollar denominated debt insurance for financial institutions. Since 2013, the swap lines have become enshrined as standing arrangements with the central banks of Switzerland, the Eurozone, Japan and the UK. To think about how swap lines can alleviate dollar funding, it is pertinent in the period where CIP deviations were high due to counterparty risk (Baba and Packer 2009). There is an asymmetric insurance of domestic borrowing vs US dollar borrowing, as the non-US central bank can provide insurance for domestic deposits but not

[6]This recycling of dollar funding by foreign financial institutions to purchase high yielding assets in the US was one of the factors behind the escalation of the sub-prime mortgage crisis.

dollar denominated borrowing. The swap lines bridge this gap as the Federal Reserve is lending US dollars to the foreign central bank, which is then used to back dollar liabilities of potentially defaulting firms. Reducing default of non-US banks and bridging the dollar funding gap should, other things equal, cause a narrowing of CIP deviations.

The paper is structured as follows. In section 2, we present some stylized facts regarding the impact of negative rate policies on bank profitability, dollar asset exposures and the demand for foreign exchange swaps. In section 3, we will briefly cover the literature, which includes theoretical modeling of CIP deviations, the empirical methodology in measuring monetary policy shocks and a discussion of central bank swap lines. In section 4, we will briefly outline definitions of covered interest rate parity and a cross-currency basis swap. In section 5, we introduce the model, with a setup of the representative agents, solution of the portfolio problem and provide a solution for the equilibrium level of CIP deviations. In section 6, we analyze the effects of monetary shocks on CIP deviations for a panel of countries. In section 7, we discuss central bank swap lines and introduce an event study to analyze the effectiveness of swap lines in reducing CIP deviations. In section 8 we conclude.

2 Negative interest rates, the dollar funding gap and demand for foreign exchange swaps

Negative interest rate policies have been implemented by 6 countries since 2014, the Denmark, Eurozone, Japan, Norway, Sweden and Switzerland (Table 1). The relevant rate is the deposit facility rate, which is the rate financial institutions may use to make overnight deposits with the central bank. In this section, we first provide a series of stylized facts to illustrate the mechanisms through which negative interest rate policies can lead to a rise in CIP deviations. First, we show that negative interest rate policies of EU, Japan and SNB lead to a decline in bank profitability as interest rate margins fall. This causes a rebalancing of the bank portfolio to hold more dollar assets, and to cover increased dollar asset exposures, banks rely on increased demand for dollar funding via the foreign exchange swap market. Finally, given limits to supply of dollar funding, the excess demand for dollars then translates to a dollar funding premium equal to the CIP deviation.

Stylized Fact #1: Negative interest rate policies dampen bank profitability

A key reason why negative interest rate policies can lead to higher demand for dollar funding via the swap market is the perverse effect of these policies on bank profitability. Theories of interest rate policies and bank profitability center on negative rates being below a risk-reversal rate, in which bank profits are squeezed as loan rates fall and deposit rates remain fixed [7] Given domestic banks typically have a majority exposure in domestic assets, we can use aggregate interest rate margins as a proxy for the decline in bank profitability following negative interest rate policies. We use bankscope data which contains annual balance sheet data for global intermediaries. A key stylized fact is that since the period of negative interest rates, there has been a leftward shift of the distribution of net interest rate margins for banks in the countries pursuing negative interest rate policies, as we go from 2013 to 2016. The decline in net interest rate margins is more prounced for Germany and Sweden.

Stylized Fact #2 Exposures to US dollar assets, both corporate and sovereign, have increased for European Banks

To establish the effects of negative interest rate policies on the portfolio composition of assets, we refer to the European Banking Authority (EBA) data that contain both sovereign and credit exposures of a set of major banks in Europe. This dataset provides indirect evidence on the portfolio share of US dollar assets, both public and corporate, for a set of reporting banks from their parent country in Europe. The relevant years of the EBA exposures data is 2014 and 2016. We expect that negative rate policies in the EU should cause banks to seek higher returns and increase their exposure to dollar assets. Indeed, for almost all countries for which the EBA has reported data, there is a clear increase in the fraction of total corporate, and central bank and sovereign exposures to the US (Figure 5, 6) for all countries. In contrast, the fraction of exposures to the EU has stayed the same or slightly declined, providing some evidence of portfolio rebalancing towards holding higher yielding dollar assets.

There are some caveats with using this data from the EBA. Firstly, the data is a subset of all European banks, as not all banks are subject to the mandatory disclosure requirements and public release of exposures in accordance with EBA [8]. Another concern is that as the currency composition of bank assets is unknown, we are making an assumption that any exposures to the US, both government and corporate, are denominated in US dollars, and any European asset exposures are in Euros. This is a safe assumption to make, however it is likely that exposures to various other countries may be denominated in a 3rd party currency, often in US dollars.

[7] Ideally we would like to see interest rate margins by currency, as the argument we make centers on interest rate margins declining in domestic currency relative to dollar assets. However,

[8] However, systemtically important financial institutions comprise the list of reporting banks, and so can be somewhat representative of European exposures more broadly

Stylized Fact #3 Dollar funding gap growing for Japan and Swiss Banks

Data from the Bank of International Settlements (BIS) locational banking statistics contain key information on the level of cross-border claims and liabilities by major currencies. The US dollar is a prominent vehicle currency for financial transactions, and for countries like Japan and Switzerland, they deal primarily in US dollars in cross-border transacitons. In particular, Japan has an interesting feature of a growing imbalance between its dollar assets and liabilities, known as the dollar funding gap (Figure 7,8), and this provides a proxy for Japan's need for dollar funding via the foreign exchange swap market as a way to hedge the mismatch of its dollar assets and liabilities. For Switzerland, the US dollar is also the primary currency for denominating cross-border assets and liabilities, and does have a net positive dollar asset position as well, and a negative net position in euros, suggesting that Swiss Banks may have an incentive to swap euros for dollars in the foreign exchange swap market as a way to hedge currency risk exposure. In contrast, major European countries like Germany still operate primarily in euros for cross-border transactions, as most of their exposures are within Europe. The spread between dollar assets and liabilities is rather thin and is in fact negative for German banks, suggesting that the need for forex swaps as a way to hedge currency mismatch of balance sheets is not entirely obvious for banks in the Eurozone [9]. The United States cross-border banking transactions is a mirror reflection of Japan's, as it runs a large net liability position in US dollars (Figure 9,10).

Stylized Fact #4 Dollar funding gap covered by increased demand for dollar funding via the foreign exchange swap market

The previous stylized facts have established that there exist a structural asymmetry in the banking system insofar as countries with negative interest rate policies are likely to hold significant dollar asset positions. The dollar funding gap noted in fact #3 is a proxy for the hedging demand using foreign exchange swaps. Since the financial crisis of 2008, tighter lending restrictions by US money market funds have meant that the swap market has become a more convenient way to raise dollar funding for non-US banks. In particular, as we argue in this paper, the extreme low opportunity cost of raising Euros with the advent of negative rate policies has a perverse effect in that borrowing dollars synthetically.

As motivating evidence on the increased use of foreign exchange swaps, we examine data on the biannual New York foreign exchange volume survey, which contains average turnover of four FX instruments (spots, forwards and swaps), for thirteen currency pairs, four counterparty types, and five execution method categories and is reported both in terms of daily average and

[9] Other European countries follow a similar qualitative pattern to Germany.

total monthly volume. The NY data only considers any transaction in foreign exchange swaps officially done in the US, and so is capturing all onshore transactions. Although this is a subset of the entire market, it still offers us insights into trends in foreign exchange swap volume at a higher frequency than aggregate BIS statistics[10]. The counterparty types are reporting dealers, other dealers (where the other dealer refers to any transaction done with a dealer outside the US), financial and non-financial customers. Examining notional amounts of average daily volume at a biannual frequency for transactions involving financial institutions, there is a large rise in average daily volumes between October 2015 and April 2016 for the Yen and Euro bilateral pairs, coinciding with Japan's move to negative interest rates in January of 2016[11] (Figure 11).The increase is particular to transactions involving financial customers, which is all the more relevant as these institutions are using the swaps as a way to fund their increasing dollar asset exposures. To the extent that the rise in swap volumes is due to rising demand from financial customers for dollar funding via the swap market, this should raise the dollar funding premium in equilibrium given limits to arbitrage in the swap market. [12].

3 Related Literature

The paper relates to several strands of literature. In the theory of modeling CIP deviations, a key component is assuming a financial friction in order to generate limits to arbitrage. One method to generate a CIP deviation is arbitrageurs having an outside option of their capital (Ivashina, Scharfstein, and Stein 2015). An alternative method, which is used in this paper, is to impose an incentive compatibility constraint on the arbitrageur, where they have an incentive to divert a fraction of assets from their creditors, leading to an equilibrium rate of return on the swap equal to the CIP basis (Gertler, Kiyotaki, et al. 2010; Gabaix and Maggiori 2015). The role of these frictions is to tighten the arbitrageur's ability to leverage. To model the portfolio problem of a bank engaging in demand for dollar swaps, this paper chooses an approach similar to (Avdjiev, Du, Koch, and Shin 2016) ; however a critical difference in their model is the assumption that

[10] The triennial survey on foreign exchange, last conducted in 2016.

[11] Although not shown, the rise in forex swap volumes is most noticeable for counterparties involving financial customers. Non-financial customers and interdealer transactions have no apparent time trend.

[12] There may be some confounding factors responsible for changes in swap volume. For example, the timing of swap demands is often due to idiosyncratic needs for liquidity in specific currencies, unrelated to any macro-related events. Secondly, the increase in trading volume of forex swaps may be due to an increase in customers from both ends of the market, rather than reflect a systematic increase in the excess demand for dollar funding via the swap market. A more revealing measure is known as order flow, which is a measure of the excess demand imbalances in the swap market. Order flow imbalances provides a cleaner measure of whether monetary policy divergence is causing an excess demand for dollars via the swap market.

the bank engages in lending in dollar swaps. Instead, we make the bank a net borrower of dollars through the swap market, with the other side of the transaction covered by arbitrageurs. We also provide a closed form solution for the level of CIP deviations and derive comparative statics with respect to exogenous shocks to dollar and foreign asset returns.

A recent literature has mentioned the importance of monetary policy for CIP deviations. The only other paper that provides theory on the impact of divergent monetary policies on CIP (Iida, Kimura, Sudo, et al. 2016) make qualitative predictions about the effect of monetary policy on interest rate margins and the relative demand for swaps, citing similar mechanisms to this paper. However, their main empirical evidence for declining interest rate margins due to divergent monetary policy is through measuring the relative growth of central bank balance sheets[13]. To better identify exogenous changes in monetary policy to establish a more direct causation, we use market based measures that use changes in underlying interest rate futures around monetary announcements. In (Du, Tepper, and Verdelhan 2016), there is high frequency evidence for the EUR/USD cross-currency basis; in this paper we employ a similar analysis by using announcements of multiple central banks in order to match predictions of the model. In addition, we use variants of the monetary shock to capture unconventional policy measures based on (Gurkaynak 2005).

Another series of papers is on the effectiveness of central bank swap lines. Much of the work has been empirical, and in (Baba and Packer 2009; Moessner and Allen 2013) a GARCH model is used in order to determine the effectiveness of swap lines reducing the volatility and mean of CIP deviations for the EUR/USD pair. The authors find some evidence of a reduction in the volatility of CIP deviations following the October 13, 2008 announcement by the Federal Reserve. The effectiveness of swap lines through a narrative approach suggests that the swap lines are useful in reducing rollover risk for non-US financial institutions, is a signal of increased central bank cooperation, and had short-term, temporary effects on reducing dollar funding costs (Bordo, Humpage, and Schwartz 2015; Fleming and Klagge 2010; Goldberg, Kennedy, and Miu 2010). Empirically, we introduce an event study methodology to test the effectiveness of swap lines with a panel of countries that received swap lines. There is, to our knowledge, no theoretical models concerning the effects of swap lines, however the approach we use involves extending a Diamond Dybvig model to a bank that obtains both domestic and foreign (dollar) funding, and is related to (Chang and Velasco 2001). This approach is tractable and provides a simple framework to explain how swap lines can reduce the probability of a bank run in a bad equilibrium.

[13] This is motivated by the empirical observation that expanding the balance sheet should lower bank funding costs and increase the net interest margin.

4 Theory behind Covered Interest Rate Parity

Before we outline the model, let us define covered interest rate parity deviations in the context of the foreign exchange swap market. Consider a European bank that wants to borrow US dollars. If the bank borrows 1 US dollar directly at rate $y_\$$, or alternatively can borrow e euros (where e is the spot exchange rate in euros per dollar) at rate y_d, and at maturity of the contract re-convert back to dollars at the forward rate f euros per dollar. The synthetic dollar borrowing rate is then given by $\frac{e}{f}y_d$. In the context of CIP deviations we see for the bilateral pair of eur/usd in Figure 1, European banks are facing a dollar borrowing premium equal to the difference between the synthetic and local dollar borrowing rate.

$$\Delta = \frac{e}{f}(1 + y_d) - (1 + y_\$) > 0$$

As an example of how the dollar premium is priced in financial instruments, we consider the cross-currency swap. This instrument involves the exchange of specific amounts of two different currencies at the outset and repayments over time in accordance with a predetermined rule that reflects amortization of the principal. A schematic of the swap is provided in Figure 12. The stages of the swap are as follows:

1. A swap arrangement where the European bank receives X Dollars, and the US Bank receives an amount equal to eX, where e is the spot exchange rate in Euros per dollar.

2. The US bank pays interest rate y_d on its Euro borrowing, where y_d is a EUR 3 month libor, for example. The European bank pays $y_\$ + \Delta$, where $y_\$$ is the USD 3 month libor, and Δ is the price of the cross-currency basis swap.

3. At maturity of the contract, the principal amounts are exchanged.

The level of CIP deviations is given by the price of the cross-currency basis swap, Δ. If $\Delta > 0$, this is indicative of a dollar lending premium. Different types of currency swaps can be used, including one in which the forward rate is used to exchange principal amounts at maturity.

5 Model

For simplicity, we only examine the financial sector in isolation to obtain our comparative statics predictions regarding the factors that drive CIP deviations. The first agent we introduce in the basic framework is the domestic bank, that has both domestic and foreign (US dollar) assets, domestic liabilities and two sources of US dollar liabilities, dollar bond issuance or dollar borrowing through the currency swap market. For tractability we generate an analytical solution for CIP deviations that we solve for in equilibrium. To generate an equilibrium level of swaps, we model the supply side of dollar swaps through a capital constrained arbitrageur. Finally, in extensions of the model we will consider the role of central bank swap lines in reducing the probability of bank runs on dollar borrowing through the lens of a Diamond and Dybvig (1983) framework of bank runs.

Bank

Definition of Portfolio

The timing of the problem is as follows. In the initial period, which we denote with (-), the bank decides on investing its capital K into a portfolio of dollar assets and dollar liabilities. The value of the bank's portfolio, denoted V_- is equal to its holdings of domestic and dollar assets less the domestic and dollar liabilities. Dollar assets and liabilities $A_\$$ and $B_\$$ are denominated in dollars and are converted to domestic currency at e_-, the nominal exchange rate expressed as units of domestic currency per US dollar.

$$V_- = A_d + e_- A_\$ - B_d - e_- B_\$ \tag{1}$$

The bank's function is to maximize the value of its portfolio in the period in which the returns on assets are realized; we denote this as period $(+)$. Domestic and dollar assets can be held in quantities A_d and $A_\$$. The stochastic domestic and dollar asset returns $\tilde{r}_d$ and $\tilde{r}_\$$ have expectation $\mathbb{E}(\tilde{r}_d) = r_d$ and $\mathbb{E}(r_\$) = r_\$$, and a covariance matrix denoted by $\Sigma = \begin{bmatrix} \sigma_d^2 & \sigma_{d,\$} \\ \sigma_{d,\$} & \sigma_\$^2 \end{bmatrix}$. The bank has three sources of funding, domestic and dollar deposits B_d and $B_\$$ and dollar swaps S. Consistent with section 3, we denoting the borrowing cost on domestic deposits to have a convex cost function $y_d = c(B_d)$ with $c'(B_d) > 0$. We also impose a zero interst rate on dollar borrowing, $y_\$ = 0$. At realization of the portfolio returns in period $(+)$, the relevant exchange rate for the valuation of dollar assets and liabilities is denoted as e_+. The level of swaps, S is denominated in dollars and has a cost Δ that is equal to the CIP deviation[14]. Critically we assume swaps are off balance-sheet and is used as a source of funding for dollar assets [15].

[14] It works the same way as the cross-currency swap in Section 3. More formally, it is given as $\Delta = \frac{e_-}{f_-} - 1$, where e_- and f_- are the relevant spot and forward exchange rates at the time of the swap agreement.

[15] An implication of making swaps a source of dollar funding is that the bank is not engaged in lending dollars in the swap market, and we ignore equilibria in which the bank finds it profitable to lend dollars in the swap market

$$V_+ = \tilde{r}_d A_d + \tilde{r}_\$ e_+ A_\$ - \Delta e_+ S - c(B_d) \tag{2}$$

In our model, monetary policy directly affects the rate of return on dollar and domestic asset returns, $\tilde{r}_\$$ and $\tilde{r}_d$, holding deposit costs fixed. More generally, the role of monetary policy is to act as a lever to adjust relative net interest rate margins on domestic and dollar assets, which in turn drives the demand imbalance in the foreign exchange swap market. This assumption mirrors a stylized behaviour of global banks (Ivashina, Scharfstein, and Stein 2015) that are increasingly prone to holding dollar assets in the form of excess reserve balances held at the Federal Reserve. This practice has become more profitable with global banking as the corresponding rate on reserves held at the ECB, BOJ and Swiss National bank decline in the advent of negative interest rate policies of these central banks.

Solution of Portfolio Problem

To determine the optimal portfolio composition of domestic and dollar assets, the bank maximizes the value of the portfolio after the realization of asset returns, taking the cost of swaps Δ and debt liabilities as given, and with knowledge of the distribution of stochastic dollar and domestic asset returns, subject to a Value at Risk (VaR) constraint, where the variance of the portfolio is less than some fraction of bank capital K. Using matrix notation, $a = \begin{bmatrix} A_d & e_+ A_\$ \end{bmatrix}^T$ and $\Sigma = \begin{bmatrix} \sigma_d^2 & \sigma_{d,\$} \\ \sigma_{d,\$} & \sigma_\$^2 \end{bmatrix}$.

$$a^T \Sigma a \leq \left(\frac{K}{\alpha} \right)^2 \tag{3}$$

The other constraints are the balance sheet constraint in equation [4].

$$K = A_d + e_- A_\$ - B_d - e_- B_\$ \tag{4}$$

The constraint in [5] represents currency neutrality of the balance sheet. Dollar assets are funded either by dollar bond issuance or through the swap market[16]. A funding gap between dollar liabilities and dollar assets needs to be met by borrowing dollars in the swap market. If a country has a net positive asset position in dollars, then they want to hedge that position by purchasing USD in a forex swap. This is a rather stylized assumption, and is meant to capture the

compared to the dollar asset return $r_\$$.

[16] All dollar assets and liabilities are expressed in dollars, and so the nominal exchange rate does not appear in equation [5]

fact that countries/regions with significant net dollar asset positions tended to have a net demand for dollars through the swap market as a way to hedge foreign exchange risk exposure.

$$A_\$ = S + B_\$ \tag{5}$$

The last constraint in [6] is a restriction on dollar borrowing, where the domestic currency value of dollar denominated debt is constrained to be some fraction of bank capital. The justification for this constraint is that dollar borrowing is relatively uninsured compared to domestic currency liabilities [17]. Note we are also assuming that there is an asymmetry between different types of dollar borrowing; borrowing through the swap market is sufficiently collateralized and hedged through a forward contract. Therefore there is a more implicit guarantee of funds borrowed through the swap market, insofar as it does not entail counterparty risk.

$$e_- B_\$ \leq \gamma K \tag{6}$$

For tractability of the solution that follows we assume that the exchange rate is non-stochastic, so the exchange rate that is realized at the maturity of the assets (in period +), is equal to the exchange rate at the formation of the portfolio, $e_- = e_+ = e$. The first order conditions with respect to $A_d, A_\$, S, B_d$ and $B_\$$ are shown in equations [7] to [10]. The Lagrangian for the aforementioned set of equations are ϕ, μ λ and θ. The necessity for the constraint on dollar denominated debt is seen in equation [10]. Suppose the debt constraint is not binding and $\theta = 0$. By proof of contradiction, this would require $c'(B_d) + \Delta = 0$, which is not possible as by definition $\Delta > 0$ and $c'(B_d) > 0$. Intuitively, a non-binding debt constraint means the bank will fund its dollar assets in entirety via bond issuance; there is no demand for dollars in the swap market, driving the premium on lending dollars down to zero in equilibrium.

$$\begin{bmatrix} r_d \\ r_\$ e \end{bmatrix} - 2\phi\Sigma \begin{bmatrix} A_d \\ e^2 A_\$ \end{bmatrix} - \begin{bmatrix} \mu \\ \mu e + \lambda \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \end{bmatrix} \tag{7}$$

$$-\Delta e + \lambda = 0 \tag{8}$$

$$-c'(B_d) + \mu = 0 \tag{9}$$

[17] This assumption of differentiated borrowing is discussed further when we examine the consumption side of the model within a Diamond Dybvig framework. Here, the introduction of swap lines connecting the Federal Reserve to other banks acts as indirect insurance, by enabling the domestic central bank to provide dollar liquidity to banks that are unable to access dollar funding.

$$\mu e + \lambda - \theta e = 0 \tag{10}$$

Rearranging equation [7] and solving for the optimal holdings of domestic and dollar assets,

$$\begin{bmatrix} A_d \\ eA_\$ \end{bmatrix} = \frac{1}{2\phi}\Sigma^{-1} \begin{bmatrix} r_d - c'(B_d) \\ r_\$ - \Delta - c'(B_d) \end{bmatrix} \tag{11}$$

Using the Var constraint we can express the Lagrangian ϕ in terms of the relevant parameters[18],

$$\frac{1}{4\phi^2} R^T \Sigma^{-1} R = \left(\frac{K}{\alpha}\right)^2$$

$$\Rightarrow \phi = \frac{\alpha}{2K}\sqrt{R^T \Sigma^{-1} R}$$

Substituting ϕ in [11] yields,

$$\begin{bmatrix} A_d \\ eA_\$ \end{bmatrix} = \frac{K}{\alpha\sqrt{R^T\Sigma^{-1}R}}\Sigma^{-1} \begin{bmatrix} r_d - c'(B_d) \\ r_\$ - \Delta - c'(B_d) \end{bmatrix} \tag{12}$$

The result in [12] common to standard portfolio problems, in which the demand for assets is proportional to the excess return on each asset as a proportion to the variance of each return. The scaling factor $\frac{K}{\alpha\sqrt{R^T\Sigma^{-1}R}}$ suggests a constant returns to scale in the level of bank equity K, and inversely related to the weighted variance of the portfolio $\sqrt{R^T\Sigma^{-1}R}$.In equilibrium, the demand for swaps is given as follows,

$$S = \frac{K}{\alpha e\sqrt{R^T\Sigma^{-1}R}} \begin{bmatrix} 0 & 1 \end{bmatrix} \Sigma^{-1} \begin{bmatrix} r_d - c'(B_d) \\ r_\$ - \Delta - c'(B_d) \end{bmatrix} - \frac{\gamma K}{e} \tag{13}$$

For simplicity in comparative statics, let us assume $\Sigma = I_{2x2}$, and $c'(B_d) = 0$. Then [13] becomes,

$$S = \frac{K}{e}\left(\frac{r_\$ - \Delta}{\alpha\sqrt{(r_\$ - \Delta)^2 + {r_d}^2}} - \gamma\right) \tag{14}$$

It is straightforward to see that under the simplifying assumptions, the demand for dollars in the swap market is an increasing function of $r_\$$ and a decreasing function in r_d and the cost of swaps Δ. Another key feature of the equilibrium demand for swaps is that it is dependent on the

[18] Here we are using the fact that the asset vector $a = \frac{1}{2\phi}\Sigma^{-1}R$, substituting into the Var constraint in equation [3]

dollar borrowing constraint; a tightening of the borrowing constraint ($\gamma \downarrow$) causes a substitution towards borrowing dollars in the swap market.

Arbitrageur of swap trade

A global arbitrageur performs a simple operation of borrowing 1 unit locally in the US, and lending e_- units of the foreign country currency, covering exchange rate risk in the forward market at rate f_- to obtain $\frac{e_-}{f_-}$ dollars. The profit per unit of capital is equal to the CIP deviation Δ.

$$V_+ = \left(\frac{e_-}{f_-} - 1\right) S_\$^s = \Delta S_\$^s \tag{15}$$

However, the arbitrageur faces an incentive compatibility constraint limiting the amount of arbitrage they can undertake, similar to the GAMA function in (Gabaix and Maggiori 2015).[19] The role of these frictions is to tighten the arbitrageur's ability to leverage.

$$V \geq \underbrace{S_\$^s}_{\text{claims to creditors}} \times \underbrace{\Gamma(S_\$^s - \bar{S})}_{\text{fraction of divertible funds}} \tag{16}$$

A rise in Γ then represents a constraint on the leverage of the arbitrageur. Importantly, we assume that the fraction of divertable funds is positive if and only if the supply of dollars in the swap market exceeds some threshold level, $\bar{S}$. The equilibrium supply of US dollar lending in the swap market is then given by,

$$S_\$^s - \bar{S} = \frac{1}{\Gamma}\Delta \tag{17}$$

The level of CIP deviations, Δ, is a piecewise non-linear function,

$$\Delta = \begin{cases} 0 & S_\$ \leq \bar{S} \\ \Gamma(S_\$ - \bar{S}) & S_\$ > \bar{S} \end{cases} \tag{18}$$

Graphically, this is depicted in Figure [13]. Once the threshold level of swap supply is reached, limits to arbitrage mean a rise in swap demand translates to a positive CIP deviation. The non-shaded region in the Figure corresponds to "normal" times when limits to arbitrage are not a problem. Here, the arbitrageur has sufficient capital to eliminate CIP deviations in entirety. However, in the shaded region ($S > \bar{S}$), the demand for dollars through the swap market is sufficiently

[19] Alternatively, one can generate a CIP deviation due to arbitrageurs having an outside option of their capital with a rate of return equal to the profit earned from an arbitrage transaction in the swap market (Ivashina, Scharfstein, and Stein 2015).

high, so the arbitrageur is now capital constrained and needs some premium in equilibrium in order to take a position to clear the market. Given we are dealing with equilibria in which $\Delta > 0$ this corresponds to a case in which the forward rate is a biased predictor of the future spot exchange rate, that is, $f_{-} < \mathbb{E}(e_{+}) = e$. The failure of the market efficiency test is rational in light of the fact that deviations from CIP are consistent with the existence of a financial friction.

Equilibrium level of CIP deviations

Solving for the equilibrium Δ by equating the demand for swaps in [13] with the supply in [17] yields the following non-linear equation for Δ. For simplicity of the solution, we impose $\bar{S} = 0$, given we are only considering equilibria in which a positive level of CIP deviations exist.

$$\frac{1}{\Gamma}\Delta = \frac{K}{e}\left(\frac{r_{\$} - \Delta}{\alpha\sqrt{(r_{\$} - \Delta)^2 + {r_d}^2}} - \gamma\right) \tag{19}$$

As the analytical solution is complex, we express $F(r_{\$}, r_d, \Delta) = \frac{r_{\$}-\Delta}{\sqrt{(r_{\$}-\Delta)^2+{r_d}^2}}$. We now do basic comparative statics to test the effect of shocks to domestic and dollar asset returns on the equilibrium level of CIP deviations.

Proposition 1: An increase in Γ, other things equal, raises the equilibrium level of (absolute) CIP deviations.

Proof:

Differentiating [19] with respect to Γ and using the fact[20] that $\frac{\partial F}{\partial \Delta} < 0$ yields the following result.

$$\frac{\partial \Delta}{\partial \Gamma} = \frac{\Delta}{\Gamma(1 - \frac{K\Gamma}{\alpha e}\frac{\partial F}{\partial \Delta})} > 0$$

A rise in Γ leads to a reduction in the supply of dollar swaps for any given level of CIP deviations, and represents a tightening of the capital constraint and ability of arbitrageurs to leverage sufficiently.Empirical evidence for the effect of balance sheet costs on leverage and the level of CIP deviations is provided in (Du, Tepper, and Verdelhan 2016).

[20] This can be proven easily by considering general functions of the form $F(a, b) = \frac{a}{\sqrt{a^2+b}}$where $a > 0, b > 0$. Taking the derivative w.r.t a, we can express $\frac{\partial F}{\partial a} = (a^2 + b)^{-\frac{1}{2}}\left[1 - \frac{a^2}{a^2+b}\right] > 0$

Proposition 2: An increase in dollar returns, other things equal, raises the equilibrium level of (absolute) CIP deviations, with $\frac{\partial \Delta}{\partial r_\$}$ *being bounded between 0 and 1 for the range of* $\Gamma \in [0, \infty]$.

Proof:

Differentiating [19] with respect to $r_\$$ leads to the following result.

$$\frac{\partial \Delta}{\partial r_\$} = \frac{\frac{\partial F}{\partial r_\$}}{\frac{\alpha e}{K\Gamma} - \frac{\partial F}{\partial \Delta}} \tag{20}$$

Given that $\frac{\partial F}{\partial r_\$} > 0$, and by symmetry $\frac{\partial F}{\partial \Delta} = -\frac{\partial F}{\partial r_\$}$, we can generate lower and upper bounds for $\frac{\partial \Delta}{\partial r_\$}$,

$$0 < \frac{\partial \Delta}{\partial r_\$} < 1$$

$\Gamma \to 0 \Rightarrow \frac{\partial \Delta}{\partial r_\$} \to 0$ and $\Gamma \to \infty \Rightarrow \frac{\partial \Delta}{\partial r_\$} \to 1$. As the bank is constrained in its dollar borrowing, an increase in demand for dollar assets has to be met by a rise in dollar funding via the swap market to hedge against the currency mismatch of the bank balance sheet.

Proposition 3: An increase in domestic returns, other things equal, reduces the equilibrium level of (absolute) CIP deviations, with $\frac{\partial \Delta}{\partial r_d}$ *being bounded between* $-(r_\$ - \Delta)$ *and zero for the range of* $\Gamma \in [0, \infty]$.

Proof:

Differentiating [19] with respect to r_d yields, where we use the fact that $\frac{\partial F}{\partial r_d} < 0$ and $\frac{\partial F}{\partial r_\$} > 0$.

$$\frac{\partial \Delta}{\partial r_d} = \frac{\frac{\partial F}{\partial r_d}}{\frac{\alpha e}{K\Gamma} + \frac{\partial F}{\partial r_\$}}$$

A rise in domestic asset returns means there is less of a need to borrow dollars, putting downward pressure on the demand for dollars through the swap market and lowering the dollar premium in equilibrium. For the extreme case of $\Gamma \to 0 \Rightarrow \frac{\partial \Delta}{\partial r_d} \to 0$. However as $\Gamma \to \infty \Rightarrow \frac{\partial \Delta}{\partial r_d} \to \frac{\frac{\partial F}{\partial r_d}}{\frac{\partial F}{\partial r_\$}} = -(r_\$ - \Delta)$. This gives the lower and upper bounds for $\frac{\partial \Delta}{\partial r_d}$.

$$-(r_\$ - \Delta) < \frac{\partial \Delta}{\partial r_d} < 0$$

The sensitivity of CIP deviations to a rise in domestic asset returns is dependent on the excess return the bank gets on dollar assets. This suggests domestic monetary policy by the ECB or

Bank of Japan are useful in narrowing CIP deviations to the extent that banks make large returns in funding dollar assets via the swap market.

Model extension: considering the role of swap lines

We embed our model with a Diamond Dybvig structure to think about the potential for bank runs on foreign (US dollar borrowing). The model is discrete time, with 2 periods, and we introduce consumers that are branched into two types, patient and impatient. Knowledge of a consumer's type is only revealed in period 1. The expected utility of representative agent is given in equation [21], where $u(c) = \frac{c^{1-\theta}}{1-\theta}$is CRRA preferences.

$$\lambda u(c_1) + (1-\lambda)u(c_2) \tag{21}$$

In period 0, the budget constraint is given by the level of bank capital K.

$$K = A_d + A_\$ - B_d - eB_{\$0} \tag{22}$$

We can express the return on capital as follows, where $A_d, A_\$$ are solved in the portfolio problem in [12].

$$R = \frac{r_d A_d + (r_\$ - \Delta)A_\$ - B_d - eB_\$}{K} \tag{23}$$

If agents are type 1, they prefer to consume in period 1 and liquidate their assets in period 1. The cost of earlier liquidation is a penalty rate $r < 1$. After liquidation only $K - l$ remains in period 2. Consumption in period 2 for the fraction of agents that do not liquidate $(1 - \lambda)$ is equal to the return on capital less the dollar borrowing in period 1.

$$\lambda c_1 \leq rl + eB_{\$1} \tag{24}$$

$$(1-\lambda)c_2 + eB_{\$1} \leq R(K - l) \tag{25}$$

Dollar borrowing in period 1 is constrained to be a fraction of bank capital.

$$eB_{\$1} \leq \gamma K \tag{26}$$

For type 2 consumers to be incentivized to truth-tell about their type and not liquidate their assets in period 1, the incentive compatibility condition is that consumption in period 2 can never fall below period 1 consumption.

$$c_2 \geq c_1 \tag{27}$$

Equilibrium with no bank run

We first characterize the equilibrium with no bank run. The bank's function is to meet all deposit claims by type 1 agents. The patient agents are type 2 and are willing to consume in period 2 and earn a higher return on their asset in period 2. In an equilibrium where agents are incentivized to tell the truth, there is no incentive to liquidate assets, $l = 0$. Summing the constraints for period 1 and 2 in equations [24] and [25], we obtain,

$$\lambda c_1 + (1 - \lambda)c_2 = RK \tag{28}$$

This yields the solution, $c_1^* = c_2^* = RK$. For a feasible solution, we assume the level of consumption does not violate the dollar debt constraint,

$$RK \leq \frac{\gamma}{\lambda}K \tag{29}$$

Given [29] is satisfied, there exists a feasible Nash equilibrium in which all agents act their type and there is no liquidation of the asset in period 1.

Bank run equilibrium

A bank run is an event given by a sunspot[21] probability ψ when all consumers, both type 1 and type 2, liquidate the asset in period 1. If this happens, the bank will fail if it does not have enough resources to meet all depositor demands in period 1. We define l^+ as the maximum liquidation allowed by the bank in order to be able to pay back dollar denominated debt in period 2.

$$R(K - l^+) = eB_{\$1} \tag{30}$$

Rearranging terms and substituting formulae for each component of dollar funding as a linear function of wealth, and assuming consumption is at the debt limit,

$$l^+ = (1 - \frac{\gamma}{R})K \tag{31}$$

[21] Given the classical Diamond and Dybvig problem is subject to multiple equilibria, the way to distinguish between equilibria is through a sunspot variable. For the occurrence of a sunspot, we venture into a bad outcome in which type 2 agents become impatient if it is collectively optimal for them to do so.

The condition for a run on foreign borrowing is when the bank has insufficient resources to meet consumption in period 1 when all depositors liquidate,

$$c_1 \geq rl^+ + \gamma K \tag{32}$$

Substituting $c_1 = RK$ and simplifying,

$$R - \gamma \geq \frac{r}{R}(R - \gamma) \Rightarrow R > r \tag{33}$$

By assumption, the rate of return on early liquidation r is at a penalty cost and so equation [33] is always satisfied. This suggests that in a bad equilibrium the bank will always fail., as it does not have enough resources to meet depositors' demands. Given a probability of bank failure equal to the sunspot probability ψ, this represents an increase in counterparty risk. The net profit for arbitrageurs is now equal to $(1 - \psi)\Delta$, and solving for the equilibrium in the swap market,

$$\frac{1}{\Gamma}(1 - \psi)\Delta = K\left(\frac{r_\$ - \Delta}{\alpha\sqrt{(r_\$ - \Delta)^2 + {r_d}^2}} - \frac{\gamma}{e}\right) \tag{34}$$

The comparative statics for an increase in the sunspot probability ψ is similar to the effects of a tightening of the arbitrageur constraint, and means arbitrageurs need a higher premium to supply a given level of dollars in the swap market[22].

Proposition 4: Swap lines provided by the Federal Reserve can prevent the outcome of a bank failure in a bad equilibrium if it is above a threshold, $\bar{S}_{CB}$, given by,

$$S_{CB} \geq \bar{S}_{CB} = (R - \gamma)(1 - \frac{r}{R})K \tag{35}$$

This is the minimum amount necessary to guarantee the bank has enough resources in the event of a bank run, in other words, to ensure $c_1 \leq rl^+ + \gamma K + \bar{S}_{CB}$. Swap lines reduce the probability of domestic bank failure by providing dollar liquidity. As we will show in section 7, swap announcements had significant effects in lowering CIP deviations witnessed in 2008 and again in 2011. However, the standing arrangements central banks have had in place since 2011 have done little to prevent the persistent deviations we have seen since 2014, suggesting that this policy response is somewhat limited in eliminating a source of CIP deviations that extends beyond counterparty risk.

[22]For more details on the comparative statics, refer to proposition 1.

6 Effect of monetary shocks on CIP deviations

A monetary policy shock is defined component of monetary policy that is unanticipated by market participants. There are 3 different approaches in the literature to measure monetary shocks, (i) structural/Cholesky VAR approach, (ii) residuals from Taylor rule projections, or (iii) market-based measures i.e. changes in futures rates on central bank announcement days. In this paper we employ market based measures following (Kuttner 2001; Gurkaynak, Sack, and Swanson 2004). The identifying assumption for the market-based shock to be a good instrument for monetary policy is that during the announcement the futures rate only responds to news about monetary policy, and not other news related to the economy during that period. Interest rate futures for the US Fed Funds rate is a contract between the buyer and seller agreeing to lock in today the price of the 30-day average Fed Funds rate at the contract's expiration. For example, suppose the current-month futures contract is traded at 95 cents to the dollar at the beginning of a month where an FOMC meeting will occur. This gives an implied rate of 5%, which is what investors believe will be the average Fed Funds rate for the current month. If current Fed Funds rate is less than 5%, investors implicitly believe the Fed will tighten rates at this month's FOMC meeting. The futures rate therefore provides a good signal of what investors anticipate the future path of interest rates to be, and their prediction of the outcome of the FOMC meeting. Changes in the future rate during a short time window around an FOMC announcement provide a measure of the unanticipated component of the change in the Fed Funds rate. The identifying assumption is that during the time of the announcement, the change in the Fed Funds futures rate is responding only to the FOMC press release. Following (Gurkaynak, Sack, and Swanson 2004), we construct "wide" window around each FOMC announcement time t to compute the futures change. Intraday changes are based on the change in futures rate 15 minutes prior to the announcement and 45 minutes after the announcement,

$$\Delta f1_t = f1_{t+45} - f1_{t-15} \tag{36}$$

When looking at the current-month contract, the contract settlement price is based on what investors think the monthly Fed Funds rate is for the month. For an event taking place on day d_0, the day of the closest FOMC announcement, with D_0 days in that month, the surprise target funds rate change is calculated from the change in the rate implied by the current-month futures contract. The change in implied 30-day futures rate $\triangle f1_t$ must be scaled up by a factor related to the number of days in the month affected by the change, equal to $D_0 - d_0$ days.

$$MP1_t = \frac{D_0}{D_0 - d_0} \Delta f1_t^{surprise} \tag{37}$$

We also construct surprises in changes in expected rates at longer horizons. Different policy actions may lead to same current policy setting surprise, but can have different implications about the near-term path of monetary policy. d_j denotes the day of the jth FOMC announcement and D_j the number of days in that month. The surprise in the expected Fed Funds rate after the 2nd and 3rd FOMC announcement:

$$MP2_t = \left[\Delta f2_t - \frac{d_2}{D_2} MP1_t\right] \frac{D_2}{D_2 - d_2} \tag{38}$$

$$MP3_t = \left[\Delta f3_t - \frac{d_3}{D_3} MP2_t\right] \frac{D_3}{D_3 - d_3} \tag{39}$$

For other countries we use futures-implied MP shocks at different "horizons" and computed using surprises in the yield of a foreign central bank's corresponding 90-day/3-month interbank rate, as there do not exist liquid futures contracts analogous to the 30-day Fed Funds futures for most countries. Papers have constructed MP shocks using this approach for the ECB and SNB (Ranaldo and Rossi 2010; Brusa, Savor, and Wilson 2016). A summary of interest rate futures for the central bank policy rate is provided in Table 2. Descriptive statistics for the foreign monetary shocks, including contract length, are provided in Table 3.

Domestic country analysis

Proposition 3 predicts that a rise in the domestic rate of return should reduce the (absolute) level of CIP deviations. To test this result empirically, we regress daily changes[23] in the 3 month cross-currency basis for the Euro, Yen, Swiss Franc, the Pound and the Australian dollar [24] on monetary shocks of the policy rate in each of those countries/regions respectively. The model prediction suggests $\beta > 0$, that is, contractionary monetary shocks by the domestic country should increase the cross-currency basis and represents a decline in the dollar funding premium. In addition, we consider the marginal effect of monetary shocks on CIP deviations in the period 2014-present. To statistically test the effect of monetary shocks in the 2014-present period, we generate the linear sum of effects $\delta = \beta + \gamma$.The reason we expect a structural break between these two periods is that in the former period, the main determinants of CIP deviations were rises in counterparty risk.

[23]Daily changes are measured using Bloomberg end of day data. As a robustness check, we evaluate the effect of announcements on CIP deviations at a high frequency using quotes of the basis from Thomson Reuters tick history.

[24]Other pairs we are aiming to cover in future versions of this paper are Sweden, Denmark and Norway.

However, in the more recent period of negative interest rates implemented by the ECB, SNB and BOJ, non-US banks are more sensitive to the decline in domestic currency interest rate margins following negative policy rates, and expansionary shocks by the ECB, SNB and BOJ should cause a rise in the dollar funding premium as banks seek higher returns on dollar lending[25].

$$\Delta CIP_t = \alpha + \beta \Delta MP1_t + \gamma \Delta MP1_t * 1(post2014), + u_t \tag{40}$$

Examining results in Table 4, we match theoretical predictions for the Euro, Yen, Swiss Franc and Pound bilateral cross-currency basis for the period of negative interest rates, $\delta > 0$. The relative magnitudes of the coefficients suggest that a 1 basis point decline in the ECB or Swiss bank policy rate should lead to a 1.9 and 1.8 basis point decline in the cross-currency basis of the EUR/USD and CHF/USD basis respectively. The coefficient for the AUD is small and insignificant. In the context of our model, the impact of monetary policy shocks on CIP deviations is negligible in an environment when arbitrageurs can absorb the demand for dollars in the swap market, i.e. when their risk bearing capacity $\Gamma \to 0$. This is likely because the volume of swap demand in the AUD/USD pair is small enough such that arbitrageurs can eliminate most of the CIP deviations without being limited by capital constraints.

One legitimate concern with the results is that in the period of unconventional monetary policy, the instrument ΔMP_1 does not have sufficient variation in response to quantitative easing policies employed by Japan, as well as similar programs implemented by the ECB. In Japan for example, meetings are typically focused on setting monetary aggregates, and there is little reference made to the path of interest rates. For a more refined measure of monetary shocks in the period of unconventional policy, we use the method[26] in Gurkaynak (2005), decomposing futures-implied policy shocks into timing, level and slope components. Timing is a transitory surprise that by definition leaves expected interest rates after the next monetary policy announcement unchanged. The level surprise is orthogonal to the "timing" surprises and measures a parallel shift of interest rate expectations over a horizon of 3-6 months. The slope surprise is orthogonal to "level" and "timing" and captures revisions to interest rate changes at the long end of the yield curve, with horizons ranging from 2-10 years. The equations for timing, level and slope are provided in equations [41] to [43]. Examining Table 5, the decomposition yields significant coefficients for level

[25] Another channel in the 2014-current period could be that increased reporting requirements for financial institutions, or more binding capital constraints could lead to a higher cost of leverage for arbitrageurs. From proposition 3 we know this can increase the response of CIP deviations to a given monetary shock.

[26] Principal components analysis (PCA) has typically been used to determine the strength of co-movement between monetary shocks at different time horizons. The main criticism of principal component methods is the interpretation of coefficients, and the decomposition we use has a more direct inference in translating monetary shock changes to changes in CIP deviations.

in the post 2014 period, where it is positive and significant for the Euro, Yen and Swiss Franc cross currency basis w.r.t US dollar.

$$MP1_{i,t} = \alpha_1 + \beta_1 level_{i,t} + timing_{i,t} \tag{41}$$

$$MP3_{i,t} = level_{i,t} \tag{42}$$

$$fut2y_{i,t} = \alpha_2 + \beta_2 level_{i,t} + \gamma_2 timing_{i,t} + slope_{i,t} \tag{43}$$

We also test for the effect of domestic monetary shocks on the cross-currency basis at different maturities. Regressing the Euro/USD basis at maturities of 3 months, 1,2,5,10, 20 and 30 years on monetary shocks of ECB announcements is shown in Table 6. Consistent with Table 5, the level component is significant at all maturities, and is more sensitive at shorter maturities. The dollar funding shortage is more pronounced at lower maturity swaps as the bulk of cross-currency swaps demanded by financial institutions is at maturities of 3 months or less [27]. We find similar results for other pairs, and in Table 7 changes in CIP deviations at different horizons for the CHF/USD basis is provided.

US analysis

Proposition 2 predicts that a rise in the US interest rates increases the (absolute) level of CIP deviations. To test this result empirically, we regress daily changes[28] in the 3 month cross-currency basis for the Euro, Yen, Swiss Franc, the Pound and the Australian dollar [29] on monetary policy shocks of the US. The model prediction is now $\beta, \gamma < 0$; contractionary monetary shocks by the US should make the cross-currency basis more negative and is indicative of a higher dollar funding premium.

$$\Delta CIP_t = \alpha + \beta \Delta MP1_{us,t} + \gamma \Delta MP1_{us,t} * 1(post2014), + u_t \tag{44}$$

The Euro/USD and CHF/USD basis respond negatively in accordance with the model predictions in the 2014-present period [Table 4] . Decomposing monetary shocks into timing, level and

[27]Banks typically have a maturity mismatch in having liquid short maturity liabilities and illiquid long maturity assets, and so cross-currency swaps for funding purposes are more useful at shorter maturities.

[28]Currently we are awaiting Thomson Reuters tick history for cross-currency basis. Once we obtain high frequency data we can compute the changes around the relevant window of monetary policy meetings.

[29]Other pairs we are aiming to cover in future versions of this paper are Sweden, Denmark and Norway.

slope components (Table [8]), there is a significant negative relationship between the timing and level components for the Euro in the post 2014 period.

To understand why US monetary shocks have limited effect on the cross-currency basis, we list 2 potential reasons. First, there is a disconnect between policy shocks in the period of the zero lower bound and global US dollar liquidity, which is more reliant on quantitative easing policies pursued by the Federal Reserve. In this vein, the instrument ΔMP_1 does not have sufficient variation, and may not capture the effect of Federal Reserve expansions of the balance sheet shown in Figure 3. There is a disconnect between policy shocks in the period of the zero lower bound and global US dollar liquidity, which is more reliant on quantitative easing policies pursued by the Federal Reserve. For example, QE policies by the Federal Reserve increase global liquidity and make it easier for banks in EU, Switzerland and Japan to tap dollar funding via interbank markets. This should put less stress on demand for dollars via the swap market, lowering CIP deviations. Second, from a domestic bank's point of view, the impact on interest rate margins of a US monetary shock may have differing implications to the impact of domestic negative interest rate policies. Although not covered explicitly in the model, a rise in US interest rates will not only raise the relative rate of return on dollar assets, but potentially increase the cost of dollar borrowing. To the extent that dollar borrowing costs match the rise in dollar asset returns, the net effect on portfolio choice is minimal. In contrast, negative interest rate policies lead to an asymmetry insofar as the bank cannot charge negative rates on domestic deposits, and so has a clear role in squeezing relative profit margins on domestic assets.

Intra-day response to monetary announcements

As a robustness check, we can use high frequency data on swap trades conducted by banks using Thomson Reuters tick history[30]. We assume that although this is a subset of the market, the quotes are representative of the market and any response in the quoted prices of currency swaps should be seen as a market-wide response to monetary announcements. Examining a subset of announcements for the ECB, BOJ and Swiss National Bank in which the magnitude of the monetary shock exceeds 5 basis points [31], there is a close to one-for-one response of the cross-currency basis to a monetary shock. Examining announcements within the regime of negative interest rates, an announcement by the ECB on September 4th, 2014 announcement led to a 5 basis point decline in

[30] The quotes are obtained from select financial institutions that report to Thomson Reuters.

[31] These are the shocks in the 95th percentile in the period 2014-present. Given the low/negative interest rate policies, meetings typically have an unchanged stance of monetary policy and so interest rate futures changes are negligible.

the immediate month, three month and long-term interest rate futures. On December 3rd, 2015 there was an approximate 6 basis point increase in the aforementioned futures. How does the cross-currency basis respond in the event window of announcement? Examining Figure 14 , there is a one-for-one response around the window, with the expansionary shock leading to a rise in the (absolute) level of the CIP deviations, and the contractionary shock leading to a decline in the (absolute) cross currency basis.

We also find clear reactions of CIP deviations to negative interest rate announcements for Japan and Switzerland (Figure 15). For Switzerland, the key negative interest rate announcement was on 18th December, 2014, when the deposit rate on reserves held at the Swiss National Bank reduced to -25 basis points. The surprise component of the expansionary announcement led to a 10 basis point decline in interest rate futures at all horizons. Although there is a slight rise in (absolute) cip deviations around the event window in which the monetary shock is evaluated, most of the adjustment takes place approximately 2 hours after the event window. For Japan, the key announcement of 29th of January led to a 25 basis point decline in the official cash rate. This move surprised the market for interest rate projections, leading to a decline of 6 basis points in the immediate one month futures, and close to a 10 basis point decline in long term (2yr) interest rate futures. The (absolute) level of CIP deviations increases however full one-for-one adjustment takes place slightly after the window.

To examine a more systematic response of CIP deviations to market based measures of monetary policy shocks, we regress the change in CIP deviations from the time of meeting at different horizons. This allows us to see whether there is a level or transitory effect of monetary policy on CIP deviations in both the period since negative interest rates, and in prior periods. Given the level shock evaluated around the event window, we can evaluate the pass-through coefficent β_k at different horizons after the meeting. For the Euro, Yen and Swiss Franc since 2014, there is a systematic one-for-one pass-through in the range of 2-4 hours from the meeting followed by a gradual decline (Figure 16). However, for the pound we do not see a significant increase in the cross-currency basis.

$$cip_{t+k} - cip_t = \alpha + \beta_k level_t + \epsilon_t,\ \ k = 1, 2, ...$$

Examining results for US shocks since 2014 (Figure 17) paints a different picture; in general the evidence of high frequency response of cip deviations to US shocks are mute. The coefficient is weakly negative in a window of 1-2 hours after the meeting, however the negative beta is temporal and is not significant at horizons longer than 2 to 3 hours after the meeting. In the context of model predictions, what matters is the asymmetry induced by negative interest rate policies of the

ECB, BOJ and SNB, we find an asymmetry insofar as negative rate policies of the ECB, BOJ and SNB matter for CIP deviations, whereas US policies do not.

7 Effect of swap lines: empirical evidence

In proposition 4, we show that swap lines provided by the Federal Reserve can prevent the outcome of a bank failure in a bad equilibrium, lowering counterparty risk and the (absolute) level of CIP deviations. A summary of key events for swap lines extended by the Federal Reserve are listed in Table 10, and include dates leading into the Euro crisis as well. Although swap lines for the ECB and Bank of Switzerland first opened in December 12, 2007, this date is excluded as an event as the drawing of significant amounts through the auction process really did not occur until much later. Another potential issue in analyzing the effect of swap lines for some countries is that they were never drawn, for the countries of Canada, New Zealand and Brazil.

Identifying the true causal effect of swap announcements is difficult in practice as it is difficult to obtain a reference to a control group with similar characteristics to the affected banks. For example, countries that did not draw swap lines cannot be used as a control group because they do not face the equivalent dollar funding pressures faced by banks in the Eurozone and Switzerland. We conduct an event study by first using a panel of countries, the Euro, Swiss Franc, Japan and the UK, and specific swap line events listed in Table 19. Using a panel regression specification with event study coefficients, we can analyze the dynamics of CIP deviations pre and post the swap events, Z_{it} includes a set of controls, such as stock market indices, 3 month libor rate differentials of the domestic country with respect to the US rate, changes in the Vix index, the US dollar trade weighted index and the relevant bilateral exchange rate. One issue in estimation is deciding on the event window. As the swap lines were put in place at precisely the time of most distress in financial markets, it is not surprising that extending the event window to longer horizons will suggest only a temporary effect of the announcement as dollar shortage pressures continue to persist. As a robustness check, we can also examine event study responses of libor-ois spreads to swap announcements, as from proposition 5 we predict the introduction of swap lines reduces CIP deviations through the channel of declining counterparty risk.

$$\Delta_{it} = \alpha_i + \sum_{k=-S}^{S} \gamma_k 1.[event_{t+k} \times Treatment_i] + \lambda_{it} Z_{it} + u_{it} \tag{45}$$

A key identification assumption we are making is that full allotment had a much stronger effect on stemming dollar funding pressures than previous expansions of the swap line. The key date for the ECB, Swiss and UK Central banks was October 13, 2008, which was an expansion of the swap line to full allotment, in which there is no limit on the value of swap amounts that counterparty central banks can bid. In Figure [18], there is a noticeable increase in swap amounts outstanding by the ECB and BOJ at the announcement of full allotment. Another key event in Table 10 is November 30, 2011, where the borrowing rate on swaps from Federal Reserve decreased by 50 basis points, translating to more favorable conditions for dollar funding from foreign central banks. Figure [19] shows the effects of the swap line policies of October 13, 2008 of full allotment (left) and November 30, 2011 of the decline in bid rates on dollar swap auctions (right) in attenuating the CIP deviations during this period.

The event study results in Figure 20 provide evidence of a decline in CIP deviations following the extension of swap lines for the Euro and Swiss Franc, with a peak effect occurring 5 days after the event. The reason for a delayed response is that mitigating the dollar funding gap of foreign banks by providing dollar liquidity may not be immediate and takes time; the extra dollar liquidity provided to domestic central banks then have to be distributed to local banks. In aggregate some local banks may still not obtain sufficient dollar liquidity to maintain solvency. The effect on the Yen basis is less significant, and is suggestive that the swap lines were more useful in alleviating the dollar shortage for European and Swiss banks.

8 Conclusion

We argue the main mechanism through which monetary policy can impact CIP deviations is through affecting the relative demand for US dollar assets. A constraint on dollar borrowing through debt markets translates to an excess demand for dollars through the foreign exchange swap market. Assuming capital constraints on the supply of dollar swaps, the excess demand translates to a dollar lending premium equal to the CIP deviations we see empirically. An implication of this result is that convergent monetary policies would eliminate CIP deviations, by eliminating the excess "carry trade" of banks borrowing in low interest rate currencies and investing in high interest rate currencies. An implication for central banks in the Eurzone, Japan and Switzerland is, what are the repercussions of negative interest rate policies in distorting financial institutions net interest margins on domestic currency asset positions? As these institutions seek higher returns by investing in other currencies, this may have perverse effects on domestic bank lending practices, and go against the ideology of negative interest rates in spurring domestic investment through forcing banks to lend excess reserves. Given the US Federal Reserve's commitment to tapering its balance sheet in coming years, an equally important question is the role of US monetary policy in ensuring dollar liquidity for non-US banks. The role of the US dollar as a principal funding currency for non-US financial institutions has lent itself to almost a decade of a dollar funding premium. This is suggestive that if monetary policies continue to remain divergent, and if the dollar persists as a vehicle currency for financial flows, CIP deviations will remain the norm in the years ahead.

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Figures

Figure 2: Positive relationship between libor rate differentials and the cross-currency basis for the Euro and Yen

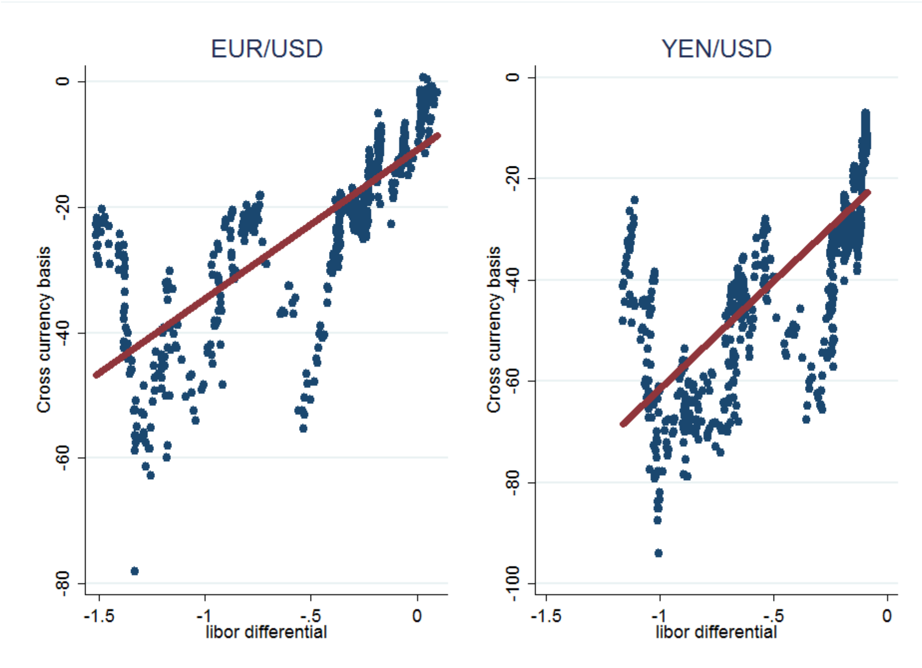


Figure 3: Reserve balances of Federal Reserve correlated with CIP deviations

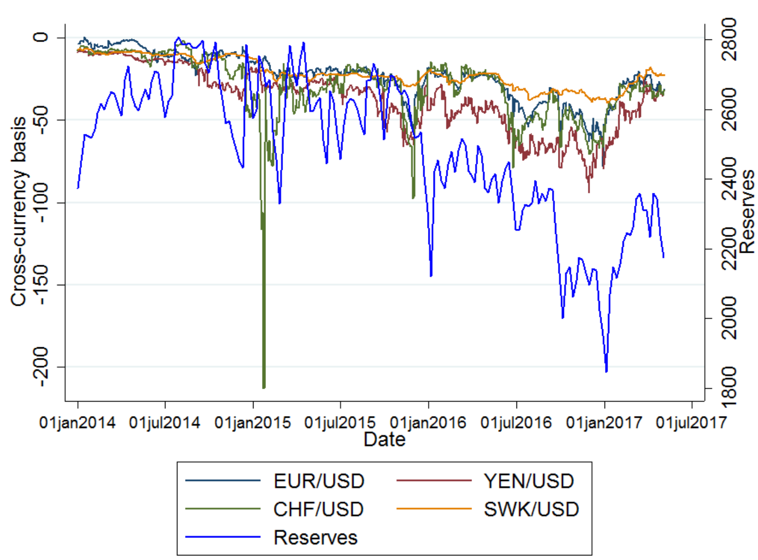


Figure 4: Net interest rate margins for Germany (DE), Switzerland (CH), Japan (JP) and Sweden (SE)

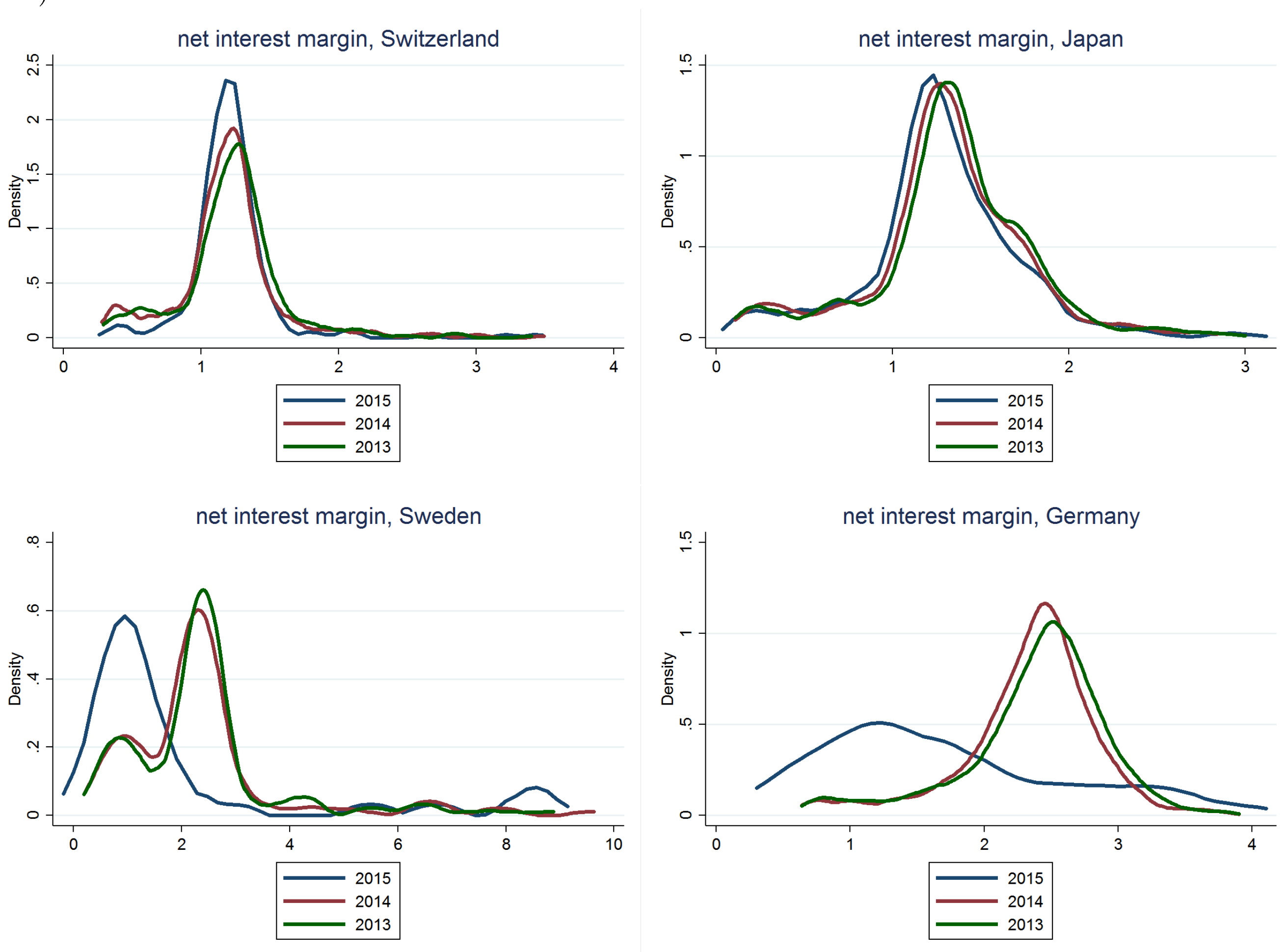
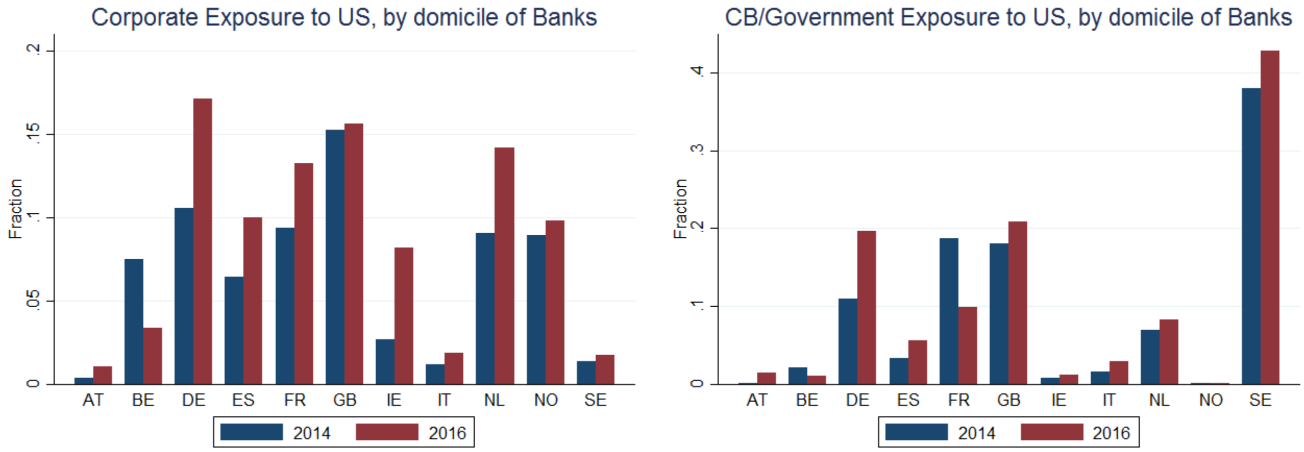


Figure 5: Fraction of Corporate exposure of European Banks to US, 2014-2016



Source: European Banking Data Stress Test Data. Countries are, from left to right, Austria, Belgium, Germany, Spain, France, UK, Iceland, Italy, Netherlands, Norway, Sweden

Figure 6: Fraction of Corporate credit exposure of European Banks to US, 2014-2016

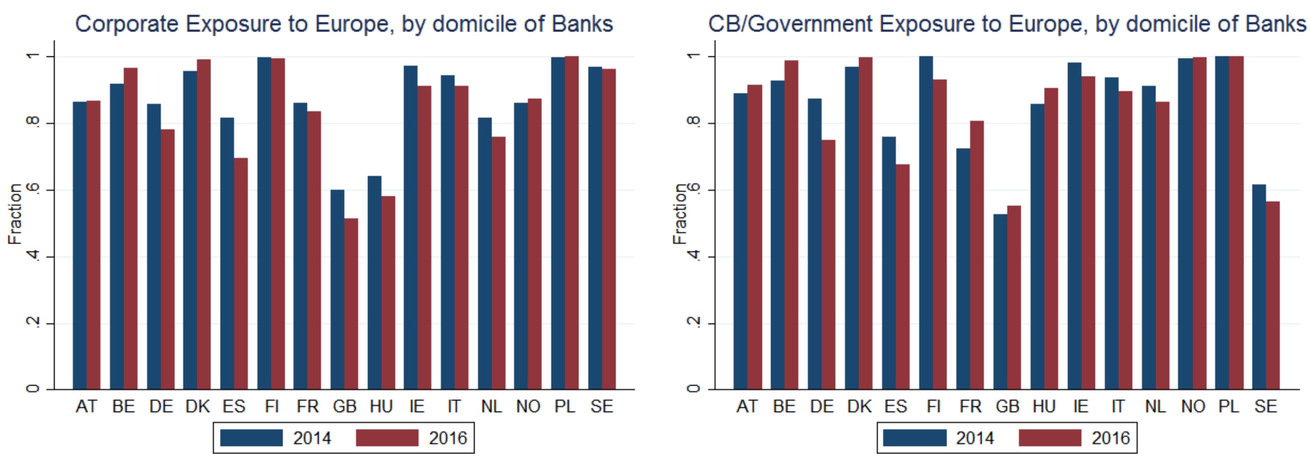


Figure 7: Dollar is prinicpal currency for cross-border transactions for Japanese (left) and Swiss (right) Banks

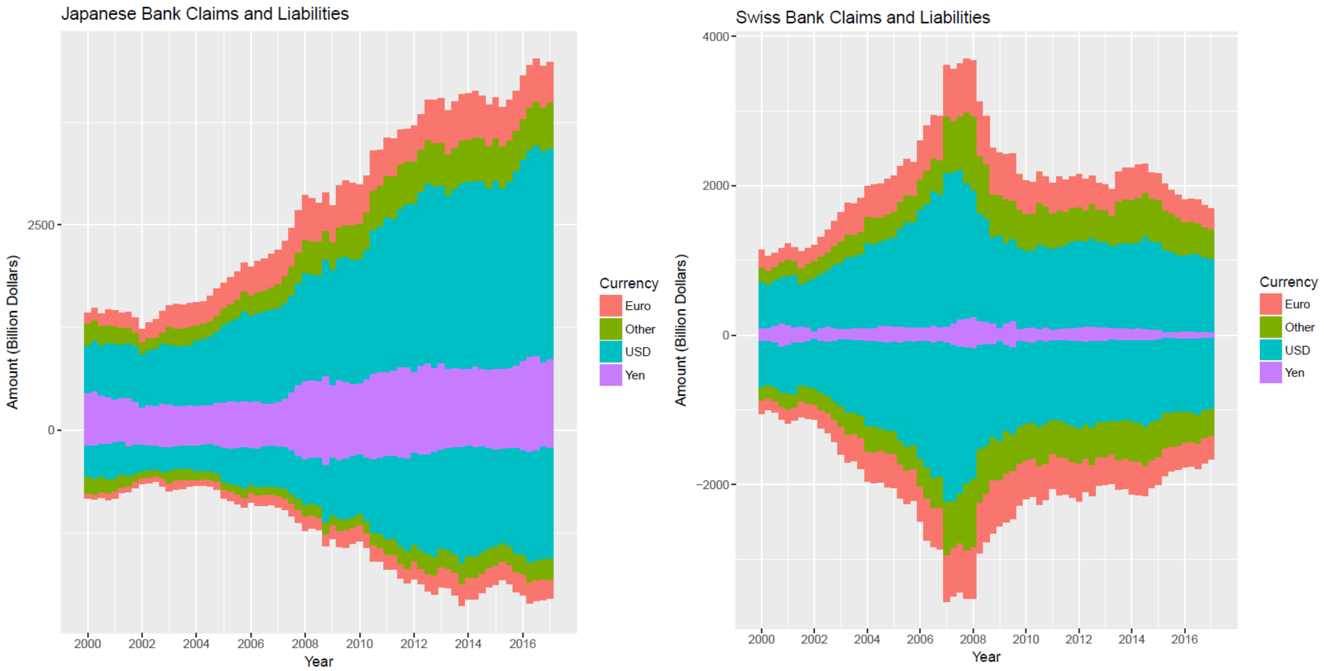


Figure 8: Currency funding gaps for Japan and Switzerland

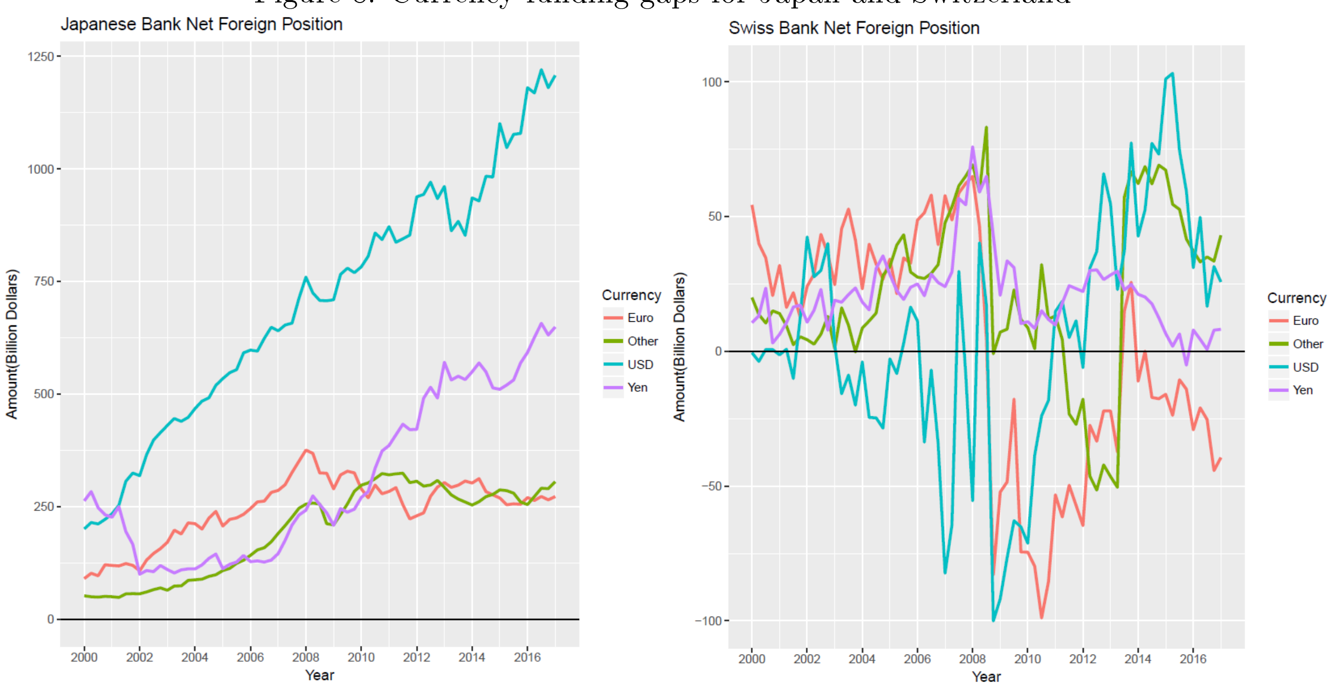


Figure 9: Germany (left) cross-border transactions predominantly in domestic currency (Euros), US (right) run a significant net liability position in dollars

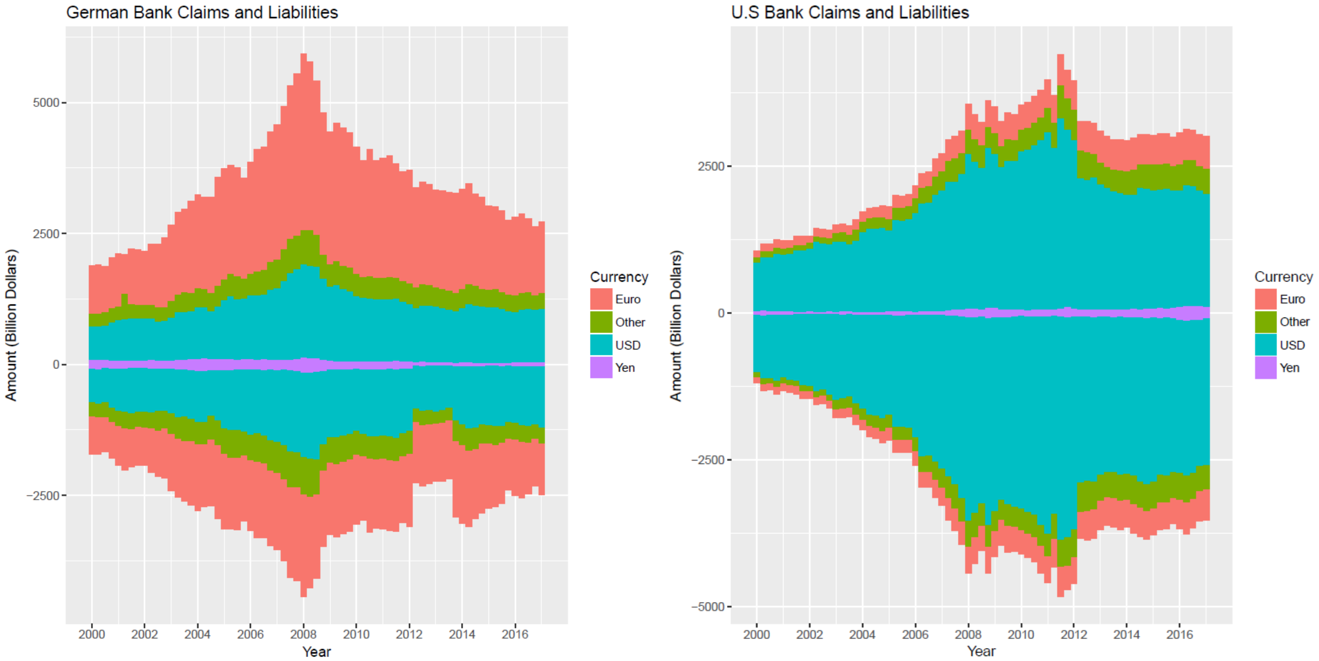


Figure 10: Currency funding gaps for Germany and the US

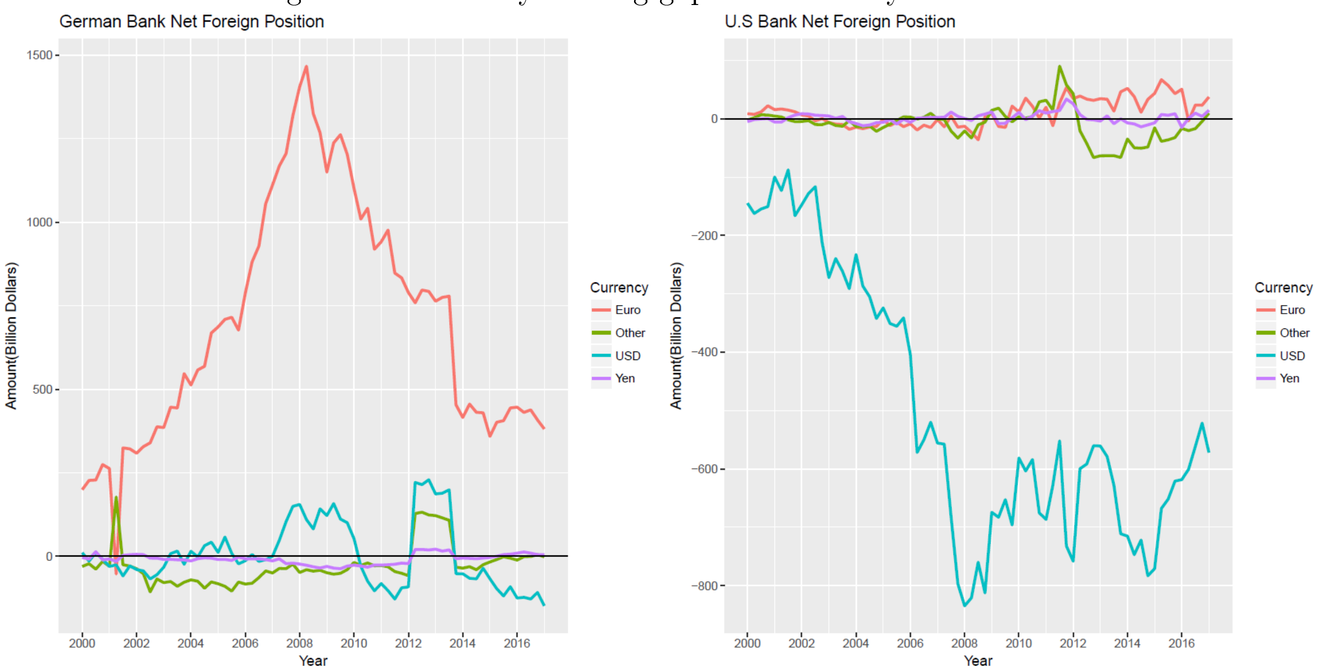


Figure 11: Total forex swap volume by currency

Source: New York Biannual Survey on Foreign Exchange

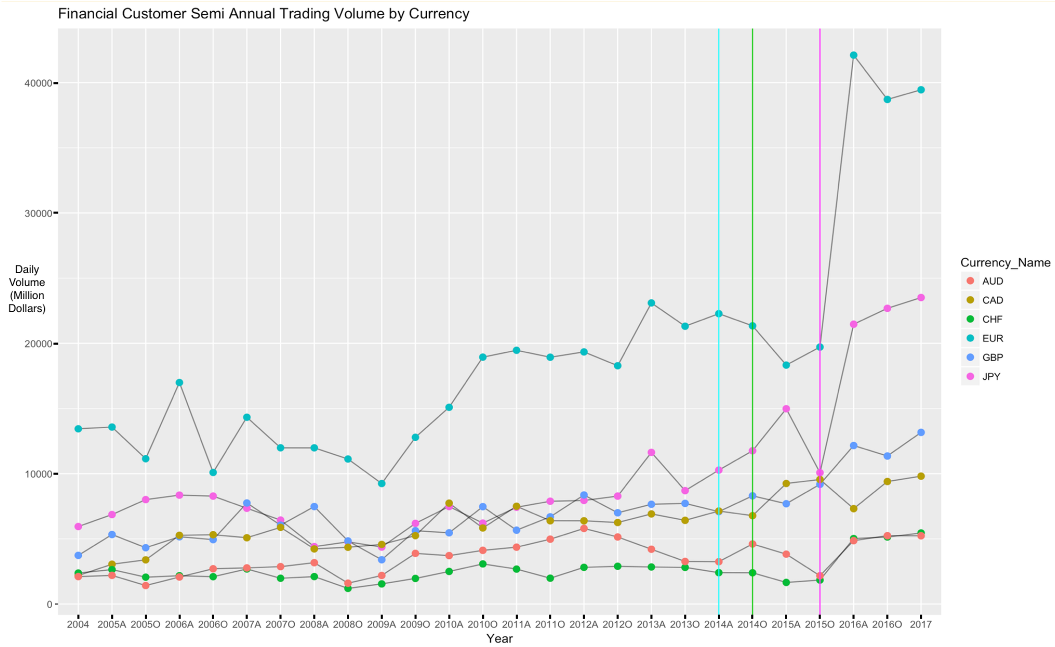


Figure 12: Cross-currency Swap Schematic

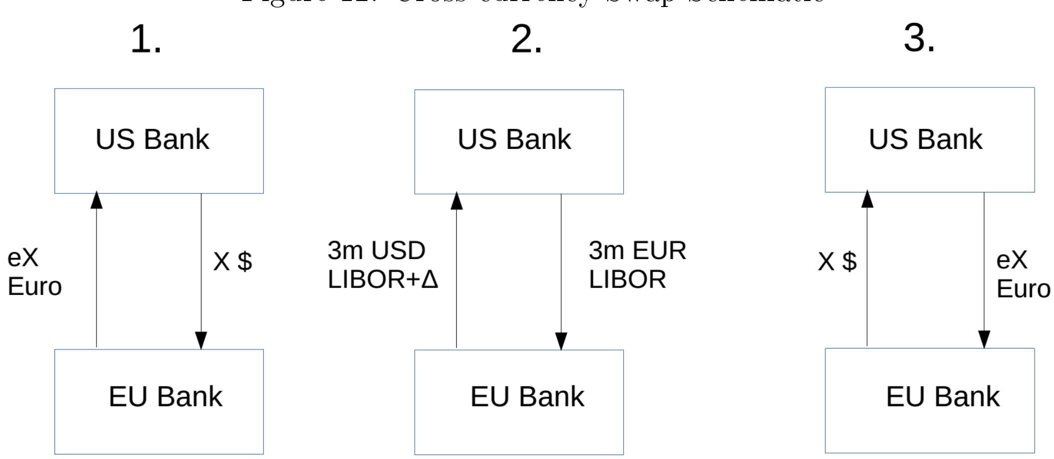


Figure 13: Equilibrium in the swap market, how an increase in demand can generate CIP deviations if there are limits to arbitrage.

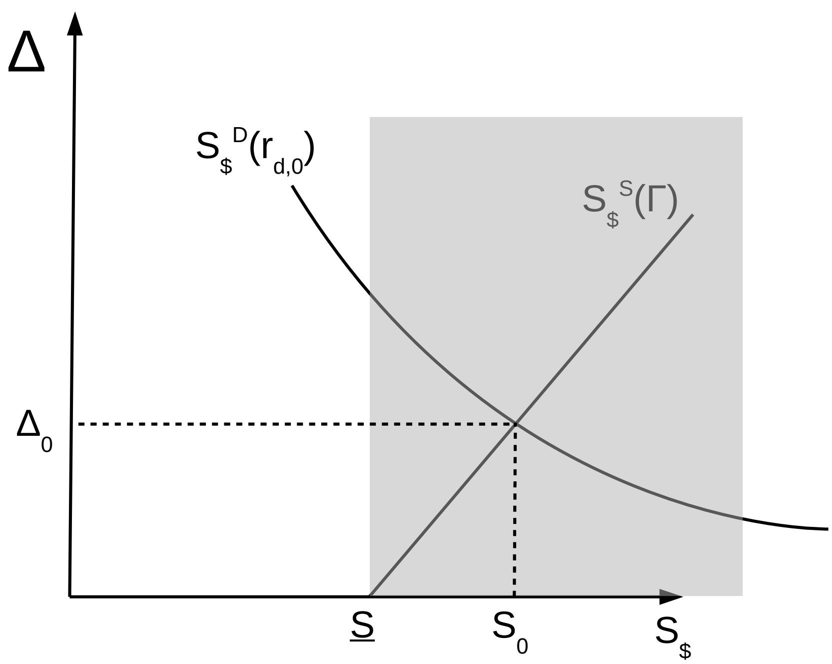


Figure 14: Swap announcements around window for the ECB

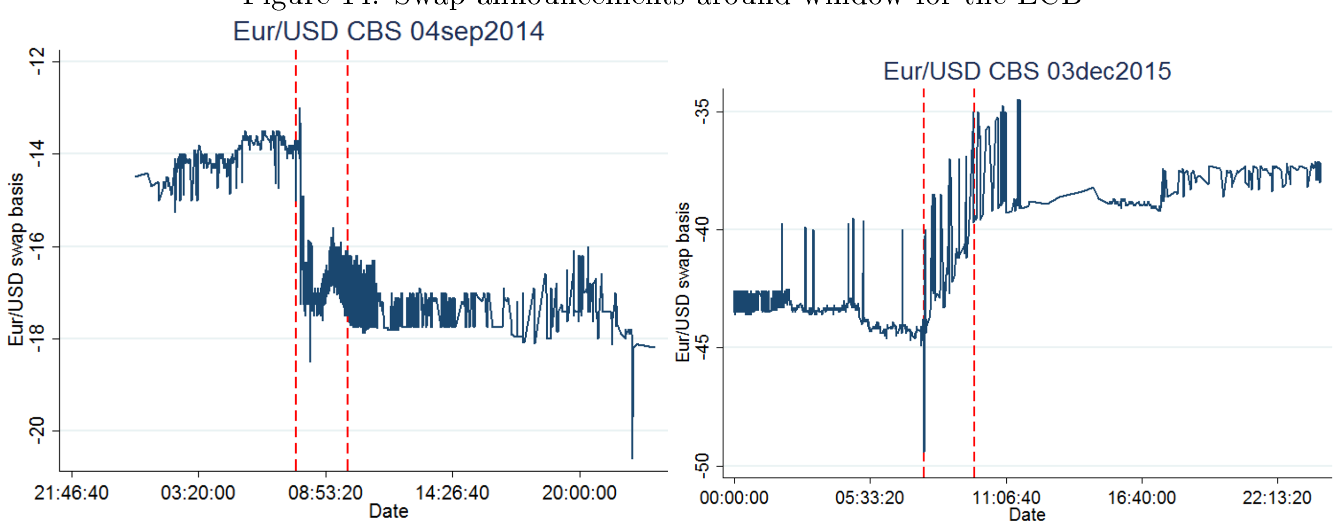


Figure 15: Left: Japan's negative interest rate announcement on 29 January, 2016, Right: Switzerland's negative interest rate announcement on 18 December 2014

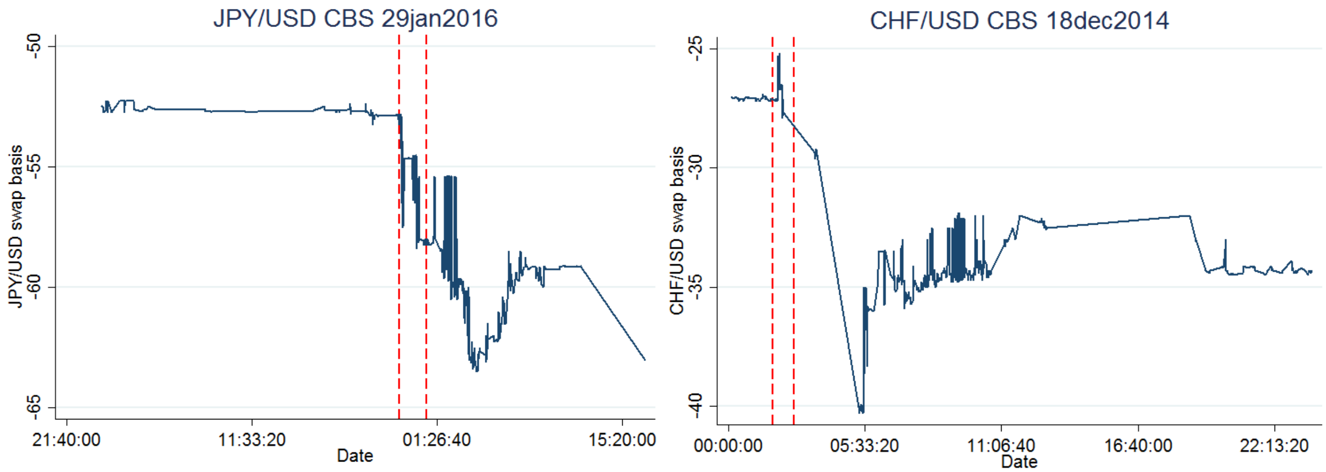


Figure 16: Cross Currency Basis in response to a surprise 1 basis point rise in the domestic policy rate. Top left: Eur/USD. Top right: Yen/USD. Bottom left: Swiss Franc/USD. Bottom right: pound/USD

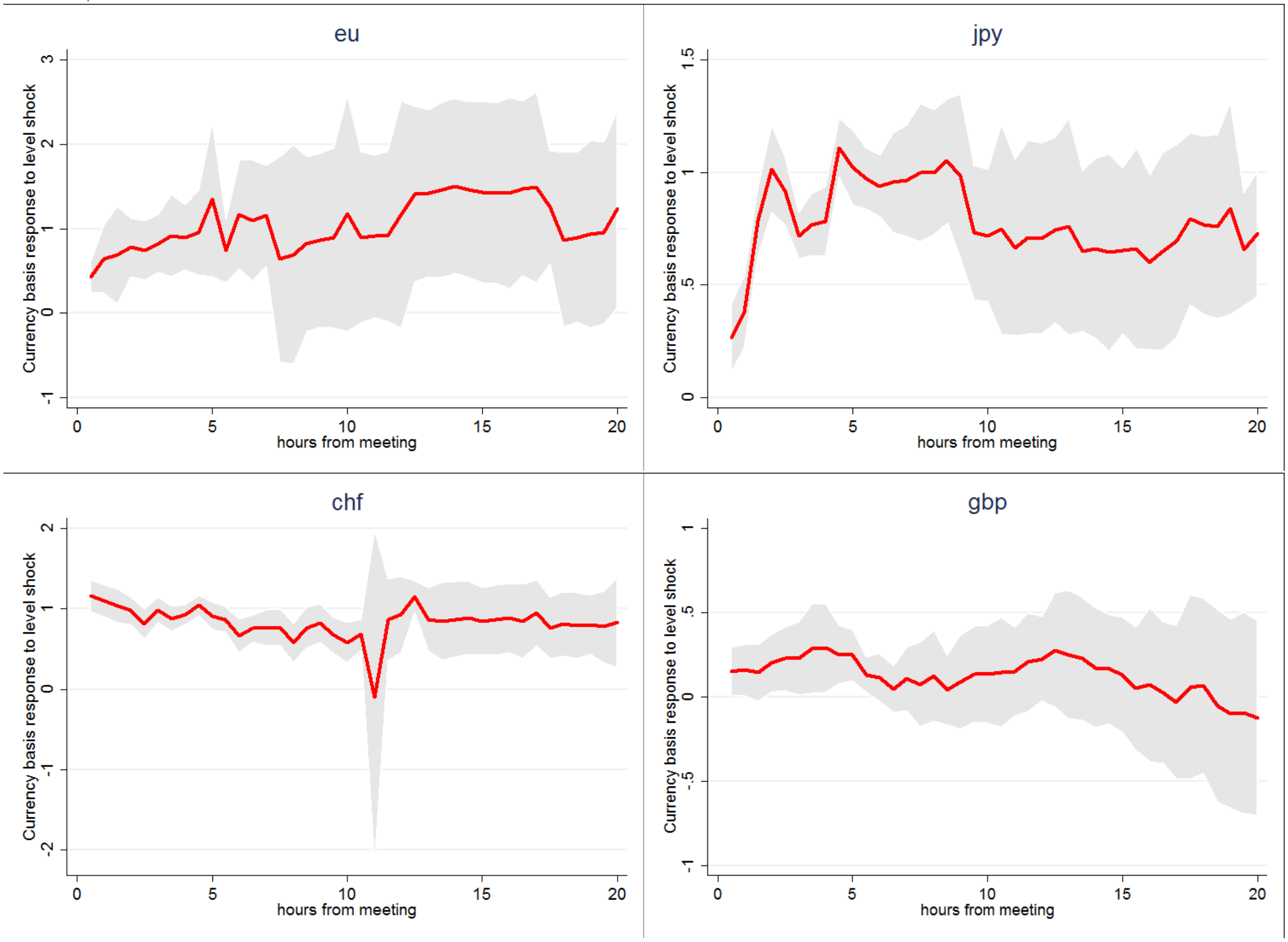


Figure 17: Cross Currency Basis in response to a surprise 1 basis point rise in the US policy rate. Top left: Eur/USD. Top right: Yen/USD. Bottom left: Swiss Franc/USD. Bottom right: pound/USD

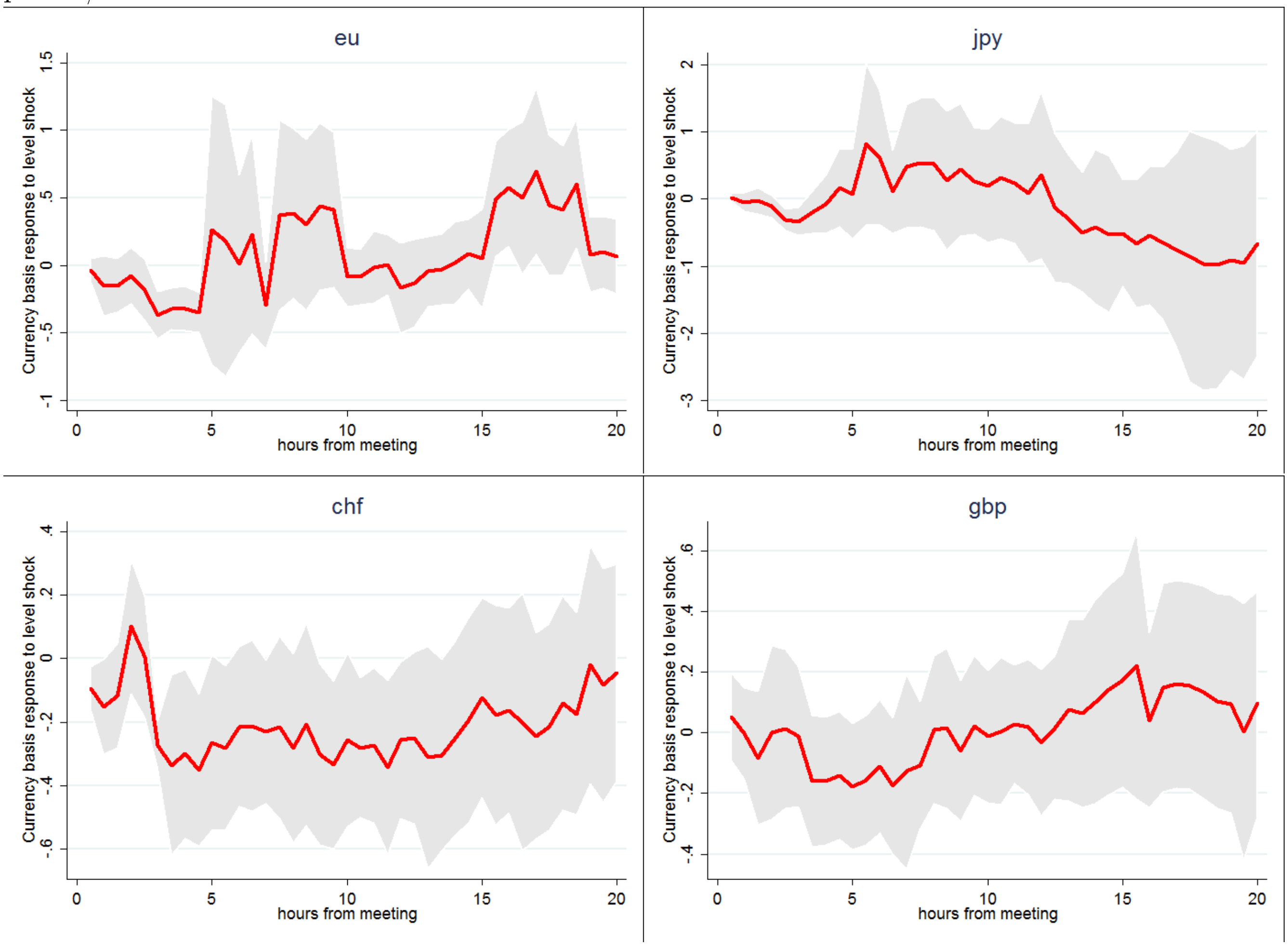


Figure 18: Swap amounts outstanding in 2008-2010

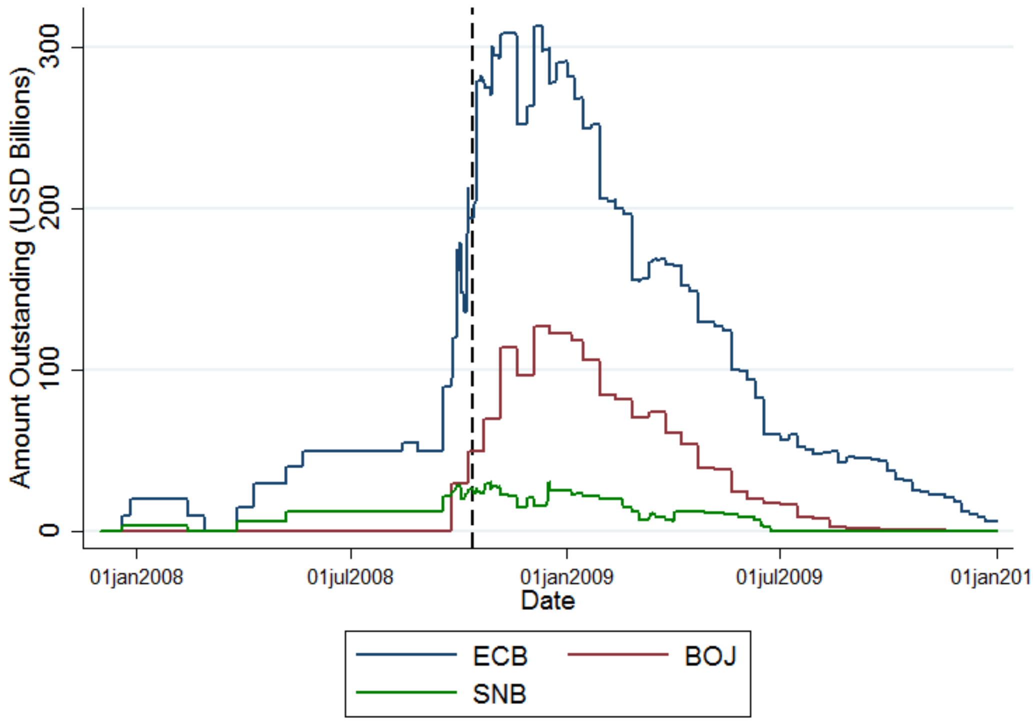


Figure 19: CIP deviations in EUR/USD, YEN/USD AND CHF/USD fall after the swap policies enacted in October 13, 2008 (Left) and November 30, 2011 (Right)

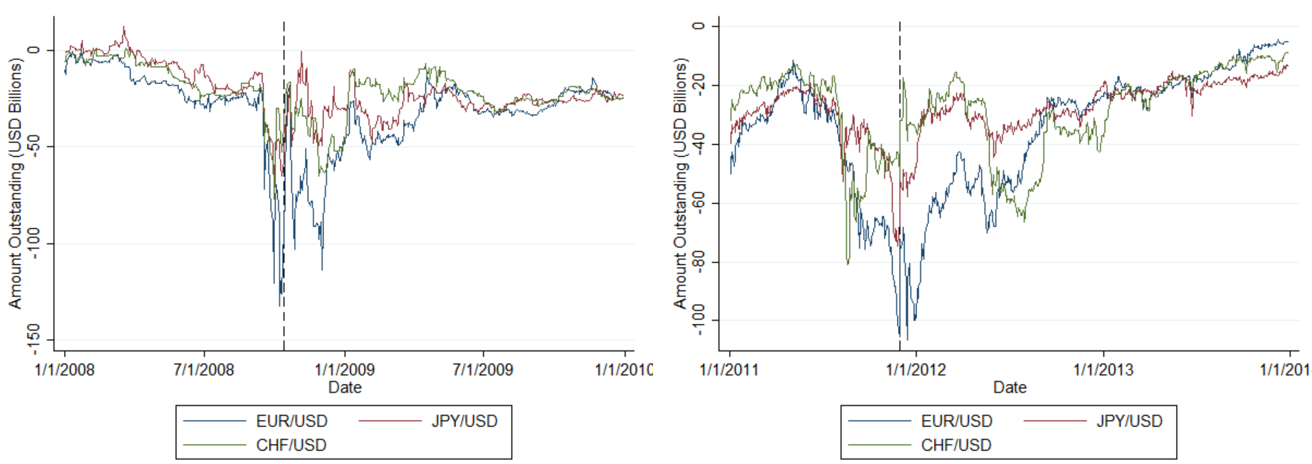
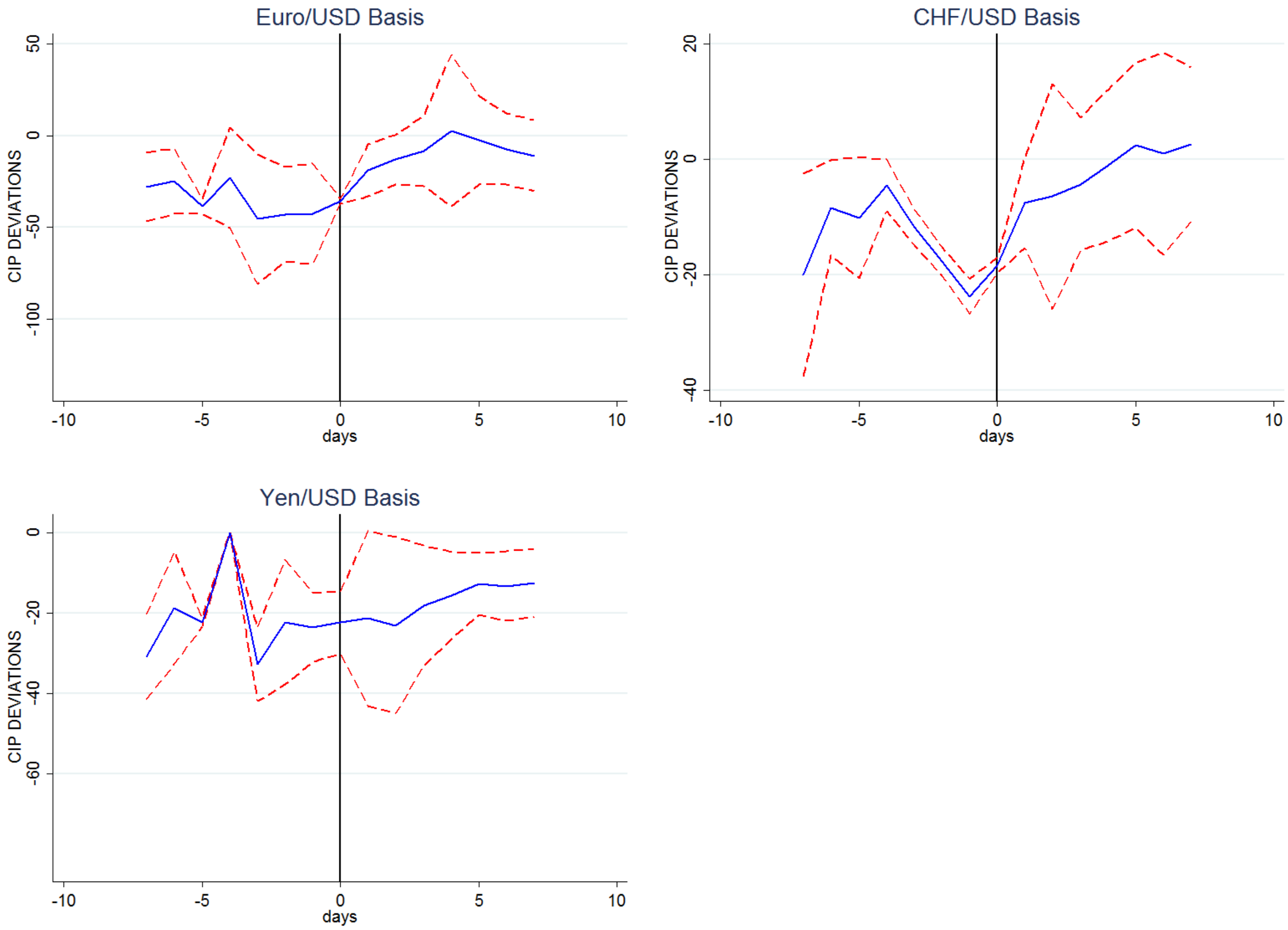


Figure 20: Event Study of response of Euro/USD,CHF/USD and Yen/USD basis w.r.t Federal Reserve swap announcements



Tables

Table 1: Negative Rate policies (in basis points)

Country	Overnight lending Rate	Deposit Rate Facility	Date of Introduction
Denmark	5	-65	April 2014
Euro Area	25	-40	June 11, 2014
Japan	10	-10	February 16, 2016
Norway	150	-50	September 24, 2015
Sweden	25	-125	February 12, 2015
Switzerland	50	-75	January 15, 2015

Table 2: Underlying interest rate futures to measure monetary shocks

Country	Underlying policy rate	Monetary shock
US	Fed Funds Rate	$\Delta MP1_{US,t} = \frac{D}{D-d} \Delta f1_t^{surprise}$
AUS	SFE 90-Day Bank Accepted Bill Rate	$\Delta MP1_{AUS,t} = \Delta f1_{AUS,t}^{surprise}$
EU	EUREX 3-Month Euribor	$\Delta MP_{EU,t} = \Delta f1_{EU,t}^{surprise}$
JPY	TFX (TIFFE) 3-Month Euroyen Tibor	$\Delta MP_{JPY,t} = \Delta f1_{JPY,t}^{surprise}$
SWZ	LIFFE 3-Month Euroswiss Franc	$\Delta MP_{SWZ,t} = \Delta f1_{SWZ,t}^{surprise}$
UK	LIFFE 3-Month Short Sterling Libor	$\Delta MP_{UK,t} = \Delta f1_{UK,t}^{surprise}$

Table 3: Descriptive statistics, monetary shocks

	Mean	SD	p-5	p-25	p-50	p-75	p-95	Obs	Contract Period
$MP1_{\text{US}}$	-0.012	0.076	-0.121	-0.010	0.000	0.006	0.087	190	02/94 - 09/16
MP_{AUS}	-0.014	0.110	-0.180	-0.020	0.000	0.020	0.100	285	01/90 - 09/16
MP_{NZ}	0.002	0.137	-0.240	-0.030	0.005	0.040	0.210	168	07/95 - 09/16
MP_{SWZ}	-0.029	0.101	-0.180	-0.060	-0.010	0.010	0.080	90	02/91 - 09/16
MP_{UK}	-0.006	0.063	-0.090	-0.020	0.000	0.010	0.080	232	06/97 - 09/16
MP_{EU}	0.001	0.042	-0.060	-0.015	0.000	0.020	0.068	240	01/99 - 09/16

All values in percentage points

Table 4: Domestic monetary shocks and cross-currency basis, 2007-Current

	AUS	EU	JPY	SWZ	UK
	b/se	b/se	b/se	b/se	b/se
mp1	-0.013	0.602	0.139	-0.335	0.745
	(0.031)	(0.173)***	(1.080)	(0.494)	(0.764)
mp1*1$\{_{\text{post-2014}}\}$	0.054	1.335	1.665	2.130	0.001
	(0.053)	(0.397)**	(1.167)	(0.487)***	(0.784)
δ(mp1*1$\{_{\text{post-2014}}\}$)	0.041	1.937	1.803	1.795	0.746
	(.037)	(.354)***	(.436)***	(.189)***	(.305)**
R2	0.008	0.161	0.282	0.555	0.155
observations	61	96	69	22	98

*** p<0.01, ** p<0.05 *p<0.1, robust standard errors in parantheses.

Table 5: Domestic monetary shocks and cross-currency basis, Decomposition to level, timing and slope

	AUS	EU	JPY	SWZ	UK
timing	-0.023	0.941	0.655	-3.869	0.740
	(0.191)	(0.474)	(1.061)	(2.574)	(1.214)
level	0.091	0.359	0.847	-2.658	0.696
	(0.157)	(0.588)	(0.866)	(1.470)	(0.606)
slope	0.092	0.171	0.062	-0.217	0.008
	(0.126)	(0.426)	(0.055)	(0.115)	(0.012)
timing*$1\{_{\text{post-2014}}\}$	0.281	0.706	-0.004	6.127	0.418
	(0.227)	(1.354)	(1.318)	(3.706)	(0.987)
level*$1\{_{\text{post-2014}}\}$	-0.072	1.552	0.463	4.279	0.209
	(0.187)	(0.708)*	(0.987)	(1.595)*	(0.554)
slope*$1\{_{\text{post-2014}}\}$	-0.095	-0.035	-0.026	0.182	-0.025
	(0.142)	(0.535)	(0.080)	(0.168)	(0.024)
δ(timing*$1\{_{\text{post-2014}}\}$)	0.258	1.646	0.651	2.257	1.158
	(.113)**	(1.269)	(1.152)	(3.047)	(.489)**
δ(level*$1\{_{\text{post-2014}}\}$)	0.019	1.910	1.310	1.621	0.904
	(.113)	(.391)***	(.51)**	(.529)***	(.321)***
δ(slope*$1\{_{\text{post-2014}}\}$)	-0.003	0.137	0.036	-0.035	-0.016
	(.083)	(.367)	(.059)	(.119)	(.015)
R2	0.082	0.209	0.301	0.679	0.158
observations	61	96	69	22	98

*** $p<0.01$, ** $p<0.05$ *$p<0.1$, robust standard errors in parantheses.

Table 6: ECB monetary shocks and Euro/USD Cross-Currency Basis at different horizons

	3m	1y	2y	5y	10y	30y
	b/se	b/se	b/se	b/se	b/se	b/se
timing	1.133	0.504	0.024	-0.101	-0.027	0.024
	(0.347)**	(0.369)	(0.161)	(0.121)	(0.069)	(0.052)
level	0.173	-0.991	-0.359	-0.112	-0.059	-0.023
	(0.154)	(0.695)	(0.201)	(0.088)	(0.036)	(0.019)
slope	0.171	0.346	0.164	0.129	0.075	-0.001
	(0.428)	(0.303)	(0.112)	(0.076)	(0.037)*	(0.038)
timing*1$\{_{\text{post-2014}}\}$	0.681	-0.116	0.271	0.587	0.593	0.075
	(1.026)	(0.589)	(0.392)	(0.381)	(0.423)	(0.358)
level*1$\{_{\text{post-2014}}\}$	1.590	1.644	0.911	0.543	0.430	0.340
	(0.553)**	(0.760)*	(0.284)**	(0.170)**	(0.136)**	(0.117)**
slope*1$\{_{\text{post-2014}}\}$	-0.027	-0.292	-0.103	-0.070	-0.084	0.010
	(0.542)	(0.352)	(0.157)	(0.129)	(0.098)	(0.088)
δ(timing*1$\{_{\text{post-2014}}\}$)	1.814	0.388	0.295	0.486	0.566	0.099
	(.998)*	(.362)	(.348)	(.359)	(.416)	(.353)
δ(level*1$\{_{\text{post-2014}}\}$)	1.764	0.654	0.551	0.431	0.371	0.317
	(.537)***	(.2)***	(.19)***	(.142)***	(.13)***	(.115)***
δ(slope*1$\{_{\text{post-2014}}\}$)	0.144	0.054	0.061	0.058	-0.010	0.008
	(.331)	(.107)	(.101)	(.103)	(.09)	(.08)
R2	0.209	0.292	0.239	0.171	0.160	0.059
observations	96	113	113	113	113	113

*** p<0.01, ** p<0.05 *p<0.1, robust standard errors in parantheses.

Table 7: SNB monetary shocks and CHF/USD Cross-Currency Basis at different horizons

	3m	1y	2y	5y	10y	30y
	b/se	b/se	b/se	b/se	b/se	b/se
timing	-3.731	0.313	0.108	0.020	-0.019	0.000
	(2.532)	(0.120)*	(0.048)*	(0.018)	(0.021)	(0.030)
level	-3.051	0.047	0.027	0.017	0.020	-0.006
	(1.875)	(0.042)	(0.019)	(0.009)	(0.010)	(0.026)
slope	-0.227	-0.041	-0.019	-0.009	-0.005	0.009
	(0.108)	(0.018)*	(0.009)*	(0.005)	(0.004)	(0.012)
timing*1$\{_{\text{post-2014}}\}$	5.636	0.526	0.015	0.368	0.167	0.210
	(2.431)*	(0.826)	(0.497)	(0.471)	(0.436)	(0.408)
level*1$\{_{\text{post-2014}}\}$	4.976	0.746	0.624	0.278	0.210	0.272
	(1.896)*	(0.112)***	(0.049)***	(0.064)***	(0.068)**	(0.053)***
slope*1$\{_{\text{post-2014}}\}$	0.181	0.078	0.022	0.017	-0.010	-0.000
	(0.163)	(0.050)	(0.026)	(0.019)	(0.019)	(0.021)
δ(timing*1$\{_{\text{post-2014}}\}$)	1.905	0.839	0.123	0.388	0.148	0.210
	(2.45)	(.819)	(.492)	(.47)	(.436)	(.413)
δ(level*1$\{_{\text{post-2014}}\}$)	1.926	0.793	0.651	0.295	0.229	0.266
	(.176)***	(.107)***	(.046)***	(.064)***	(.068)***	(.053)***
δ(slope*1$\{_{\text{post-2014}}\}$)	-0.045	0.038	0.003	0.007	-0.015	0.009
	(.121)	(.046)	(.024)	(.018)	(.019)	(.019)
R2	0.698	0.407	0.481	0.336	0.218	0.088
observations	22	45	44	45	45	44

*** p<0.01, ** p<0.05 *p<0.1, robust standard errors in parantheses.

Table 8: US monetary shocks and cross-currency basis, 2007-Current

	AUS	EU	JPY	SWZ	SWE	UK
mp1	0.678	0.424	0.337	-1.695	-0.002	-0.892
	(0.567)	(0.416)	(1.763)	(2.994)	(0.017)	(1.502)
mp1*1{post-2014}	-0.601	-2.183	0.106	0.823	0.026	0.738
	(0.587)	(0.677)**	(1.835)	(3.017)	(0.059)	(1.706)
δ(mp1*1{post-2014})	0.077	-1.759	0.443	-0.872	0.024	-0.155
	(.061)	(.359)***	(.431)	(.498)*	(.06)	(.28)
R2	0.054	0.043	0.024	0.055	0.000	0.032
observations	47	67	43	42	70	67

*** p<0.01, ** p<0.05 *p<0.1, robust standard errors in parantheses.

Table 9: US monetary shocks and cross-currency basis, decomposition to level, timing and slope

	AUS	EU	JPY	SWZ	SWE	UK
timing	0.586	-0.373	-2.011	-2.000	-0.168	8.100
	(0.560)	(1.332)	(2.200)	(2.629)	(0.116)	(4.913)
level	0.102	1.035	2.479	0.338	0.089	4.718
	(0.561)	(1.108)	(1.104)*	(1.817)	(0.054)	(2.722)
slope	0.135	-0.448	-0.441	0.864	-0.057	-0.524
	(0.053)*	(0.445)	(0.239)	(0.342)*	(0.038)	(0.359)
timing*$1\{_{\text{post-2014}}\}$	-0.415	-0.557	2.144	1.001	0.213	-8.003
	(0.573)	(1.390)	(2.221)	(2.692)	(0.136)	(4.896)
level*$1\{_{\text{post-2014}}\}$	-0.187	-2.689	-1.947	-0.903	-0.150	-5.742
	(0.588)	(1.694)	(1.140)	(2.009)	(0.109)	(3.166)
slope*$1\{_{\text{post-2014}}\}$	-0.111	0.713	0.354	-0.779	0.070	0.752
	(0.057)	(0.582)	(0.270)	(0.355)*	(0.043)	(0.455)
δ(timing*$1\{_{\text{post-2014}}\}$)	0.171	-0.930	0.134	-1.000	0.044	0.097
	(.139)	(.533)*	(.475)	(.658)	(.071)	(.518)
δ(level*$1\{_{\text{post-2014}}\}$)	-0.085	-1.654	0.532	-0.565	-0.061	-1.024
	(.139)	(.843)**	(.467)	(.559)	(.083)	(.638)
δ(slope*$1\{_{\text{post-2014}}\}$)	0.024	0.265	-0.087	0.085	0.013	0.228
	(.035)	(.196)	(.137)	(.143)	(.021)	(.147)
R2	0.212	0.166	0.392	0.392	0.075	0.470
observations	47	62	43	42	64	63

*** p<0.01, ** p<0.05 *p<0.1, robust standard errors in parantheses.

Table 10: Swap announcements by Federal Reserve to enhance dollar funding

Date	Countries affected	Line size	bid rate	Drawn
9.29.08	JPY	Full allotment	OIS+100bp	Y
	AUS	30B	USD Libor	Y
	SWE		OIS+50 bp	Y
	CAN	-	-	N
10.13.08	EU, SWZ, UK	Full allotment	OIS+100 bp	Y
10.28.08	NZ	-	-	N
10.29.08	MEX	30B	OIS+50 bp	Y
	BR	-	-	N
5.9.10	EU, SWZ, UK, JPY	Full allotment (re-established)	OIS+100 bp	Y
	CAN	30B		Y
11.30.11	EU, SWZ, UK, JPY	Full allotment	OIS+50 bp, reduced by 50 bp	Y

Source: Federal Reserve, ECB