

# The dollar, bank leverage and the deviation from covered interest parity\*

Stefan Avdjiev

Bank for International Settlements

Wenxin Du

Federal Reserve Board

Cathérine Koch

Bank for International Settlements

Hyun Song Shin

Bank for International Settlements

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## Abstract

We document the triangular relationship formed by the strength of the US dollar, cross-border bank lending in dollars and deviations from covered interest parity (CIP). A stronger dollar goes hand-in-hand with bigger deviations from CIP and contractions of cross-border bank lending in dollars. Differential sensitivity of CIP deviations to the strength of the dollar can explain cross-sectional variations in CIP arbitrage profits. Underpinning the triangle is the role of the dollar as proxy for the shadow price of bank leverage.

*Keywords:* exchange rates, bank leverage, cross-currency basis

*JEL Classifications:* F3, G1, G2

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# 1 Introduction

One of the most significant developments in global financial markets in recent years has been the breakdown of covered interest parity (CIP). CIP is perhaps the best-established principle in international finance, and states that the interest rates implicit in foreign exchange swap markets coincide with the corresponding interest rates in cash markets. Otherwise, someone could make a riskless profit by borrowing at the low interest rate and lending at the higher interest rate with currency risk fully hedged. However, the principle broke down during the height of the 2008-2009 crisis. After the Great Financial Crisis (GFC), CIP deviations have persisted and have become more significant recently, especially since mid-2014.

Why do such apparent risk-free arbitrage opportunities exist? In competitive markets, market participants are price takers, and can take on any quantity of goods at the prevailing market price. The textbook arbitrage argument is that someone could borrow at the low interest rate and lend out at the higher interest rate, having hedged currency risk completely. The failure of CIP would thereby open up the possibility of unlimited riskless profits. However, in textbooks, there are no banks. In practice, though, such arbitrage typically entails borrowing and lending through banks, and the competitive assumption is violated due to balance sheet constraints that place limits on the size of the exposures that can be taken on by banks. Even for non-banks, their ability to exploit arbitrage opportunities rely on banks to provide leverage. Hence, if deviations from CIP persist, it is because banks do not or cannot exploit such opportunities.

Our focus, therefore, is on the banking sector, and the ability of banks to take on leverage. The key message of our paper is that the value of the dollar plays the role of a barometer of risk-taking capacity in capital markets. In particular, it is the spot exchange rate of the dollar which plays a crucial role. Deviations from CIP turn on the strength of the dollar; when the dollar strengthens, the deviation from CIP becomes larger. To the extent that CIP deviations turn on the constraints on bank leverage, our results suggest that the strength of the dollar is a key determinant of bank leverage.

The *cross-currency basis* is the difference between the dollar interest rate in the cash

US dollar broad index and the cross-currency basis

Figure 1



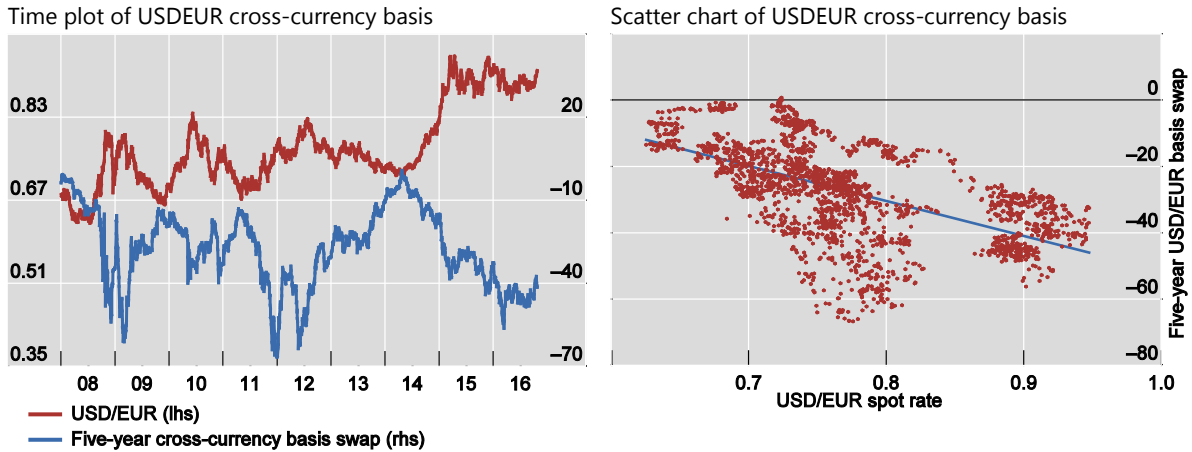
The red line shows the Federal Reserve Board's US trade-weighted broad dollar index, with higher values indicating a stronger US dollar. The blue line is the simple average of the five-year cross currency basis swap spreads for AUD, CAD, CHF, DKK, EUR, GBP, JPY, NOK, NZD and SEK vis-à-vis the US dollar.

Sources: Board of Governors of the Federal Reserve System; Bloomberg.

market and the implied dollar interest rate from the swap market when swapping foreign currency into dollars. The cross-currency basis measures deviations from the CIP condition. Figure 1 plots the broad dollar index (in red), which is the trade-weighted US dollar exchange rate against its major trading partners. When the red line goes up, the dollar strengthens. The blue line tracks the average cross-currency basis for the ten most liquid currencies vis-à-vis the dollar. We see that the cross-currency basis is the mirror image of dollar strength. When the dollar strengthens, the CIP deviations widen. This is especially so in the last 24 months, reflecting the stronger dollar.

We see the same pattern for individual currencies. Figure 2 shows the cross-currency basis for the euro, or the CIP deviations between dollar interest rates and implied interest rates of swapping euros into dollars in the FX markets. We see that the size of the cross-currency basis for the euro is the mirror image of the strength of the dollar, like mountains reflected in a lake. The right-hand panel shows a daily frequency scatter chart of the basis and the dollar exchange rate. The basis co-moves very closely with the exchange rate, even at the daily frequency.

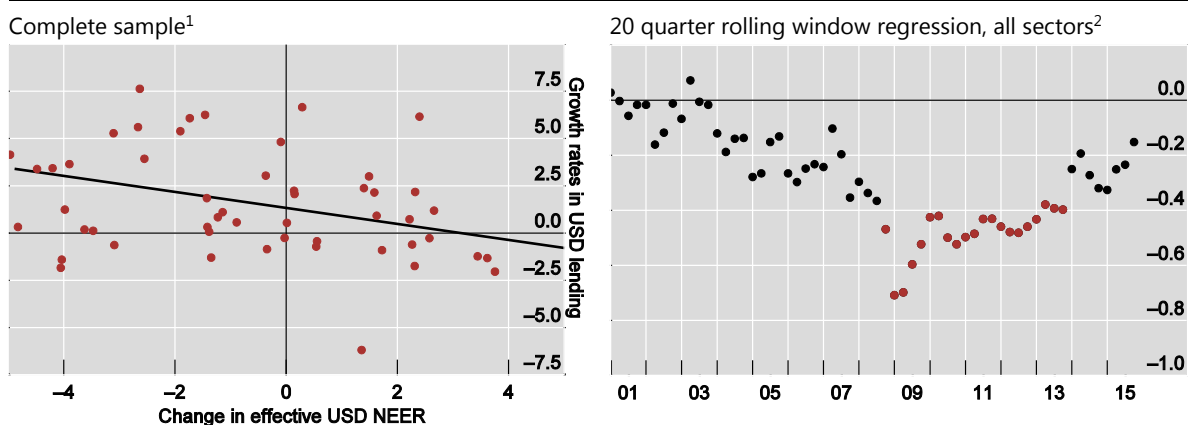
As we demonstrate below, there is also an asset-pricing relationship underpinning these empirical observations. The exposure to the dollar exchange rate is priced in the cross-section of CIP deviations in the sense that variations in such deviations across



Source: Bloomberg.

currencies are explained by the sensitivity of the deviations to fluctuations in the broad dollar index. The CIP deviations of different currencies have differing exposures to the dollar factor. Interestingly, we document a reversal of roles. The classical “safe haven” currencies, such as the Japanese yen and the Swiss franc, have the highest exposure to the dollar factor, and high-yielding “carry” currencies, such as the Australian dollar and the New Zealand dollar, have the lowest exposure to the dollar factor. Currencies with higher exposure to the dollar factor exhibit larger CIP deviations and thereby offer greater potential arbitrage profits for banks. Furthermore, the relationship between the level of the basis and the sensitivity to the dollar factor is strongly supported by the event study based on the strong dollar depreciation following the 2016 U.S. Presidential Election.

Our results point to the *financial channel* of exchange rates, through which fluctuations in the strength of the dollar set in motion changes in capital market intermediation spreads that respond at a high frequency. The net exports channel of exchange rate changes is standard in open economy macro models, but the financial channel is less standard, and may operate in the opposite direction to the net exports channel. Under the net exports channel, it is when the domestic currency *depreciates* that real economic activity picks up. By contrast, the financial channel appears to operate in the opposite direction; it is when the domestic currency *appreciates*, financial conditions in that country loosen, and CIP deviations narrow.



<sup>1</sup> Covers the Q1 2010–Q3 2015 period. Lending refers to the extension of loans and holdings of debt securities by BIS reporting banks, while all borrowers (the total of banks and non-banks) reside outside of the United States. The black line is a fitted regression line. Positive changes in the foreign exchange rate indicate an appreciation of the USD. For presentational purposes, outliers with FX rate changes exceeding 5% in absolute value have been dropped from the panel, but not from the regressions. <sup>2</sup> Extension of the LHP static regression to a rolling window framework of 20 quarters per estimation for cross-border lending (loans and debt securities) denominated in US dollars. The position of dots with respect to the vertical axis gives the coefficient estimate, while the horizontal timeline refers to the last period of the rolling window. Red dots indicate a negative coefficient estimate that is statistically significant at the 10% level.

Sources: BIS Locational Banking Statistics; BIS effective exchange rate indices; BIS calculations.

Why do the CIP deviations narrow when the domestic currency strengthens against the dollar? Underpinning this relationship is the role of bank leverage and cross-border bank lending in dollars. Indeed, we will show the existence of a “triangle” that coherently ties together (i) the value of the dollar; (ii) the cross-currency basis; and (iii) cross-border bank lending. In this triangle, a depreciation of the dollar is associated with greater borrowing in dollars by non-residents.

The relationship between cross-border dollar lending and the dollar is illustrated in Figure 3. The left-hand panel plots the quarterly growth rate of global dollar-denominated cross-border bank lending flows against the broad dollar index. It reveals that there is a negative relationship between the two variables. Furthermore, the relationship is strongly statistically significant. As we demonstrate in the empirical section of this paper, the statistical significance of the above relationship is robust to controlling for a number of additional factors.

The right-hand panel of Figure 3 examines how the above relationship has evolved over time. More concretely, it displays the coefficients obtained from rolling window regressions of the quarterly growth rate of dollar-denominated cross-border bank lending on changes

in the value of the dollar. It appears that, while the negative relationship between the above two variables has been strong throughout the sample period, it gradually strengthened over the decade leading up to the GFC and reached a peak in 2008 during the acute phase of the crisis.

This empirical regularity has several drivers, both on the demand for dollar credit on the part of borrowers as well as on the supply of dollar credit by lenders. The negative relationship between dollar credit, a proxy for bank leverage, and the magnitude of CIP deviations, the price of balance sheet capacity, point in favor of supply drivers. The mechanism whereby a dollar depreciation leads to an increase in the supply of dollar credit has been dubbed the “risk-taking channel” by Bruno and Shin (2015a, b). When there is potential for valuation mismatches on borrowers’ balance sheets arising from exchange rate changes, a weaker dollar flatters the balance sheet of dollar borrowers, whose liabilities fall relative to assets. From the standpoint of creditors, the stronger credit position of borrowers reduces tail risks in the credit portfolio and creates spare capacity for additional credit extension even with a fixed exposure limit through a value-at-risk (VaR) constraint or economic capital constraint.

In addition, we show that similar relationship between the exchange rate, the cross-currency basis and cross-border bank lending can also be found for the euro in the post-crisis sample. This is the case despite the fact that the triangular relationship is absent for other major currencies, which points to the unique role of international funding currencies in affecting leverage and risk-taking via fluctuations in exchange rate valuations.

Finally, we provide some direct empirical evidence using equity prices of internationally active banks to support the main mechanism of the paper that a stronger dollar negatively affects bank equities. In particular, we show that equity returns of internationally active banks have negative loadings on the strength of the broad dollar after controlling for benchmark equity market returns. Furthermore, bank equities in currency areas with more negative basis (indicating a dollar funding shortage) are more adversely affected by a broad dollar appreciation.

The bulk of the existing literature on CIP deviations focuses on the GFC and the

European debt crisis (see, for example: Baba, Packer, and Nagano (2008); Baba, McCauley and Ramaswamy (2009); Baba and Packer (2009); Coffey, Hrun, and Sarkar (2009); Goldberg, Kennedy, and Miu (2011); Grifolli and Ranaldo (2011); McGuire and von Peter (2012); Bottazzi, Luque, Pascoa, and Sundaresan (2012); and Ivashina, Scharfstein, and Stein (2015) ). More recently, several new papers studying CIP deviations in the post-crisis period have emerged. Du, Tepper and Verdelhan (Forthcoming) formally establish CIP arbitrage opportunities that cannot be explained away by credit risk or transaction costs, and present evidence that bank balance sheet costs and asymmetric monetary policy shocks are the main drivers of CIP deviations. Borio et al (2016) and Sushko et al (2016) construct empirical proxies for net hedging demand of different national banking systems and show that they are consistent with the cross-sectional variations in CIP deviations. Liao (2016) focuses on corporate issuance patterns and links strategic funding cost arbitrage across currencies with CIP deviations. Iida, Kimura and Sudo (2016) also examine the role of the recent divergence in the monetary policies of advanced economies and post-crisis regulatory reforms in driving CIP deviations. The key contribution of our paper is the unique perspective for linking the strength of the dollar to CIP deviations through the lens of bank leverage and risk-taking.

Our paper also sheds light on the large literature on intermediary- and margin-based asset pricing (for example, Bernanke and Gertler (1989), Holmstrom and Tirole (1997), Brunnermeier and Pedersen (2009), Garleanu and Pedersen (2011), He and Krishnamurthy (2012, 2013), Brunnermeier and Sannikov (2014), Adrian and Shin (2014) and Adrian, Etula and Muir (2014)). Furthermore, our paper is related to the model for exchange rate determination in the presence of financial frictions presented in Gabaix and Maggiori (2015), and the role of the dollar in bilateral exchange rates as shown in Verdelhan (Forthcoming).

The rest of the paper is organised as follows. Section 2 defines the cross-currency basis and provides an overview of the triangular relationship between the dollar exchange rate, the cross-currency basis and cross-border bank lending in dollars. Section 3 outlines a model to explain the triangular relationship via the shadow cost of bank leverage. Section

4 presents empirical evidence on the relationship between the US dollar and the cross-currency basis, and between the dollar and cross-border bank lending in dollars. Section 5 discusses the emergence of the euro as a global funding currency during the post-crisis period. Section 6 provides empirical support for the impact of dollar movements on bank equities. Section 7 concludes.

## 2 An overview of the issues

We define the  $n$ -year cross-currency basis of currency  $i$  vis-à-vis the US dollar, denoted  $x_{it,t+n}$ , as the deviation from the CIP condition between currency  $i$  and the dollar :

$$(1 + y_{t,t+n}^{\$})^n = (1 + y_{t,t+n}^i + x_{it,t+n})^n \frac{S_{it}}{F_{it,t+n}}, \quad (1)$$

where  $y_{t,t+n}^{\$}$  is the  $n$ -year dollar interest rate,  $y_{t,t+n}^i$  is the  $n$ -year interest rate in currency  $i$ ,  $S_{it}$  is the dollar spot exchange rate of currency  $i$  and  $F_{it,t+n}$  is the outright forward rate for currency  $i$ . Both forward and spot exchange rates are defined in terms of currency units  $i$  per dollar. Equivalently, in logs, the currency basis is equal to:

$$x_{it,t+n} = y_{t,t+n}^{\$} - (y_{t,t+n}^i - \rho_{it,t+n}), \quad (2)$$

where  $\rho_{it,t+n} \equiv \frac{1}{n}[\log(F_{it,t+n}) - \log(S_{it,t+n})]$  is the market-implied forward premium to hedge foreign currency  $i$  against the US dollar.

The cross-currency basis measures the difference between the direct dollar interest rate in the cash market,  $y_{t,t+n}^{\$}$ , and the implied dollar interest rate in the swap market,  $y_{t,t+n}^i - \rho_{it,t+n}$ . Consistent with market conventions, we focus on the cross-currency basis derived from benchmark interbank rates in the respective currency. The existence of a negative cross-currency basis implies CIP arbitrage opportunities for borrowing dollars in the dollar interbank market and lending dollars via the foreign interbanks market in combination with the FX swap markets. As shown in Du, Tepper and Verdelhan (2016), the arbitrage profits associated with the CIP trades cannot be explained away by trans-



action costs or credit risk. Apparently, banks do not arbitrage away these opportunities due to constraints on their balance sheet capacity. Non-regulated entities, such as hedge funds, obtain leverage from dealer banks, and thus the balance sheet constraints facing the banking market remains at the center of attention. Therefore, such CIP deviations give the shadow price of bank balance sheet capacities.

We use the aggregate dollar index and the bilateral exchange rate vis-à-vis the dollar to measure the strength of the dollar. In particular, we choose a widely-used aggregate dollar index, the Federal Reserve Board (FRB) broad dollar index, which is the trade-weighted average of the foreign exchange value of the dollar against the currencies of a broad group of major US trading partners. An increase in the broad dollar index indicates a dollar appreciation.<sup>1</sup>

We obtain data on cross-border bank lending flows from the BIS locational banking statistics (LBS). They capture outstanding claims and liabilities of banks located in BIS reporting countries, including intragroup positions between offices of the same banking group (BIS (2015)). The locational statistics are compiled following principles that are consistent with balance of payments statistics. The LBS also provide information on the currency composition of banks' balance sheets, which in turn allows to calculate quarterly flows that take exchange rate fluctuations into account. In addition, the estimated quarterly flows are statistically adjusted for breaks in series. Furthermore, the LBS feature breakdowns by borrowing counterparty sector and country. In the context of our empirical exercises, these additional breakdowns allow us to distinguish among borrowers from different sectors and countries.

Figure 4 presents an overview the triangular relationship between the dollar, the cross-currency basis and dollar-denominated cross-border bank lending. The red line shows quarterly changes in the broad dollar index, the blue line tracks the first principal component of quarterly changes in the five-year cross-currency basis for G10 currencies,<sup>2</sup> and the bars reflect growth rates in dollar-denominated cross-border bank lending.

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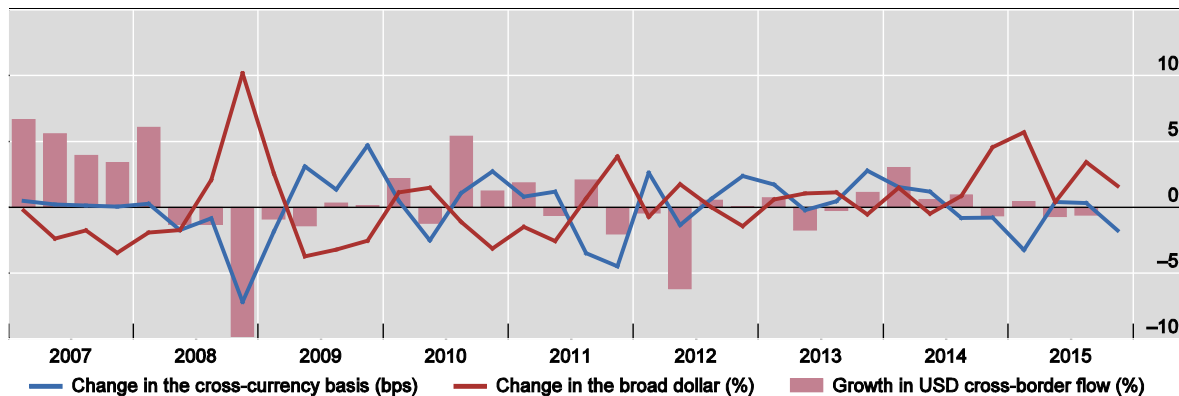
<sup>1</sup>In results that are available upon request, we obtain very similar empirical findings by using other alternative dollar indices, such as the BIS nominal effective exchange rate index or a simple average of all dollar exchange rates for our sample currencies.

<sup>2</sup>We perform a principal component analysis on quarterly changes in the 5-year cross-currency basis

Changes in the broad dollar index are -75% correlated with changes in the first principal component of the cross-currency basis, and -56% correlated with the growth rates of dollar-denominated cross-border lending. Therefore, a stronger dollar is associated with greater CIP deviations (or a higher price for balance sheet capacity) and with lower growth rates in dollar-denominated cross-border bank lending.

Cross-currency basis, US dollar index and cross-border lending

Figure 4



The bars show percentage growth rates of total cross-border lending denominated in US dollars. The red line plots quarterly changes in the broad US dollar index in percentage points, while the blue line plots the first principal component of quarterly changes in the 5-year cross-currency basis for G10 currencies expressed in basis points.

Sources: Bloomberg; Board of Governors of the Federal Reserve System; BIS Locational Banking Statistics; BIS calculations.

### 3 Model

We sketch a model of a bank located outside the United States, but which has significant US dollar business. The bank's dollar business has two parts. The first is lending in dollars to borrowers, such as emerging market corporates, which have retained some currency mismatch on their balance sheets. For concreteness, consider the dollar borrowers to be emerging market property developers who borrow dollars in order to finance domestic real estate developments. The second element of the bank's dollar business is to provide dollar funding in the FX swap market. The bank lends dollars in the FX swap market in exchange for domestic currency. At maturity, the bank receives dollars in exchange for the domestic currency.

The bank is risk neutral and is a price taker in the dollar loan market as well as in the AUD, CAD, CHF, DKK, EUR, GBP, JPY, NOK, NZD and SEK and find that the first principal component explains 53% of total variations.

the FX swap market. The risk neutral bank maximises profits subject to VaR constraint, to be described below.

We adopt the following notation. Denote by  $a_1$  the dollar amount lent to emerging market corporates and denote by  $a_2$  the dollar face value of FX swap claims. The bank does not hold any other asset. The balance sheet identity of the bank is:

$$a_1 + a_2 = e + d \quad (3)$$

where  $e$  is the bank's book equity in dollar terms and  $d$  is the dollar value of debt financing. Assume for simplicity that the dollar funding  $d$  can be raised at the riskless dollar rate and that the riskless dollar rate is zero. The profit  $r$  of the bank is then given by:

$$r = a_1 r_1 + a_2 r_2 \quad (4)$$

where  $r_1$  is the gross return on dollar loans to corporates and  $r_2$  is the gross return to the bank in the FX swap.

The bank maximises expected profits subject to a VaR constraint. The bank's optimisation problem can be written as:

$$\max_{a_1, a_2} E(r) \quad \text{subject to} \quad \text{VaR} \leq e$$

where  $E(r)$  is the expected profit of the bank. We limit attention to the choice of  $a_1$  and  $a_2$  only, as the bank's debt funding  $d$  follows from the balance sheet identity (3).

Assume that the VaR is a multiple  $\alpha$  of the standard deviation of portfolio return  $\sigma_r$ , so that  $\text{VaR} = \alpha \sigma_r$ . The constraint is:

$$\alpha \sigma_r \leq e \quad (5)$$

We transform the constraint by squaring both sides and dividing by  $\alpha^2$  to give:

$$\sigma_r^2 \leq \left(\frac{e}{\alpha}\right)^2$$

Then, write the Lagrangean as:

$$\begin{aligned}\mathcal{L} &= E(r) - \lambda \left( \sigma_r^2 - \left( \frac{e}{\alpha} \right)^2 \right) \\ &= E(r) - \lambda \sigma_r^2 + \lambda \left( \frac{e}{\alpha} \right)^2\end{aligned}\tag{6}$$

where  $E(r)$  is the expected return of the bank's asset portfolio,  $\lambda$  is the Lagrange multiplier of the VaR constraint and  $\sigma_r^2$  is the variance of the bank's profit.

The third term in the Lagrangean  $\mathcal{L}$  in (6) does not depend on  $a_1$  or  $a_2$ , and so will drop out when the first-order condition is taken. The first two terms of the Lagrangean is a quadratic expression. We use the shorthand:

$$\mu_1 = E(r_1), \quad \mu_2 = E(r_2),$$

and denote the covariance matrix of returns as:

$$\Sigma = \begin{bmatrix} \sigma_1^2 & \sigma_{12} \\ \sigma_{12} & \sigma_2^2 \end{bmatrix}$$

We can interpret  $\mu_2 - 1$  as the size of the CIP deviation in the absolute value (or the negative of the cross-currency basis). It is the expected payoff from lending dollars in the FX swap market. The investor faces mark-to-market risk, and so there is some risk in the trade.

The first two terms of the Lagrangean can be written as the quadratic form:

$$\begin{bmatrix} a_1 & a_2 \end{bmatrix} \begin{bmatrix} \mu_1 \\ \mu_2 \end{bmatrix} - \lambda \begin{bmatrix} a_1 & a_2 \end{bmatrix} \begin{bmatrix} \sigma_1^2 & \sigma_{12} \\ \sigma_{12} & \sigma_2^2 \end{bmatrix} \begin{bmatrix} a_1 \\ a_2 \end{bmatrix}.$$

The first-order condition is:

$$\begin{bmatrix} \mu_1 \\ \mu_2 \end{bmatrix} = 2\lambda \Sigma \begin{bmatrix} a_1 \\ a_2 \end{bmatrix},$$

Solving for  $a_1$  and  $a_2$ , the optimal portfolio is:

$$\begin{bmatrix} a_1 \\ a_2 \end{bmatrix} = \frac{1}{2\lambda} \Sigma^{-1} \begin{bmatrix} \mu_1 \\ \mu_2 \end{bmatrix}. \quad (7)$$

Meanwhile, the variance of profit is given by the quadratic form:

$$\sigma_r^2 = a' \Sigma a$$

where  $a'$  is the transpose of  $a$ . From (7) we have

$$\begin{aligned} \sigma_r^2 &= a' \Sigma a \\ &= \frac{1}{4\lambda^2} \mu' \Sigma^{-1} \mu \end{aligned}$$

Finally, from the VaR constraint, we have  $\sigma_r^2 = \left(\frac{e}{\alpha}\right)^2$ . Thus,

$$\frac{1}{4\lambda^2} \mu' \Sigma^{-1} \mu = \left(\frac{e}{\alpha}\right)^2$$

The Lagrange multiplier of the transformed constraint is:

$$\lambda = \frac{\alpha}{2e} \sqrt{\mu' \Sigma^{-1} \mu} \quad (8)$$

The expression  $\sqrt{\mu' \Sigma^{-1} \mu}$  is the analogue of the Sharpe ratio  $\mu/\sigma$ , generalised to the context of two risky assets. The Lagrange multiplier is the shadow value of balance sheet capacity for the bank.

Substituting (8) into the first-order condition (7) allows us to solve for the optimal portfolio of the bank:

$$\begin{bmatrix} a_1 \\ a_2 \end{bmatrix} = \frac{e}{\alpha} \cdot \frac{1}{\sqrt{\mu' \Sigma^{-1} \mu}} \Sigma^{-1} \begin{bmatrix} \mu_1 \\ \mu_2 \end{bmatrix} \quad (9)$$

The optimal portfolio in (9) is proportional to equity  $e$ . When the equity of the investor doubles, the size of its positions also doubles. In this sense, the portfolio holdings of the risky assets satisfy a “constant returns to scale” property. Two implications flow from

this property. The first is that when the bank suffers losses, it scales back its portfolio in proportion to the erosion of its equity.

Second, our model has an aggregation property for the banking sector as a whole in which the aggregate lending and outstanding amounts of the FX swap have the same expression as in (9), but in which we have equity for the banking sector as a whole. Specifically, if  $e_k$  is the equity of bank  $k$ , let:

$$E = \sum_{k \in B} e_k \quad (10)$$

be the aggregate equity of the banking sector as a whole, where  $B$  is the set of banks. Denote by  $A_1$  and  $A_2$  the aggregate values of  $a_1$  and  $a_2$  across the banking sector. Then, from (9), the assets of the banking sector as a whole are given by:

$$\begin{bmatrix} A_1 \\ A_2 \end{bmatrix} = \frac{E}{\alpha} \cdot \frac{1}{\sqrt{\mu' \Sigma^{-1} \mu}} \Sigma^{-1} \begin{bmatrix} \mu_1 \\ \mu_2 \end{bmatrix} \quad (11)$$

It remains to solve for  $\mu_1$  and  $\mu_2$  from the market-clearing condition. Denote by  $X_1(\mu_1)$  the demand for dollar loans by EME corporates, which is a decreasing function of  $\mu_1$ . Denote by  $X_2(\mu_2)$  the demand for dollars in the FX swap market, decreasing in  $\mu_2$ . Recall that we interpret  $\mu_2 - 1$  as the (negative of the) cross-currency basis. The downward sloping demand for loans and dollar funding via the FX swap market is consistent with models with preferred habitat, as in Vayanos and Vila (2009) and Greenwood and Vayanos (2014). From (11), the market clearing condition can be written:

$$\begin{bmatrix} X_1(\mu_1) \\ X_2(\mu_2) \end{bmatrix} = \frac{E}{\alpha} \cdot \frac{1}{\sqrt{\mu' \Sigma^{-1} \mu}} \Sigma^{-1} \begin{bmatrix} \mu_1 \\ \mu_2 \end{bmatrix} \quad (12)$$

We now consider the comparative statics of an appreciation of the US dollar. The appreciating dollar entails losses for the corporate borrowers who have borrowed dollars to finance local currency assets. As a consequence, the aggregate value of banks' loans also suffer some losses, resulting in a lower level of the aggregate equity of the banking

sector, from  $E$  to  $E'$  where  $E' < E$ . To restore market clearing, both  $\mu_1$  and  $\mu_2$  increase. For us, it is the increase in  $\mu_2$  which is of interest, as it represents a widening of the cross-currency basis. We thus have:

**Proposition.** *An appreciation of the dollar entails a widening of the cross-currency basis and a contraction of bank lending in dollars.*

In terms of our expression for the Lagrange multiplier of the VaR constraint (8), the shadow value of bank balance sheet capacity increases for two reasons. The first is that the price of credit increases and raises  $\mu$ . Second, the erosion of equity means that the denominator declines. The cross-currency basis fluctuates with the shadow value of balance sheet capacity, and the fluctuation is higher for banks that are more leveraged. Based on these features of our model, we now turn to our empirical investigation.

## 4 Empirical investigation

### 4.1 Summary Statistics

Our empirical investigation of the dollar's role is based on its position vis-a-vis the ten most liquid currencies in the world (other than the dollar itself). We consider all currencies with a total daily turnover exceeding \$2 trillion as of April 2013. In particular, the currencies we focus on are the Australian dollar, the Canadian dollar, the Swiss franc, the Danish krone, the euro, the British pound, the Japanese yen, the Norwegian krone, the New Zealand dollar, and the Swedish krona (Bank of International Settlements (2013)). All raw data are obtained from Bloomberg and our sample period ranges from 1 January 2007 to 2 February 2016.

Table 1 provides some descriptive statistics for the three-month and five-year cross-currency basis for our sample of 10 currencies vis-à-vis the US dollar. The cross-currency basis here is defined as the difference between the US Libor and the implied dollar interest rate by swapping foreign currency into dollars. On average, the cross-currency basis is negative in our sample, which suggests that the dollar interest rate in the cash market

is lower than the implied dollar interest rate in the swap market, and banks can borrow dollars in the cash market and lend dollars in the swap market to make arbitrage profits. The average three-month basis is positive for the Australian and the New Zealand dollar, but negative for all other currencies, ranging from -11 to -62 basis points. The average five-year basis is positive for the Australian, the New Zealand, and the Canadian dollar, and negative for all other currencies.

Summary statistics for the cross-currency basis			Table 1	
Currency	3-month basis		5-year basis	
	mean	sd	mean	sd
AUD	0.02	(0.15)	0.20	(0.11)
CAD	-0.11	(0.13)	0.07	(0.08)
CHF	-0.23	(0.23)	-0.30	(0.17)
DKK	-0.62	(0.37)	-0.39	(0.22)
EUR	-0.30	(0.29)	-0.23	(0.15)
GBP	-0.19	(0.25)	-0.10	(0.13)
JPY	-0.20	(0.18)	-0.44	(0.28)
NOK	-0.29	(0.27)	-0.15	(0.1)
NZD	0.09	(0.12)	0.24	(0.14)
SEK	-0.24	(0.22)	-0.04	(0.08)
Total	-0.21	(0.3)	-0.11	(0.27)

This table provides summary statistics for the 3-month and the 5-year cross-currency bases for the period between 1 January 2007 and 2 February 2016. Means and standard deviations are expressed in percentage points.

Source: Bloomberg; BIS calculations.

## 4.2 The dollar spot rate and the cross-currency basis

In our baseline specification, we regress changes in the cross-currency basis on contemporaneous changes in the aggregate dollar index and on changes in the bilateral dollar exchange rates.<sup>3</sup> To check the robustness of our results, we control for other potential drivers. Our benchmark regression specification is given by:

$$\Delta x_{it} = \alpha_i + \beta \Delta Dollar_t + \gamma \Delta BER_{it} + \delta \mathbf{CONTR}_{it} + \varepsilon_{it} \quad (13)$$

<sup>3</sup>We consider daily changes in case of the three-month basis, and quarterly changes in case of the five-year basis.



Let  $\alpha_i$  be a currency fixed effect and  $\Delta x_{it}$  stand for changes in the cross-currency basis of currency  $i$  vis-à-vis the US dollar between  $t$  and  $t - 1$ . The variable  $\Delta Dollar_t$  denotes changes in the Federal Reserve Board (FRB) US trade-weighted broad dollar index and  $\Delta BER_{it}$  indicates changes in the bilateral exchange rate for currency  $i$  vis-à-vis the dollar. Positive values of  $\Delta Dollar_t$  and  $\Delta BER_{it}$ , respectively, both denote a dollar appreciation. Finally,  $\mathbf{CONTR}_{it}$  is a vector of control variables.

In terms of the vector of controls, first, we follow Bruno and Shin (2015a) and include the log level of the CBOE implied volatility of S&P 500 index options (VIX),  $\ln VIX_t$ , and the log changes in the VIX,  $\Delta \ln VIX_t$ , in order to track both level and changes in global risk sentiment. Second, we control for changes in the implied volatility of FX options,  $\Delta \ln Vol_{it}$ , and for changes in the 25-delta FX option risk reversal,  $\Delta RR_{it}$ . These two controls capture changes in the risk-neutral volatility of FX movements and the cost of hedging against large depreciations, respectively. Third, we add changes in the spread of the 10-year foreign currency government bond yield over the 10-year US Treasury yield,  $\Delta(y_{it} - y_t^{US})$ , and we add changes in the foreign and US Treasury (10-year over two-year) term spread differential,  $\Delta(ts_{it} - ts_t^{US})$ . These controls are in part driven by divergent monetary policy stances between foreign countries and the US.

#### 4.2.1 Daily Regressions

Table 2 shows our regression results for the daily changes in the three-month cross-currency basis. The coefficient estimate on  $\Delta Dollar_t$  is negative and significant across all specifications, suggesting that a dollar appreciation is associated with a more negative cross-currency basis, and, hence, greater CIP deviations. In terms of the magnitude, the coefficient estimate on  $\Delta Dollar_t$  in Column 1 (excluding additional control variables) implies that a one percentage point appreciation of the US dollar is associated with a 2.6 basis point decrease in the cross-currency basis, which corresponds to a 2.6 widening of CIP deviations. After including all controls, a one percentage point appreciation of the dollar is associated with a 2.1 basis point decrease in the cross-currency basis in Column 6. Given that the standard deviation for daily changes in the cross-currency basis is about

7 basis points, the impact of the broad dollar index on the basis is not only statistically significant but also economically meaningful. These results are especially remarkable, because they draw on *daily* changes in the cross-currency basis and spot exchange rates, which are notoriously noisy.

Regression results of the 3-month cross-currency basis (daily frequency)						Table 2
	(1)	(2)	(3)	(4)	(5)	(6)
$\Delta Dollar_t$	-2.641*** (0.682)		-2.915*** (0.786)	-2.908*** (0.793)	-2.307*** (0.731)	-2.080*** (0.634)
$\Delta BER_{it}$		-0.440* (0.236)	0.228 (0.233)	0.284 (0.238)	0.238 (0.222)	0.239 (0.194)
$\ln VIX_t$				0.000596 (0.00489)	0.00135 (0.00477)	0.00130 (0.00417)
$\Delta \ln VIX_t$				-0.0183 (0.0231)	0.00465 (0.0237)	-0.0158 (0.0191)
$\Delta \ln Vol_{it}$					-0.263*** (0.0613)	-0.221*** (0.0519)
$\Delta RRR_{it}$					0.0112* (0.00587)	0.0110 (0.00748)
$\Delta(y_{it} - y_t^{US})$						0.106*** (0.0367)
$\Delta(ts_{it} - ts_t^{US})$						-0.140*** (0.0492)
Observations	21,555	21,949	21,555	20,896	20,495	18,092
R-squared	0.016	0.002	0.016	0.016	0.026	0.038

This table shows regression results of daily changes in the 3-month Libor cross-currency basis on changes in spot exchange rates and other controls for the period between 1 January 2007 and 2 February 2016. The dependent variable is the daily change in the 3-month Libor cross-currency basis in all specifications. The independent variables are:  $\Delta Dollar_t$ , daily change in the FRB broad dollar index ( $\Delta Dollar_t > 0$  indicates dollar appreciation);  $\Delta BER_{it}$ , daily change in the bilateral spot exchange rate of the local currency against the dollar ( $\Delta BER_{it} > 0$  indicates dollar appreciation);  $\ln VIX_t$ , log of VIX,  $\Delta \ln VIX_t$ , daily change in the log of VIX,  $\Delta \ln Vol_{it}$ , daily change in the log of implied volatility on 3-month at-the-money currency options;  $\Delta RRR_{it}$ , daily change in the 25-delta risk reversal;  $\Delta(y_{it} - y_t^{US})$ , daily change in the spread of the 10-year foreign Treasury yield over the 10-year U.S. Treasury yield; and  $\Delta(ts_{it} - ts_t^{US})$ , daily change in the difference between the foreign and the U.S. Treasury term spreads (10-year over 2-year). Currency fixed effects are included in all specifications. Robust, two-way clustered standard errors by currency and time are shown in the parentheses. \*\*\*p<0.01, \*\*p<0.05, \*p<0.1.

Sources: Bloomberg; BIS calculations.

Furthermore, we note that the bilateral exchange rate enters negatively with marginal significance in Column 2, when the broad dollar index is not included in the regression. However, in all other specifications, once the aggregate dollar index is controlled for, the coefficient on the change in the bilateral dollar exchange rate is small in absolute size and turns insignificant. This result points to the role of the dollar as a significant global driver

of variations in the cross-currency basis. The insignificance of the bilateral exchange rate suggests that changes to currency hedging demand due to idiosyncratic fluctuations of the domestic currency against the dollar do not significantly drive cross-currency basis variations.

In terms of control variables, neither the level nor changes in the VIX do enter significantly once  $\Delta Dollar_t$  is part of our regression specification. Changes in the implied volatility of currency options are negatively correlated with changes in the cross-currency basis. This is intuitive in the context of our model, as higher currency volatility makes the VaR constraint more binding and thus reduces the risk-bearing capacity of the financial intermediary. In addition, changes in FX option risk reversal are also negatively correlated with changes in the cross-currency basis, suggesting that an increase in the skewness of the distribution towards a foreign currency depreciation (or dollar appreciation) also contributes to higher CIP deviations. Finally, the (foreign over US Treasury) yield differential enters with a significantly positive sign, which is consistent findings of Du, Tepper and Verdelhan (2016) in that the nominal interest rate differential acts as a driver of the basis. However, the difference in the slope of the government bond yield curves between foreign countries and the US enters with the opposite sign when compared with the coefficient on the interest rate margin in Iida, Kimura and Sudo (2016).

#### 4.2.2 Quarterly Regressions

The significantly negative correlation between changes in the cross-currency basis and the strength of the dollar is not restricted to short-dated contracts at the daily frequency. We obtain similar results for the longer-term cross-currency basis at the quarterly frequency. Table 3 presents our regression results for the quarterly changes in the five-year cross-currency basis on contemporaneous changes in the aggregate dollar index and other control variables. Again, the coefficient on  $\Delta Dollar_t$  is significantly negative in all specifications ranging from -1 to -1.4. Thus, a one standard deviation increase of quarterly changes in the broad dollar index (3%) corresponds to a 3-4 basis point reduction in the five-year cross-currency basis. In addition,  $\Delta Dollar_t$  as a standalone variable already

explains 19% of time series variations in the changes of the five-year basis. Similar to the daily regressions, the level and changes of the VIX index do not enter significantly. Most of the other control variables that are significant in our daily regressions lose their significance in quarterly regressions, such as changes in FX volatility, risk reversal, and the difference in the slope of Treasury yields,  $\Delta(ts_{it} - ts_t^{US})$ . The Treasury yield spread  $\Delta(y_{it} - y_t^{US})$ , however, remains significant, but with the opposite sign compared with the daily regression.

Regression results of the 5-year cross-currency basis (quarterly frequency)					Table 3	
	(1)	(2)	(3)	(4)	(5)	(6)
$\Delta Dollar_t$	-1.399***		-1.293***	-1.071***	-1.078***	-0.965**
	(0.303)		(0.437)	(0.370)	(0.404)	(0.404)
$\Delta BER_{it}$		-0.562***	-0.0738	-0.0885	-0.0398	-0.409**
		(0.126)	(0.137)	(0.126)	(0.148)	(0.202)
$\ln VIX_t$				-0.0338	-0.0326	-0.0383*
				(0.0250)	(0.0248)	(0.0223)
$\Delta \ln VIX_t$				-0.0472**	-0.0398	-0.0108
				(0.0238)	(0.0279)	(0.0342)
$\Delta \ln Vol_{it}$					-0.0188	0.0144
					(0.0436)	(0.0333)
$\Delta RR_{it}$					-0.00327	-0.00450
					(0.00987)	(0.00937)
$\Delta(y_{it} - y_t^{US})$						-0.0929***
						(0.0236)
$\Delta(ts_{it} - ts_t^{US})$						0.0152
						(0.0151)
Observations	360	360	360	360	358	316
R-squared	0.191	0.117	0.191	0.208	0.209	0.278

This table shows regression results of running quarterly changes in the 5-year Libor cross-currency basis on changes in spot exchange rates and other controls for the period between 1 January 2007 and 2 February 2016. The dependent variable is the quarterly change in the 5-year Libor cross-currency basis in all specifications. The independent variables are:  $\Delta Dollar_t$ , quarterly change in the FRB broad dollar index ( $\Delta Dollar_t > 0$  indicates dollar appreciation);  $\Delta BER_t$ , quarterly change in the bilateral spot exchange rate of the local currency against the dollar ( $\Delta BER_t > 0$  indicates dollar appreciation);  $\ln VIX_t$ , log of VIX,  $\Delta \ln VIX_t$ , quarterly change in the log of VIX,  $\Delta \ln Vol_{it}$ , quarterly change in the log of implied volatility on 3-month at-the-money currency options;  $\Delta RR_{it}$ , quarterly change in the 25-delta risk reversal;  $\Delta(y_{it} - y_t^{US})$ , quarterly change in the spread of 10-year foreign Treasury yield over the 10-year U.S. Treasury yield; and  $\Delta(ts_{it} - ts_t^{US})$ , quarterly change in the difference between the foreign and U.S. Treasury term spreads (10-year over 2-year). Currency fixed effects are included in all specifications. Robust, two-way clustered standard errors by currency and time are shown in the parentheses. \*\*\*p<0.01, \*\*p<0.05, \*p<0.1.

Sources: Bloomberg; BIS calculations.

In unreported regressions, we find that these results are not driven by the GFC. We repeat all daily and quarterly regression specifications for the subsample starting in Jan-

uary 2009 and obtain negative coefficient estimates on  $\Delta Dollar_t$  of similar magnitude at even higher levels of statistical significance. In sum, we find that when the dollar appreciates, the cross-currency basis becomes more negative, which entails larger arbitrage opportunities of borrowing dollars in the cash market and lending dollars via the FX swap market.

### 4.3 The dollar beta and the cross-currency basis

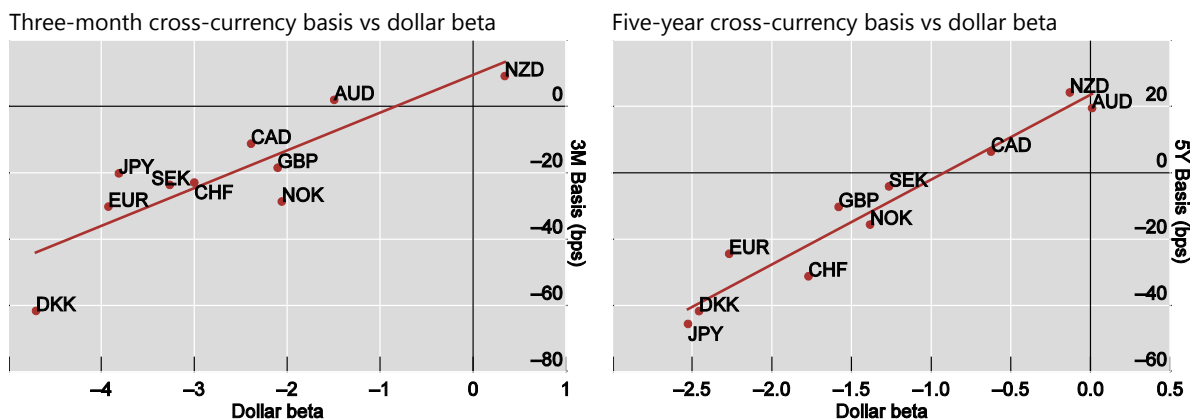
In addition to the strong contemporaneous correlation between changes in the cross-currency basis and changes in the broad dollar index, we also find that differential loadings on the dollar index help to explain the magnitude of the basis in the cross section. Our results suggest that the strength of the dollar likely acts as a risk factor in the global investor's pricing kernel.

We first estimate the currency-specific loadings on the broad dollar index,  $\beta_i$ , from the following regression:

$$\Delta x_{it} = \alpha_i + \beta_i \Delta Dollar_t + \epsilon_{it} \quad (14)$$

We obtain the dollar beta using both daily regressions for the three-month basis and quarterly regressions for the five-year basis. Figure 5 plots the average basis against the corresponding dollar beta. The dollar beta for the three-month basis is negative for all currencies except for the Australian dollar. The dollar beta for the five-year basis is close to zero for the Australian dollar and the New Zealand dollar, and negative for all other currencies. We can see a strong positive relationship between the average basis and the dollar beta with a bivariate correlation equal to 85% for the three-month basis and 97% for the five-year basis.

These findings suggest that the aggregate dollar exchange rate is a potential risk factor that is priced in the cross section of the cross-currency basis. To see this, we note that an arbitrageur's expected return on the CIP trade, which consists of borrowing the dollar and investing in the foreign currency, is equal to the negative of the basis. However, the return on the strategy is certain only if the arbitrageur holds the trade until maturity. During the life of the trade, the arbitrage strategy is subject to mark-to-market risks,



The vertical axis of the LHP shows the average three-month cross-currency basis expressed in basis points, while the horizontal axis indicates the regression beta of running daily regression for changes in the three-month cross-currency basis on changes in the broad US dollar index. The vertical axis of the RHP shows the average five-year cross-currency basis expressed in basis points, while the horizontal axis indicates the regression beta of running quarterly regression for changes in the five-year cross-currency basis on changes in the broad US dollar index.

Sources: Board of Governors of the Federal Reserve System; Bloomberg; BIS calculations.

which are in turn correlated with the strength of the dollar. If the dollar is a global risk factor in the arbitrageur's pricing kernel, higher systematic loadings on the dollar factor (a more negative dollar beta) require higher expected returns, or a more negative cross-currency basis.

#### 4.4 Event Study following the 2016 U.S. Presidential Election

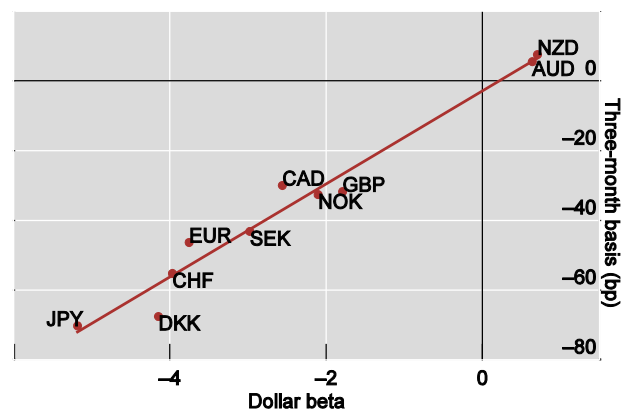
Our main sample ended before the U.S. presidential election on November 8, 2016. The appreciation of the dollar after the election presents an opportunity to put the main predictions to an out-of-sample test. As shown in Table 4, the broad dollar index of the Federal Reserve rose by 3.9% between November 8 and November 29, 2016. During the same period, the cross-currency basis widened for all G10 currencies. The largest movement was for the yen, with the basis widening from -70.3 basis points to -90.5 basis points. For the post-election period, the “dollar beta” is defined as the ratio of the change in the cross-currency basis (in basis points) over changes in the broad dollar index (in percentage points). In line with the findings in the previous section, the dollar beta is highly correlated with the basis itself. The correlation coefficient is 98%.

The dollar and cross-currency basis since the US election

Table 4

Changes in the broad dollar index and three-month cross-currency basis since the US election

Currency	8/11/ 2016	29/11/ 2016	change	dollar beta <sup>1</sup>
Broad dollar	122.8	127.6	4.8 (3.9%)	
AUD	5.5	8.0	2.5 bps	0.64
CAD	-30.0	-40.0	-10.0 bps	-2.56
CHF	-55.3	-70.8	-15.5 bps	-3.97
DKK	-67.5	-83.7	-16.2 bps	-4.14
EUR	-46.4	-61.0	-14.7 bps	-3.75
GBP	-31.8	-38.8	-7.0 bps	-1.79
JPY	-70.3	-90.5	-20.3 bps	-5.18
NZD	7.5	10.3	2.8 bps	0.70
NOK	-32.6	-40.8	-8.2 bps	-2.10
SEK	-43.2	-54.9	-11.6 bps	-2.98

Cross-currency basis vs dollar beta<sup>2</sup>

<sup>1</sup> The dollar beta is calculated as the ratio of changes in the three-month cross-currency basis over changes in the broad US dollar index between 8 November and 29 November 2016.

<sup>2</sup> The vertical axis shows the three-month cross-currency basis expressed in basis points on 8 November 2016, while the horizontal axis indicates the dollar beta.

Sources: Board of Governors of the Federal Reserve System; Bloomberg; BIS calculations.

## 4.5 The dollar spot rate and cross-border bank lending flows

After establishing the negative relationship between the strength of the US dollar and the cross-currency basis, we now turn to the relationship between the dollar and bank flows. We examine the impact of fluctuations in the dollar spot exchange rate on dollar-denominated cross-border bank lending flows using two empirical frameworks. First, we run panel regressions while using borrowing-country fixed effects in order to control for heterogeneity on the demand side of cross-border credit. Next, we explore the dynamic interdependencies between the main variables of interest, while exploiting the richness of the counterparty country dimensions of our dataset.

### 4.5.1 Panel regressions

In our benchmark panel regression specification, we regress the quarterly growth rate of dollar denominated cross-border bank lending to a given counterparty country on quarterly changes in the broad dollar index and on the bilateral exchange rate of the dollar vis-à-vis the local currency of the respective borrowing country. We control for

heterogeneity on the demand side of cross-border credit by including borrowing-country fixed effects. Our benchmark specification is given by:

$$\Delta xbl_{it} = \alpha_i + \beta \Delta Dollar_t + \gamma \Delta BER_{it} + \varepsilon_{it}, \quad (15)$$

where  $\Delta xbl_{it}$  is the quarterly growth rate of dollar-denominated cross-border bank lending to borrowers in country  $i$  between  $t$  and  $t - 1$ . Let  $\alpha_i$  be a borrowing-country fixed effect. As before, the variable  $\Delta Dollar_t$  denotes changes in the broad dollar index, and variable  $\Delta BER_{it}$  indicates changes in the bilateral exchange rate for currency  $i$  vis-à-vis the dollar. Positive  $\Delta Dollar_t$  and  $\Delta BER_{it}$  imply a dollar appreciation.

Table 5 summarises our results while distinguishing between different time periods and counterparty sectors. The results in Panel A are estimated using data from Q1 2002 to Q3 2015, while those in Panel B are based on the time window between Q1 2007 to Q3 2015, which overlaps with the window used for obtaining the spot-basis results in Section 4.2. When entering the regression as a standalone variable, the estimated coefficient on the dollar index is negative and statistically significant (Column 1). The same is true for the coefficient on the bilateral dollar exchange rate (Column 2). Moreover, both of the above variables remain negative and strongly statistically significant even when jointly entering the regression (Column 3). Our results therefore show that the dollar index has explanatory power over and above the bilateral dollar exchange rate for cross-border bank lending. This finding strongly supports our previous hypothesis that the dollar is a global risk factor, which affects the risk-taking capacity of banks, and, ultimately, the supply of cross-border bank lending. The above results hold not only for lending to all sectors but also for distinct subsamples of bank (Columns 4-6) and non-bank lending (Columns 7-9).



Bilateral Panel Regressions: US dollar-denominated cross-border lending, by borrowing sector											Table 5
All sectors			Banks			Non-banks					
Panel A: Q1/2002 – Q3/2015			(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
$\Delta Dollar_t$	-0.591*** (0.055)	-0.490*** (0.066)	-0.752*** (0.103)	-0.614*** (0.119)	-0.401*** (0.058)	-0.338*** (0.068)					
$\Delta BER_t$	-0.209*** (0.043)	-0.107*** (0.041)	-0.275*** (0.062)	-0.146** (0.062)	-0.137*** (0.039)	-0.066* (0.040)					
Constant	5.068 (3.272)	5.237 (3.256)	-4.308 (2.741)	-4.866* (2.538)	3.338 (3.131)	3.443 (3.129)					
Observations	6,215	6,215	6,207	6,207	6,211	6,211					
R <sup>2</sup>	0.048	0.040	0.030	0.026	0.035	0.035					
Panel B: Q1/2007 – Q3/2015											
$\Delta Dollar_t$	-0.636*** (0.062)	-0.486*** (0.073)	-0.821*** (0.114)	-0.603*** (0.136)	-0.481*** (0.065)	-0.384*** (0.076)					
$\Delta BER_t$	-0.295*** (0.043)	-0.155*** (0.041)	-0.398*** (0.064)	-0.224*** (0.070)	-0.210*** (0.040)	-0.099** (0.041)					
Constant	-4.178* (2.264)	-4.649** (2.163)	-4.257 (2.776)	-4.866* (2.552)	-3.883 (2.870)	-3.954 (2.856)					
Observations	3,975	3,975	3,974	3,974	3,975	3,975					
R <sup>2</sup>	0.076	0.068	0.049	0.046	0.053	0.055					
This table shows results from panel regressions of borrowing-country specific quarterly growth rates in US dollar-denominated cross-border bank lending (loans and debt securities) on quarterly changes in the broad US dollar index and the bilateral exchange rate of the currency of the respective borrowing country vis-à-vis the US dollar. The results are obtained using quarterly data (from Q1/2002 to Q3/2015 for Panel A and from Q1/2007 to Q3/2015 for Panel B) for 115 borrowing countries. Columns 1-3 contain results for borrowers from all sectors; columns 4-6 contain results for bank borrowers; columns 7-9 contain results for non-bank borrowers. Country-level fixed effects are included, but not reported. Standard errors in parentheses are clustered by destination country.											
*** p <0.01, ** p<0.05, * p<0.1.											
Sources: BIS Locational Banking Statistics; BIS bilateral exchange rates; Board of Governors of the Federal Reserve System; BIS calculations.											

The magnitude of the estimated impacts is considerable. The highly significant coefficient on the US dollar index is -0.49, which implies that a one percentage point (aggregate) appreciation of the dollar is associated with a 49 basis point decline in the growth rate dollar-denominated cross-border bank lending. The estimated coefficient for lending to banks is even larger in absolute value (-0.61), implying that the decline is even stronger for interbank lending. This finding is in line with the prediction of the “double-decker” model of international banking proposed by Bruno and Shin (2015b).

#### 4.5.2 Structural Panel Vector Autoregressions (SPVARs)

In order to explore the dynamic interdependencies between the main variables of interest, while taking full advantage of the cross-sectional richness of the data, we estimate structural panel VARs. More concretely, we consider the following structural panel VAR:

$$\mathbf{B}\mathbf{y}_{it} = \mathbf{f}_i + \mathbf{A}(\mathbf{L})\mathbf{y}_{i,t-1} + \mathbf{u}_{it}, \quad (16)$$

where  $\mathbf{y}_{it}$  is an  $m$ -dimensional vector of our stacked endogenous variables,  $\mathbf{f}_i$  is a diagonal matrix of country-specific intercepts,  $\mathbf{A}(\mathbf{L}) = \sum_{j=0}^p A_j L^j$  is a polynomial of lagged coefficients  $A_j$  is a matrix of lagged coefficients,  $\mathbf{L}^j$  is the lag operator,  $\mathbf{B}$  is a matrix of contemporaneous coefficients, and  $\mathbf{u}_{it}$  is a vector of stacked structural innovations with a diagonal covariance matrix described by  $u_t \sim N(0, \mathbf{1}_m)$  and  $E(\mathbf{u}_t \mathbf{u}_s') = \mathbf{0}_m$  all  $s \neq t$ .

In our baseline specification, we set:

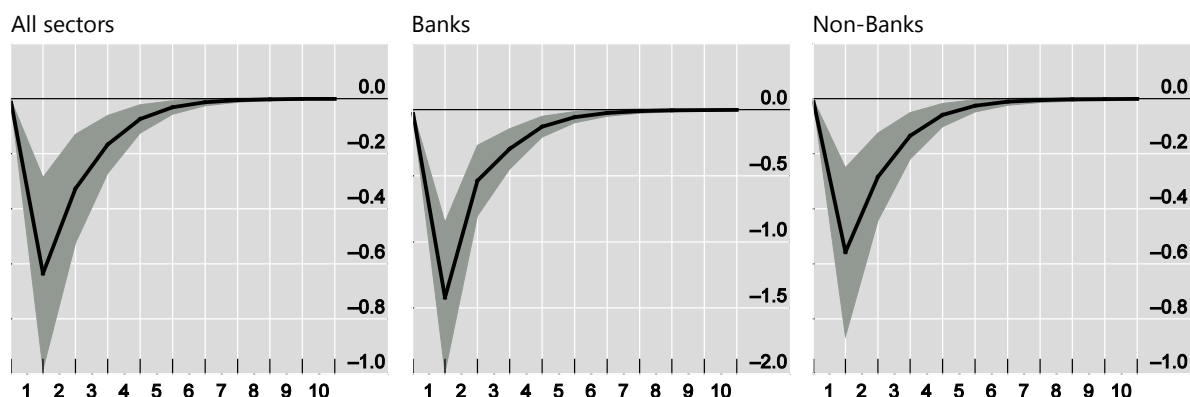
$$\mathbf{y}_{it} = [\Delta ir_t, \Delta xbl_{it}, \ln VIX_t, \Delta BER_{it}]', \quad (17)$$

where  $\Delta ir_t$  is the quarterly change in the US dollar policy rate,  $\Delta xbl_{it}$  is the quarterly growth rate in dollar-denominated lending (in percent),  $\ln VIX_t$  is the log of the VIX index, and  $\Delta BER_{it}$  denotes the percent change in the bilateral exchange rate of the local currency vis-à-vis the dollar.

We follow the variable ordering used in Bruno and Shin (2015a). Most importantly, in all panel structural VAR specifications that we explore, the cross-border lending variable

Impulse response functions of US dollar denominated cross-border bank lending to a US dollar exchange rate shock

Figure 6



All panels display the response of changes in cross-border lending to a one standard deviation shock to the local foreign exchange rate vis-à-vis the US dollar. The estimates of our orthogonalized impulse response functions are based on a Cholesky decomposition with four endogenous variables ordered as  $y_{it} = [\Delta ir_t^c, \Delta xbl_{it}^c, \ln VIX_{it}, \Delta f x_{it}^c]'$ . The shaded areas represent 95 percent confidence intervals, obtained using a Gaussian approximation based on 1000 Monte Carlos draws from the estimated structural panel VAR. Period covered: Q1/2002-Q3/2015.

Source: BIS Locational Banking Statistics; BIS effective exchange rate indices; BIS calculations.

is ordered ahead of the FX variable. This rules out any contemporaneous effects of the FX rate on cross-border lending, thus tilting the odds against the finding of results predicted by the theoretical model of Bruno and Shin (2015b).

Figure 6 displays the impulse responses from our benchmark (four variable) specification. They reveal that the bilateral exchange rate has a negative and strongly statistically significant impact on cross-border bank lending. This is the case for lending to borrowers from all sectors, as well as for our distinct subsamples of lending to bank and non-bank borrowers. The estimated negative impact is quite persistent, remaining statistically significant for up to six quarters after the occurrence of the shock.

The estimated economic magnitude of the FX shocks is also relatively large. The impact of the FX shock on the growth rate of cross-border bank claims peaks at approximately -0.6% in the case of lending to all sectors. In line with the prediction of the Bruno and Shin (2015b) model, the impact is even larger for interbank lending. It peaks at -1.4%, suggesting that a 1 percentage point increase in the average change of the bilateral exchange rate value of the dollar against a given currency leads to a 1.4 percentage point drop in the growth rate of cross-border lending to banks located in the respective country.

## 5 The euro as an alternative global funding currency

Historically, the euro has not been as widely used as a global funding currency as the US dollar. Nevertheless, we find evidence that the euro has started to exhibit some of the key properties of global funding currencies in the period after the GFC.

### 5.1 The spot-basis relationship using other base currencies

So far, the cross-currency basis has been defined with respect to the US dollar as the base currency. In this section, we examine whether the negative relationship between the cross-currency basis and the aggregate exchange rate index also applies to a set of other base currencies. We find a similar negative and significant relationship for the euro in the post-crisis period at both daily and quarterly frequencies. However, our findings do not support such a significant relationship for other currencies as the base currency, except for the Danish krone (which is pegged to the euro) and the Swedish krona at a daily frequency. These results show that there is no mechanical spot-basis relationship with respect to any arbitrary base currency. The strong, negative relationships for the US dollar and the euro (during the post-crisis period) point to their unique role as major international funding currencies.

In terms of our empirical analysis, Equation 18 redefines the basis of currency  $i$  with respect to a new base currency  $j$  :

$$\Delta x_{it}^{(j)} = \alpha_i + \beta \Delta \overline{NEER}_t^{(j)} + \gamma \Delta BER_{it}^{(j)} + \delta_1 \ln VIX_t + \delta_2 \Delta \ln VIX_t + \varepsilon_{it}^{(j)}, \quad (18)$$

where  $\Delta x_{it}^{(j)} = x_{it} - x_{jt}$  denotes changes in the cross-currency basis of currency  $i$  with respect to base currency  $j$ . We obtain  $\Delta x_{it}^{(j)}$  as the difference between the quoted cross-currency basis of currency  $i$  and that of currency  $j$ , both with respect to the US dollar. Let  $\Delta \overline{NEER}_t^{(j)}$  stand for changes in the aggregate exchange rate index of the base currency  $j$ , as given by the BIS nominal effective exchange rate index. The variable  $\Delta BER_{it}^{(j)}$  denotes changes in the bilateral exchange rate of currency  $i$  with respect to the base currency  $j$ . Again, both the level and the change of the log of the VIX index control for

global risk sentiment.

Table 6 presents our estimated regression coefficients on  $\Delta \overline{NEER}_t^{(j)}$  for 10 different base currencies, once for the three-month basis at the daily frequency (Panel A) and the five-year basis at the quarterly frequency (Panel B). The regression is estimated on the post-crisis sample starting in January 2009. Our estimated coefficient on  $\Delta \overline{NEER}_t^{(j)}$  is significantly negative in both panels using the euro as the base currency, while it turns out to be significantly negative for the Danish krone and the Swedish krona only at the daily frequency in Panel A. The Danish krone is pegged to the euro. Across all the other currencies, the coefficient on  $\Delta \overline{NEER}_t^{(j)}$  is insignificant from zero. These results point to a similar negative spot-basis relationship for the euro in that a stronger euro is associated with larger CIP deviations of other currencies vis-à-vis the euro.

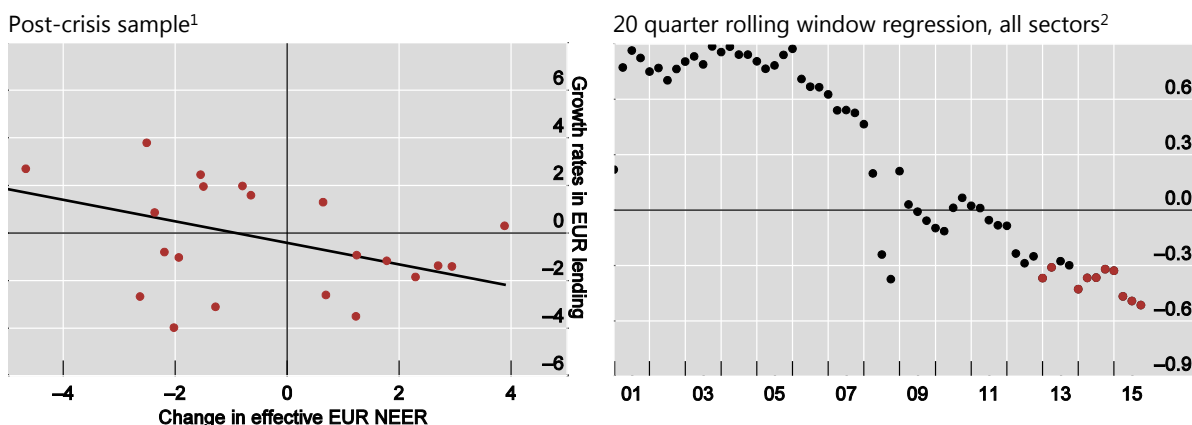
## 5.2 The euro spot rate and cross-border bank lending denominated in euros

We now turn to the relationship between the strength of the euro and cross-border bank lending denominated in euros. The left-hand panel of Figure 7 plots the quarterly growth rate of global euro-denominated cross-border bank lending against the euro NEER index for the post-crisis (Q1 2010–Q3 2015) period. It turns out that the relationship between these two variables is negative and statistically significant.

Cross-currency basis and aggregate exchange rates, using alternative base currencies										Table 6
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	AUD	CAD	CHF	DKK	EUR	GBP	JPY	NOK	NZD	SEK
<b>Panel (A): 3-month basis, daily frequency</b>										
$\Delta NEEER_t^{(j)}$	-0.0963 (0.209)	-0.179 (0.209)	-0.0476 (0.274)	-0.633*** (0.239)	-0.378** (0.174)	-0.165 (0.194)	-0.231 (0.232)	0.114 (0.206)	0.0677 (0.270)	-0.598*** (0.159)
<b>Panel (B): 5-year basis, quarterly frequency</b>										
$\Delta NEEER_t^{(j)}$	0.156 -0.32	0.093 -0.293	-0.143 -0.162	-0.418* -0.233	-0.589** -0.232	-0.0722 -0.206	-0.119 -0.283	-0.142 -0.172	0.241 -0.302	-0.14 -0.183

This table reports regression coefficients of changes in the cross-currency basis of currency  $i$  against the base currency  $j$  on changes in the aggregate exchange rate against the base currency  $j$ ,  $\Delta NEEER_t^{(j)}$ , controlling for changes in the bilateral exchange rate of  $i$  against  $j$ , and the log level and changes in VIX. The variable  $\Delta NEEER_t^{(j)}$  is the change in the BIS nominal effective exchange rate for currency  $j$ . Each column corresponds to a different base currency. Panel A is performed on daily changes for the 3-month basis and Panel B is performed on quarter changes for the 5-year basis.

Sources: Bloomberg; BIS bilateral exchange rates ; BIS calculations



<sup>1</sup> Covers the Q1 2010–Q3 2015 period. Lending refers to the extension of loans and holdings of debt securities by BIS reporting banks, while all borrowers (the total of banks and non-banks) reside outside of the euro areas. The black line is a fitted regression line. Positive changes in the foreign exchange rate indicate an appreciation of the EUR. For presentational purposes, outliers with FX rate changes exceeding 5% in absolute value have been dropped from the panel, but not from the regressions. <sup>2</sup> Extension of the LHP static regression to a rolling window framework of 20 quarters per estimation for cross-border lending (loans and debt securities) denominated in euros. The position of dots with respect to the vertical axis gives the coefficient estimate, while the horizontal timeline refers to the last period of the rolling window. Red dots indicate a negative coefficient estimate that is statistically significant at the 10% level.

Sources: BIS Locational Banking Statistics; BIS effective exchange rate indices; BIS calculations.

The right-hand panel of Figure 7 displays the coefficients obtained from rolling window regressions of the quarterly growth rate of cross-border bank lending denominated in euros on the change in the exchange rate value of the euro. During the pre-crisis (2002–2007) period, the impact of fluctuations in the euro exchange rate on cross-border bank lending denominated in euros was not statistically significant (and, at times, was even positive). Nevertheless, the post-crisis period has seen a sustained dive of the estimated impact coefficients into negative territory.

In summary, in the post-crisis sample, we find a triangular relationship for the euro that is similar to the one that exists for the US dollar. More concretely, a stronger euro is associated with wider CIP deviations vis-à-vis the euro and contractions in cross-border bank lending denominated in euros. This points to a more prominent role of the euro as a global funding currency in recent years.

## 6 Bank Equities and the Broad Dollar

Finally, in this section, we provide empirical support that a strong dollar has a negative impact on bank equities. In particular, we focus on a sample of 51 internationally active

Table 7: Regressions of bank equity returns on the broad dollar movements

	(1)	(2)	(3)
	Bank Equity Return	Bank Equity Return	Bank Equity Return
$\Delta Broad_t$	-2.016*** (0.127)	-0.268** (0.103)	-0.0303 (0.0838)
$\Delta Broad_t \times bs_t$			2.875*** (0.808)
$\Delta Market_t$		1.246*** (0.0527)	1.236*** (0.0524)
Constant	-0.00444*** (3.25e-05)	-0.00762*** (0.000122)	-0.00728*** (0.000166)
Observations	3,755	3,755	3,755
R-squared	0.102	0.452	0.459

Notes: In all three columns, the dependent variable is the quarterly equity return in local currency. The independent variables are  $\Delta Broad_t$ , quarterly change in the broad dollar index ( $\Delta Broad_t > 0$  indicates broad appreciation),  $\Delta Broad_t \times bs_t$ , the interaction between the broad dollar movement and the 5-year cross-currency basis, and  $\Delta Market_t$ , quarterly benchmark equity index return. All regressions include bank fixed effects and use robust standard errors clustered by banks, \*\*\* $p < 0.01$ , \*\* $p < 0.05$  and \* $p < 0.1$ .

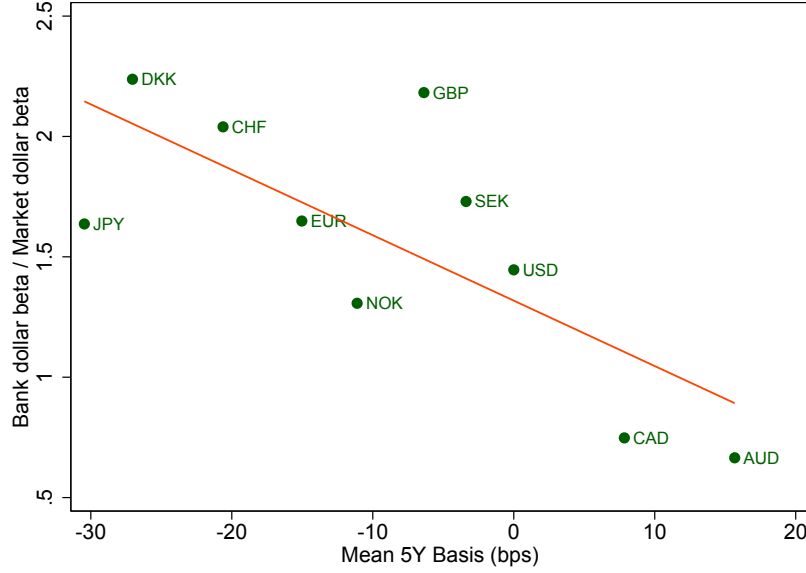
banks in G10 currency areas. The list of banks is provided in Appendix A. We perform panel regressions with bank fixed effects of bank equity returns in local currency on broad dollar movements at the quarterly frequency. In Column 1 of Table 7, we show that a 1% appreciation of the broad dollar index is associated with a 2% decline in bank equities. Once we control for the market returns in Column 1, the change in the broad dollar remains significant: a 1% appreciation of the broad is still associated with 0.27% decline in bank equities.

In Column 3, we examine differential sensitivity of bank equities with respect to the dollar movements by including an interaction between movements in the broad dollar index and the 5-year cross-currency basis. The coefficient on the interaction term is significantly positive, which indicates that bank equities in countries with a more negative cross-currency basis respond more negatively to a dollar appreciation. The coefficient on the change in the broad dollar is very small and no longer significant once the interaction term is added. This suggests that for countries with the cross-currency basis equal to zero (e.g. the United States), bank equities are not significantly correlated with movements



in the dollar after controlling for the market returns. For countries with a positive basis, such as the Australia, bank equities actually respond positively to a dollar appreciation after controlling for benchmark equity index returns.

Figure 8: Sensitivity of bank equity returns to the dollar vs. cross-currency basis



Notes: On the x-axis, we plot the mean 5-year cross-currency basis by currency. On the y-axis, we plot the average ratio of the regression beta of changes in the bank equities on changes in the broad dollar index over the regression beta of changes in the benchmark equity index on changes in the broad dollar index by currency. The sample period is 2000-2016.

Figure 8 visualize the relationship between the bank equity beta and the cross-currency basis. On the horizontal axis, we plot the mean 5-year cross-currency basis by currency. On the vertical axis, we plot the mean ratio of individual bank equity's dollar beta over the respective equity index's dollar beta across banks headquartered in each currency area. We can see that the relative sensitivity of bank equities over equity index's sensitivity with respect to the dollar decreases in the level of cross-currency basis. In countries with positive bases, such as Australia and Canada, bank equities are less sensitive to dollar fluctuation than their respective equity indices. In countries with very negative bases, such as Denmark, Switzerland and Japan, bank equities have significantly higher sensitivity to dollar fluctuation than their respective equity indices.

In summary, we find that a stronger dollar has a negative impact on bank equities, and the effect is particularly pronounced for banks headquartered in countries with a

more negative cross-currency basis or a more severe dollar funding shortage.

## 7 Conclusion

In this paper, we document a triangular relationship formed by the strength of the US dollar, CIP deviations and cross-border bank lending denominated in dollars. A stronger dollar is associated with wider CIP deviations and lower growth of cross-border bank lending denominated in dollars. We interpret the magnitude of CIP deviations as the price of bank balance sheet capacity and dollar-denominated credit as a proxy of bank leverage, and argue that such a triangular relationship exists because of the impact of the dollar on the shadow price of bank leverage.

In particular, a strengthening of US dollar has adverse impacts on bank balance sheets, which, in turn, reduces banks' risk bearing capacity. As a result, wider CIP deviations and lower dollar-denominated cross-border bank lending both reflect a higher price of bank leverage as a result of a stronger dollar. Furthermore, we also find evidence that the euro has started to exhibit characteristics of a global funding currency in the period after the Great Financial Crisis.

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## A Appendix: List of International Banks in the Sample

- Australia: Westpac, ANZ, Commonwealth Bank of Australia, National Australia
- Canada: Bank Royal Bank of Canada, Bank of Montreal (BMO), Canadian Imperial Bank of Commerce, Bank of Nova Scotia, Toronto-Dominion (TD) Bank
- Switzerland: UBS AG, Credit Suisse
- Denmark: Danske Bank
- Euro Area: Erste Group, Dexia, KBC, BNP Paribas, Credit Agricole, Natixis, Societe Generale, Commerzbank, Deutsche Bank, UniCredit AG, Banca Monte dei Paschi di Siena, Intesa San Paolo, UniCredit Spa, Banco de Sabadell, Bank Santander, BBVA, La Caixa
- United Kingdom: Barclays, HSBC Holdings, Lloyds Bank, Royal B. Scotland, Standard Chartered
- Japan: Mizuho Financial Group, MUFG, Nomura, Sumitomo Mitsui Financial
- Norway: DNB ASA
- Sweden: Nordea Bank, Skandinaviska Enskilda Banken, Svenska Handelsbanken, Swedbank
- United States: Bank NY Mellon, Bank of America, Citigroup, Goldman Sachs, JPMorgan Chase, Morgan Stanley, State Street, Wells Fargo