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

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Abstract

We document a triangular relationship formed by the broad 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 larger 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. We argue that underpinning the triangle is the role of the dollar as a key barometer of risk-taking capacity in global capital markets.

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

JEL Classifications: F3, G1, G2

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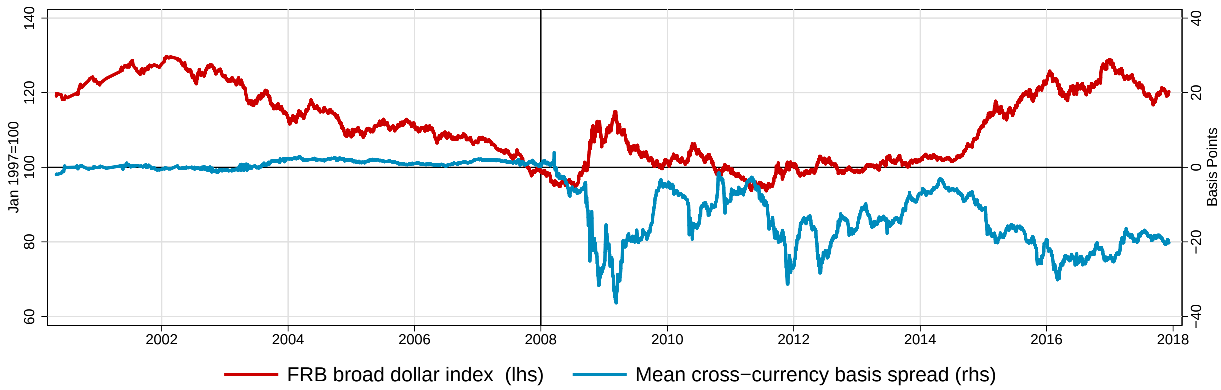
1 Introduction

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 must be 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 against a broad basket of currencies that 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.

Figure 1: U.S. dollar broad index and the cross-currency basis (2000-2017)



Notes: This figure plots the Federal Reserve Board broad dollar index (in red) and the average five-year cross-currency basis (in blue) for G10 currencies from January 1, 2000 to December 8, 2017. The ten sample currencies are: the Australian dollar, the British pound, the Canadian dollar, the Danish krone, the euro, the Japanese yen, the New Zealand dollar, the Norwegian krone, Swedish krona, and the Swiss franc.

The *cross-currency basis* is the difference between the dollar interest rate in the cash 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 Federal Reserve Board 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 since the GFC. When the dollar strengthens, the CIP deviations widen. As we demonstrate later in our empirical analysis, the relationship between the broad dollar index and the cross-currency basis post-crisis is robust to a host of controls, such as the bilateral exchange rate, the implied volatility of the S&P options (VIX), implied currency volatility and risk reversal, and measures of asymmetric monetary policy stances. Prior to the GFC, such a relationship is absent as the CIP condition holds and the cross-currency basis is close to zero.

Furthermore, we document a risk-return asset-pricing relationship underpinning these empirical observations. The exposure to the broad dollar exchange rate is priced in the cross section of CIP deviations in the sense that variations in CIP deviations across currencies are explained by the sensitivity of the CIP deviations to fluctuations in the broad dollar index. The CIP deviations of different currencies have differing exposures 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. 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.

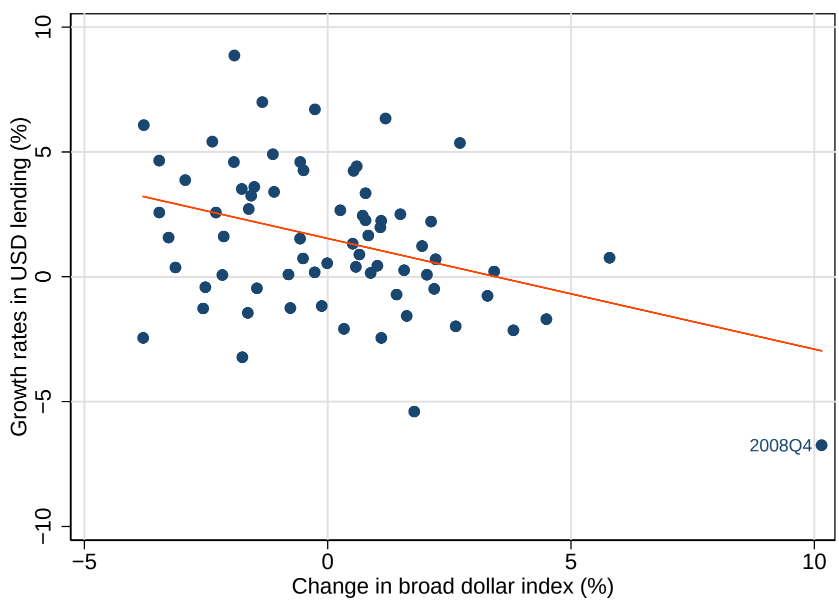
To provide additional support to our results, we study a short event window following the 2016 US Presidential Election. Following the election result, the broad dollar sternghened by 5 percent. Despite expectations of rollbacks of financial regultions under the Trump administration, CIP deviations widened signifcantly following the election. The relationship between the level of the basis and the sensitivity to the dollar factor is also strongly supported in the event window. CIP deviations widened signficantly for the Japanese yen and the Swiss franc, but not for the Australian dollar nor the New Zeland dollar.

One possible explanation for our results is related 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 rates 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.

Why do the CIP deviations narrow when the domestic currency strengthens against the dollar? We argue that 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, an appreciation of the dollar is associated with a reduction in the supply of dollar funding to the non-residents.

The relationship between cross-border dollar lending and the dollar is illustrated in Figure 2. The left-hand panel plots the quarterly growth rate of global aggregated dollar-denominated cross-border bank lending flows against the broad dollar index. It reveals that there is a significantly negative relationship between the two variables. Furthermore, we examine dollar-denominated lending to different destination countries in a panel regression setting. We find the broad dollar index remains significant in explaining the bank lending flows after controlling for the bilateral exchange rates, VIX and the US policy rate.

Figure 2: U.S. dollar-denominated cross-border bank lending vs. the broad dollar index



Notes: In this figure, on the vertical axis, we plot quarterly percentage growth rates of cross-border bank lending (extension of loans and holding of debt securities) denominated in US dollars by BIS reporting banks. On the horizontal axis, we plot the quarterly percentage change in the broad dollar index, where the quarterly broad dollar index is averaged across daily observations. Positive changes in the broad dollar index indicate dollar appreciations. The red line is a fitted regression line. The sample period covers 2000Q1-2017Q2.

In addition, we show that the triangular relationship between the exchange rate, the cross-currency basis, and the cross-border bank lending is largely absent for other major currencies. This result points to the unique role of the US dollar as an international funding currency in affecting leverage and risk taking via fluctuation in exchange rates.

This empirical regularity has several potential 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 as the "risk-taking channel" by Bruno and Shin (2015ab). 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. We sketch on a simple model in this setting to illustrate that a stronger dollar increases the shadow cost of bank balance sheet capacity, and therefore reduces the supply of dollar credit and increases CIP deviations.

Finally, guided by the simple model, we provide some empirical evidence using equity prices of internationally active banks to show that a stronger dollar negatively affects bank market equities. In particular, we show that bank equities in currency areas with a more negative basis (indicating a more severe 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, Hrung, and Sarkar (2009); Goldberg, Kennedy, and Miu (2011); Griffolli and Ranaldo (2011); McGuire and von Peter (2012); Bottazzi, Luque, Pascoa, and Sundaresan (2012); and Ivashina, Scharfstein, and Stein (2015)). More recently, CIP deviations post-crisis have become an active area of research. 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. Rime, Schrimpf and Syrstad (2017) examine the impact of money market segmentation on 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)). In addition, our paper contributes to the literature on "global financial cycles". For example, Rey (2013) and Miranda-Agrippino and Rey (2015) focus on VIX and the US monetary policy as key drivers of global financial cycles. We show that the broad dollar remains significant in explaining the cross-currency basis and the cross-border flows after controlling VIX and US monetary policy. Finally, 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 discusses data sources and presents some summary statistics. Section 3 presents empirical evidence on the relationship between the US dollar and the cross-currency basis. Section 4 examines the relationship between the dollar and cross-border bank lending in dollars. Section 5 outlines a model to explain the triangular relationship via the shadow cost of bank leverage. Finally, Section 6 provides empirical support for the impact of dollar movements on bank equities. Section 7 concludes.

2 Data and summary statistics

2.1 Cross-currency basis

We define the n-year cross-currency basis of currency i vis-à-vis the US dollar at time t, denoted $x^i_{n,t}$, as the deviation from the CIP condition between currency i and the dollar :

$$(1 + y^{\$}_{n,t})^n = (1 + y^i_{n,t} + x^i_{n,t})^n \frac{S^i_t}{F^i_{n,t}}, \tag{1}$$

where $y^{\$}_{n,t}$ is the n-year dollar interest rate, $y^i_{n,t}$ is the n-year interest rate in currency i, S^i_t is the dollar spot exchange rate of currency i and $F^i_{n,t}$ is the outright forward rate for currency i. Both forward and spot exchange rates are defined in terms of units of currency i per dollar. Equivalently, in logs, the currency basis is equal to:

$$x^i_{n,t} = y^{\$}_{n,t} - (y^i_{n,t} - \rho^i_{n,t}), \tag{2}$$

where $\rho^i_{n,t} \equiv \frac{1}{n}[\log(F^i_{n,t}) - \log(S^i_t)]$ 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, $y^i_{n,t} - \rho^i_{n,t}$. Since we focus on leverage and risk-taking of banks, we focus on the cross-currency basis derived from benchmark interbank rates in the respective currency, commonly referred to as the Libor rates and interest rate swap rates indexed to Libor. We focus on two maturities: three-month for the short-term maturity and five-year for the long-term maturity. For the three-month basis, we construct the basis based on Equation 2 using the spot exchange rates, three-month forward exchange rates and interbank benchmark interest rates from Bloomberg. For the five-year basis, as shown in Du, Tepper and Verdelhan (Forthcomng), the spread on the cross-currency basis swap, which exchanges the floating interbank rate in foreign currency i against the US Libor, exactly measures CIP deviations at long maturity, Therefore, we use the five-year cross-currency basis from Bloomberg to directly measure five-year CIP deviations.

We consider the cross-currency basis of the ten most liquid developed country currencies in the world against the US dollar, including the Australian dollar (AUD), the Canadian dollar (CAD), the Swiss franc (CHF), the Danish krone (DKK), the euro (EUR), the British pound (GBP), the Japanese yen (JPY), the Norwegian krone (NOK), the New Zealand dollar (NZD), and the Swedish krona (SEK). As the cross-currency basis emerged during the GFC, we choose our sample period from January 1, 2007 to December 8, 2017.

Table 1 provides some summary statistics for the three-month and five-year cross-currency basis. 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 -15 to -60 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, ranging from -5 to -50 basis points. For offshore market participants without access to cash market dollar funding, a more negative cross-currency basis corresponds to a higher price of dollar liquidity in the FX swap market.

As shown in Du, Tepper and Verdelhan (Forthcoming), the arbitrage profits associated with the CIP trades cannot be explained away by transaction costs or credit risk. 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 constraint facing the banking market remains at the center of attention. Therefore, the magnitude of the cross-currency basis sheds light on the shadow cost of banks' balance sheet constraints.

Table 1: Summary statistics for the cross-currency basis (basis points)

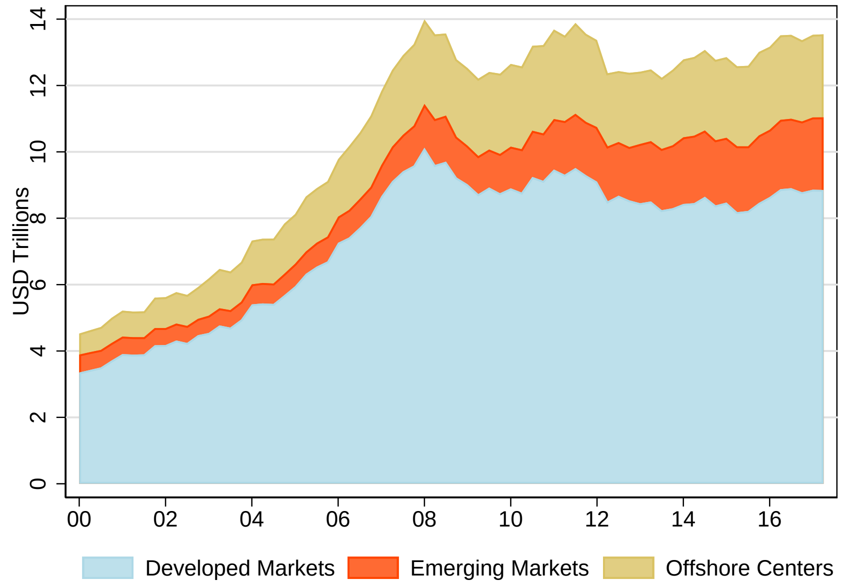
	Three-month		Five-year	
Currency	mean	s.d.	mean	s.d.
AUD	0.2	(14.0)	20.1	(10.1)
CAD	-15.2	(14.1)	4.7	(9.0)
CHF	-24.7	(22.1)	-32.7	(16.9)
DKK	-60.2	(34.3)	-43.3	(21.1)
EUR	-31.0	(26.5)	-25.9	(15.4)
GBP	-19.0	(23.3)	-9.9	(11.7)
JPY	-24.2	(20.6)	-49.7	(28.5)
NOK	-30.4	(24.6)	-14.8	(9.6)
NZD	7.0	(10.1)	24.3	(12.8)
SEK	-25.8	(20.2)	-5.2	(8.5)
Total	-22.3	(28.0)	-13.2	(28.5)

Notes: This table provides summary statistics for the three-month and the five-year cross-currency bases in basis points for the period between January 1, 2007 and December 8, 2017. Means and standard deviations are calculated for daily observations expressed in basis points.

2.2 Cross-border dollar flows

We obtain data on cross-border bank lending flows from the BIS locational banking statistics (LBS). The LBS captures outstanding claims and liabilities of banks located in BIS reporting countries. We construct a panel consisting of growth rates of US dollar-denominated lending (including extensions of loans and holdings of debt securities) from all BIS reporting banks to over 100 destination countries. As shown in Figure 2, the total cross-border dollar-denominated lending amounts to about $14 trillion in 2017, with lending to developed markets accounting for 65% of the total and lending to emerging markets and offshore financial shares accounting for the rest 35% of the total lending.

Figure 3: U.S. dollar-denominated cross-border bank lending by destination regions



Notes: This figure plots the dollar-denominated cross-border banking lending by destination regions in trillions of US dollars from the BIS Locational Banking Statistics. The blue area denotes lending from BIS reporting banks to developed markets. The orange area denotes lending to emerging markets. The yellow area denotes lending to offshore financial centers. The sample period is 2000Q1-2017Q2.

3 The dollar and the cross-currency basis

In this section, we examine the empirical relationship between the dollar spot exchange rate and the cross-currency basis. We first show a strong contemporaneous relationship between the broad dollar index and CIP deviations. Next, we present evidence that the dollar exchange rate acts as a risk factor in pricing the cross-section of CIP deviations. We then show that our main time-series and cross-sectional predictions hold well during the event window following the 2016 US Presidential Election. Finally, we show that there is no robust spot-basis relationship when using other major currencies as the base currency.

3.1 The dollar spot rate and the cross-currency basis

We now examine the relationship between the dollar spot exchange 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.[1] To check the robustness of our results, we control for other potential drivers. Our benchmark regression specification is given by:

$$\Delta x_{it} = \alpha_i + \beta \Delta Dollar_t + \gamma \Delta BER_{it} + \delta' \mathbf{CONTR}_{it} + \varepsilon_{it} \tag{3}$$

Let α_i be a currency fixed effect and Δx_{it} stand for changes in the cross-currency basis of currency i vis-à-vis the US dollar between $t-1$ and t. The variable $\Delta Dollar_t$ denotes changes in the Federal Reserve Board (FRB) US trade-weighted broad dollar index and ΔBER_{it} indicates changes in the bilateral exchange rate for currency i vis-à-vis the dollar. Positive values of $\Delta Dollar_t$ and ΔBER_{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, ΔRR_{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 meant to capture divergent monetary policy stances between foreign countries and the US.

[1] We consider daily changes in case of the three-month basis, and quarterly changes in case of the five-year basis.

3.1.1 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 2.3 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.

Table 2: Regression results of the 3-month cross-currency basis (daily frequency)

	(1)	(2)	(3)	(4)	(5)	(6)
$\Delta Dollar_t$	-2.610***		-3.007***	-2.964***	-2.229***	-2.291***
	(0.539)		(0.775)	(0.767)	(0.658)	(0.684)
ΔBER_{it}		-0.585**	0.284	0.303	0.173	0.286
		(0.263)	(0.324)	(0.316)	(0.266)	(0.269)
$\ln VIX_t$				0.0531	-0.00259	0.0273
				(0.411)	(0.399)	(0.409)
$\Delta \ln VIX_t$				-0.0195	-0.00189	-0.0163
				(0.0188)	(0.0197)	(0.0189)
$\Delta CurrVol_{it}$					-0.192***	-0.179***
					(0.0576)	(0.0571)
ΔRR_{it}					1.040	1.173
					(0.806)	(0.827)
$\Delta(y_{it} - y_{it}^{US})$						0.0888**
						(0.0370)
$\Delta(ts_{it} - ts_{it}^{US})$						-0.0900*
						(0.0501)
Observations	25,166	26,513	25,166	24,604	24,530	23,426
R-squared	0.015	0.004	0.015	0.016	0.019	0.024

Notes: 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. 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); ΔBER_{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, $\Delta CurrVol_{it}$, daily change in the log of implied volatility on 3-month at-the-money currency options; ΔRR_{it}, daily change in the 25-delta risk reversal; $\Delta(y_{it} - y_{it}^{US})$, daily change in the spread of the 10-year foreign Treasury yield over the 10-year U.S. Treasury yield; and $\Delta(ts_{it} - ts_{it}^{US})$; 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.

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 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 an intuitive result, 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 (Forthcoming) 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).

3.1.2 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 -0.8 to -1.2. 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 14% 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 $\Delta(y_{it} - y_{it}^{US})$, however, remains significant, but with the opposite sign compared with the daily regression.

In unreported regressions, we find that these results are not driven by the GFC. We repeat all daily and quarterly regression specifications for the post-crisis subsample starting in January 2009 and obtain negative coefficient estimates on $\Delta Dollar_t$ of similar magnitude. 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.

Table 3: Regression results of the 5-year cross-currency basis (quarterly frequency)

	(1)	(2)	(3)	(4)	(5)	(6)
$\Delta Dollar_t$	-1.180***		-0.996**	-0.806**	-0.774**	-0.771**
	(0.276)		(0.408)	(0.334)	(0.366)	(0.325)
ΔBER_{it}		-0.522***	-0.131	-0.140	-0.0899	-0.273*
		(0.102)	(0.123)	(0.112)	(0.145)	(0.145)
$\ln VIX_t$				-2.440	-2.226	-2.086
				(2.172)	(2.123)	(2.041)
$\Delta \ln VIX_t$				-0.0389	-0.0258	-0.000603
				(0.0237)	(0.0274)	(0.0304)
$\Delta CurrVol_{it}$					-0.0490	-0.0247
					(0.0440)	(0.0388)
ΔRR_{it}					-0.0215	-0.184
					(1.008)	(0.932)
$\Delta(y_{it} - y_{it}^{US})$						-0.0696***
						(0.0227)
$\Delta(ts_{it} - ts_{it}^{US})$						0.00148
						(0.0148)
Observations	430	430	430	430	430	411
R-squared	0.144	0.101	0.147	0.159	0.168	0.208

Notes: This table shows regression results of quarterly changes in the 5-year Libor cross-currency basis on changes in spot exchange rates and other controls. The dependent variable is the daily 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); ΔBER_{it}, quarterly 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, $\Delta \ln VIX_t$, quarterly change in the log of VIX, $\Delta CurrVol_{it}$, quarterly change in the log of implied volatility on 3-month at-the-money currency options; ΔRR_{it}, quarterly change in the 25-delta risk reversal; $\Delta(y_{it} - y_{it}^{US})$, quarterly change in the spread of the 10-year foreign Treasury yield over the 10-year U.S. Treasury yield; and $\Delta(ts_{it} - ts_{it}^{US})$; quarterly 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.

3.2 Cross-country relationship between the dollar and the 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.

3.2.1 Benchmark estimation

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

$$\Delta x_{it} = \alpha_i + \beta_i \Delta Dollar_t + \epsilon_{it} \tag{4}$$

We obtain the dollar beta using both daily regressions for the three-month basis and quarterly regressions for the five-year basis. The dollar betas for individual currencies are presented in Table 4. We can see that the dollar beta is significantly negative for most currencies. The exceptions are the Australian dollar at the three-month horizon, and the Australian dollar, the Canadian dollar and the New Zealand dollar at the five-year horizon.

To see whether the broad dollar acts as a risk factor, we regress the mean of the cross-currency basis on the dollar beta as follows,

$$\overline{bs}_i = \lambda_0 + \lambda_1 \beta_i, \tag{5}$$

where $\overline{bs}_i$ is the mean cross-currency basis for currency i. If the dollar is a priced risk factor, we should expect $\lambda_1 > 0$. 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, which are in turn correlated with the strength of the dollar to different extent. 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. Therefore, we should expect a positive relationship between the level of the cross-currency basis and the dollar beta.

To visualize the cross-sectional relationship, Figure 4 plots the average basis against the corresponding dollar beta. We can see a strong positive relationship between the average basis and the dollar beta with a bivariate correlation equal to 75% for the three-month basis and 97% for the five-year basis. Table (5) reports the regression coefficients for the relationship. As increase in the magnitude of the dollar beta by 1 corresponds to an increase in the expected returns of 17 basis points based on three-month CIP deviations and 32 basis points based on five-year CIP deviations.

Taking together, these findings suggest that the aggregate dollar exchange rate acts as a risk factor that is priced in the cross section of CIP arbitrage returns. The cross-currency basis with more systematic exposure to the dollar tends to have higher expected returns for the CIP trade.

Table 4: Dollar beta by country

	(1) AUD	(2) CAD	(3) CHF	(4) DKK	(5) EUR	(6) GBP	(7) JPY	(8) NOK	(9) NZD	(10) SEK
Panel (A): 3-month basis, daily frequency										
$\Delta Broad_{it}$	-1.122***	-1.303***	-1.519***	-2.193***	-2.511***	-0.903***	-2.060***	-1.243***	0.339	-1.993***
	(0.344)	(0.301)	(0.354)	(0.386)	(0.312)	(0.311)	(0.297)	(0.358)	(0.340)	(0.329)
Panel (B): 5-year basis, quarterly frequency										
$\Delta Broad_{it}$	0.00326	-0.523	-1.563***	-1.904***	-1.825***	-1.310***	-2.283***	-1.177***	-0.0953	-1.113***
	(0.379)	(0.546)	(0.374)	(0.608)	(0.479)	(0.292)	(0.520)	(0.278)	(0.408)	(0.235)

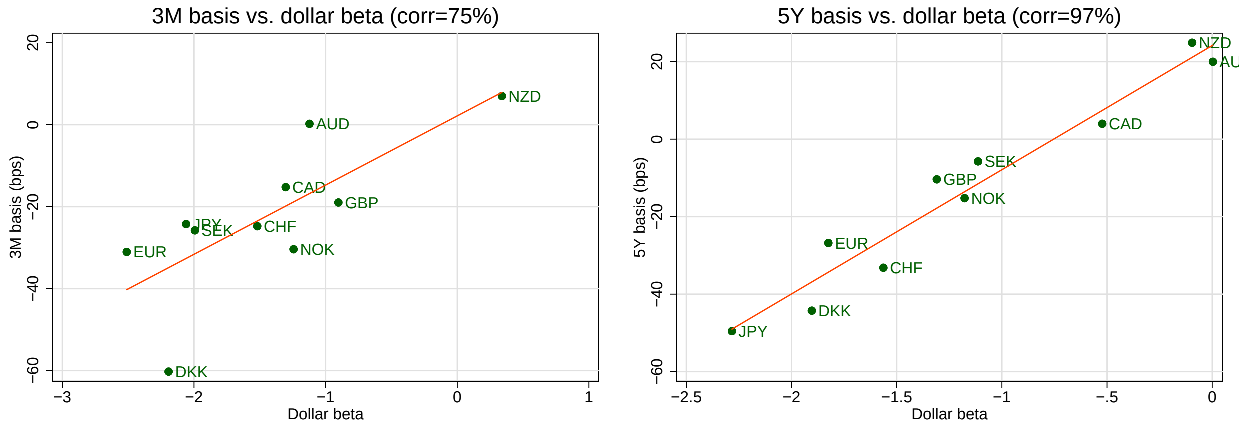
Notes: This table reports regression coefficients of changes in the cross-currency basis of currency i on the changes in the broad dollar. Panel A shows regressions based on daily changes using the three-month cross-currency basis and Panel B shows results based on quarterly changes using the five-year cross-currency basis. We winsorize the daily changes in the cross-currency basis at 1 percent on both tails. The sample period is January 1, 2007 to December 8, 2017. Robust standard errors are shown in the parentheses. ***p<0.01, **p<0.05, *p<0.1.

Table 5: Dollar beta and the cross-currency basis

	(1) Mean 3M Basis	(2) Mean 5Y Basis
β_i	16.89***	32.06***
	(2.24)	(4.94)
Constant	2.154	24.17***
	(4.64)	(6.58)
Observations	10	10
R-squared	0.567	0.948

Notes: This table reports the regression coefficients of the mean cross-currency basis in basis points on the dollar beta across countries. Column 1 reports results based on the three-month basis and Column 2 reports results based on the five-year basis. e winsorize the daily changes in the cross-currency basis at 1 percent on both tails. The sample period is January 1, 2007 to December 8, 2017.Bootstrapped standard errors for the two-pass regressions based on 10,000 replications are shown in the parentheses. ***p<0.01, **p<0.05, *p<0.1.

Figure 4: Cross-currency basis vs. dollar beta (2007-2017)



Notes: The vertical axis of the left figure 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 right figure 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. We winsorize the daily changes in the cross-currency basis at 1 percent on both tails. The sample period is January 1, 2007 to December 8, 2017.

3.3 Event study following the 2016 U.S. Presidential Election

The appreciation of the dollar after the election presents an opportunity to perform an event study for our main prediction in the time series and cross section. If financial regulations were the sole driver of banks' balance sheet constraints, we would expect the cross-currency basis to narrow following the election as market participants expect significant rollbacks of the financial regulations under the Trump administration. However, if the strength of the dollar is an important driver of the bank's balance sheet capacity, then the dollar rally following the election should lead to wider cross-currency bases.

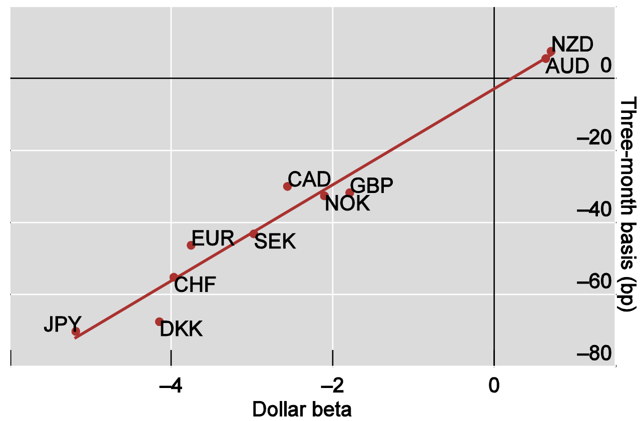
As shown in Table 6, the broad dollar index of the Federal Reserve rose by 3.9% between November 8 and November 29, 2016. During the same period, the cross-currency basis widened for all G10 currencies. The largest movement was for the yen, with the basis widening from –70.3 basis points to –90.5 basis points. Furthermore, we define the "dollar beta" for the event window as the ratio of the change in the cross-currency basis (in basis points) over changes in the broad dollar index (in percentage points) between November 8 and November 29, 2016. 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 "safe haven" currencies in conventional carry trade experience largest widening in the cross-currency basis following the election, whereas the risky currencies in carry trade experience little widening in the cross-currency basis.

Table 6: The dollar and cross-currency basis following the U.S. Presidential Election

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[1]
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[2]



[1] 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.

[2] 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.

3.4 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. Our findings generally do not support a robust significant relationship for other currencies as the base currency, which suggests that there is no mechanical relationship between the spot exchange rate and the cross-currency basis with respect to any arbitrary base currency.

In terms of our empirical analysis, Equation 6 redefines the basis of currency i with respect to a new base currency j :

$$\Delta x_{it}^{(j)} = \alpha_i + \beta \Delta \overline{NEER}_t^{(j)} + \varepsilon_{it}^{(j)}, \tag{6}$$

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.

Table 7 presents our estimated regression coefficients on $\Delta \overline{NEER}_t^{(j)}$ for 10 different base currencies, both for the three-month basis at the daily frequency (Panel A) and the five-year basis at the quarterly frequency (Panel B). Our estimated coefficient on $\Delta \overline{NEER}_t^{(j)}$ is significantly negative only for the British pound at the daily frequency. At the quarterly frequency, the coefficient on $\Delta \overline{NEER}_t^{(j)}$ is only significantly negative for the Swiss franc and the euro. None of the other base currencies have a significant negative spot-basis relationship at both frequency.[2] The weak evidence on the spot-basis relationship for the other major currencies as the base currency points to the unique role of the US dollar as an international funding currency.

[2]In unreported regressions, we include additional controls, such as changes in the bilateral exchange rates, the level and changes in VIX, changes in the yield spread and the slope of the yield curve. The coefficient on $\Delta \overline{NEER}_t^{(j)}$ does not become significantly negative after including additional controls.

Table 7: Cross-currency basis and aggregate exchange rates, using alternative base currencies

	(1) AUD	(2) CAD	(3) CHF	(4) DKK	(5) EUR	(6) GBP	(7) JPY	(8) NOK	(9) NZD	(10) SEK
Panel (A): 3-month basis, daily frequency										
$\Delta\overline{NEER}_t^{(j)}$	0.187	0.133	0.928	-1.736	0.164	-1.236***	0.677*	0.567	0.581*	-0.199
	(0.466)	(0.269)	(0.593)	(1.123)	(0.305)	(0.279)	(0.399)	(0.548)	(0.301)	(0.297)
Panel (B): 5-year basis, quarterly frequency										
$\Delta\overline{NEER}_t^{(j)}$	0.284	-0.582	-0.565**	0.199	-1.166***	-0.104	-0.286	0.206	0.449**	-0.0307
	(0.317)	(0.770)	(0.279)	(1.414)	(0.282)	(0.158)	(0.239)	(0.137)	(0.203)	(0.322)

Notes: This table reports regression coefficients of changes in the cross-currency basis of currency i against the base currency j on the aggregate exchange rate against the base currency j, $\overline{NEER}_t^{(j)}$. The variable $\overline{NEER}_t^{(j)}$ denotes the BIS nominal effective exchange rate for country i. 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. The sample period is from January 1, 2007 to December 8, 2017.

4 The dollar 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 examine the impact of fluctuations in the broad dollar exchange rate on dollar-denominated cross-border bank lending flows using two empirical frameworks. First, we perform panel regressions using BIS cross-border dollar bank lending flows. Second, we explore the dynamic interdependence between the main variables of interest through a vector autoregression. Finally, we show that we generally do not find a significant relationship between the exchange rate and cross-border flows denominated in other major currencies.

4.1 Panel regressions

In our benchmark panel regression specification, we regress the quarterly growth rate of dollar denominated cross-border bank lending flows to a given counterparty country from the BIS reporting banks on quarterly changes in the broad dollar index and in the bilateral exchange rate of the local currency of the respective borrowing country against the US dolar, a host of other global controls, and borrowing country fixed effects. Our benchmark specification is given by:

$$\Delta xbl_{it} = \alpha_i + \beta \Delta Dollar_t + \gamma \Delta BER_{it} + \delta\prime \mathbf{CONTR}_t + \varepsilon_{it}, \tag{7}$$

where Δxbl_{it} is the quarterly growth rate of dollar-denominated cross-border bank lending to borrowers in country i between $t-1$ and t. Let α_i be a borrowing-country fixed effect. As before, the variable $\Delta Dollar_t$ denotes changes in the broad dollar index, and variable ΔBER_{it} indicates changes in the bilateral exchange rate for currency i vis-à-vis the dollar. Positive $\Delta Dollar_t$ and ΔBER_{it} imply a broad and a bilateral dollar appreciation, respectively. The control variables include the log level and quarterly changes in VIX and changes in the U.S. policy rate. These control variables have been identified main drivers of the "global credit cycles", such as in Rey (2013) and Miranda-Agrippino and Rey (2015).

Table 8 presents the panel regression results for the quarterly sample from 2000Q1 to 2017Q2. Since we have over 100 borrowing countries in the sample of different sizes, we weight our panel using borrowing countries' average debt outstanding. Column 1 presents our benchmark estimates. The estimated coefficient on the dollar index is negative and statistically significant. One percent appreciation of the broad dollar is associated with 0.4 percent contraction in cross-border dollar flows. Furthermore, we note that the bilateral exchange also enters significantly negative, but does not drive away the significance of the broad dollar. Consistent with results in Rey (2013), the coefficient on the level of VIX is also significantly negative, which suggests that an increase in volatility is also corrected with a reduction in cross-border dollar flows. In Column 2, we re-estimate the same regression without applying any panel weights, so that all borrowing countries have equal weights in the estimation. The coefficient on the broad dollar is largely unchanged. In Column 3, we repeat the estimation only using the subsample since the GFC (2007Q1-2017Q2), the coefficient on the broad is again little changed. Therefore, unlike the negative relationship between the broad dollar and the cross-currency basis that only emerges since the GFC, the negative relationship between the broad dollar and the cross-border dollar flows is similar in the pre-crisis and post-crisis sample.

In Columns 4-6, we estimate the regression for different borrowing country groups, developed markets (DM), emerging markets (EM), and offshore financial centers (OFC), respectively. We find that the coefficient on the broad dollar is negative and significant for all three groups. In terms of the magnitude, cross-border dollar flows to emerging markets and offshore financial centers are more sensitive to fluctuations in the broad dollar than the flows to developed markets. The higher sensitivity with respect to the broad dollar for EM borrowing countries is consistent with the exchange rate risk-taking channel as in Bruno and Shin (2015ab). Given the high levels of currency mismatch for emerging market corporate borrowers (for example, Du and Schreger (2016)), a strengthening in the dollar has larger impacts on the tail risk of banks' EM loan portfolios, which then translates into greater contractions in cross-border dollar lending to EMs.

Overall, our results show that the dollar index has robust explanatory power over and above the bilateral dollar exchange rate, VIX and the U.S. policy rate for cross-border bank lending. These results support our 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.

Table 8: Panel Regressions of dollar cross-border lending on the broad dollar

	(1) benchmark	(2) equal-weight	(3) since GFC	(4) DM	(5) EM	(6) OFC
$\Delta Dollar_t$	-0.426***	-0.468***	-0.488***	-0.263**	-0.794***	-0.728***
	(0.117)	(0.100)	(0.134)	(0.115)	(0.155)	(0.143)
ΔBER_{it}	-0.174***	-0.0724**	-0.175*	-0.235***	-0.0957***	-0.311**
	(0.0524)	(0.0308)	(0.0936)	(0.0808)	(0.0348)	(0.115)
$\ln VIX_t$	-1.996**	-2.788***	-1.566*	-1.976**	-3.770***	-1.054**
	(0.869)	(0.637)	(0.917)	(0.944)	(1.094)	(0.377)
$\Delta \ln VIX_t$	0.00681	-0.00296	0.0250**	0.00393	0.00357	0.0156
	(0.0131)	(0.00930)	(0.0113)	(0.0146)	(0.00998)	(0.0320)
$\Delta IR_{US,t}$	0.102	-1.058**	0.436	0.181	-0.975	0.527
	(0.650)	(0.439)	(0.811)	(0.681)	(0.692)	(1.262)
Observations	6,759	6,759	4,133	1,943	4,096	720
R-Squared	0.066	0.058	0.110	0.058	0.106	0.084

Notes: 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 ($\Delta Dollar_t$), quarterly changes in the the bilateral exchange rate of the currency of the respective borrowing country vis-à-vis the US dollar (ΔBER_{it}), the log level of VIX ($\ln VIX_t$), quarterly changes in VIX ($\Delta \ln VIX_t$) and quarterly changes in the U.S. policy rate ($\Delta IR_{US,t}$) based on the actual Fed Funds rates and the shadow rate estimated by Wu and Xia (2016) during the zero-lower-bound period. All regressions are weighted by borrowing countries' average debt outstanding in the sample except in Column 2. Column 1 presents the benchmark estimation using the full sample from 2000Q1 to 2017Q2. Column 2 applies equal weights to all borrowing countries. Column 3 estimates using the subsample from 2007Q1 to 2017Q2. Columns 4-6 estimate the regression for flows into developed markets (DM), emerging markets (EM), and offshore financial centers (OFC), respectively. Country-level fixed effects are included in all regression specifications. Standard errors in parentheses are two-way clustered by quarter and borrowing country. *** $p < 0.01$, ** $p<0.05$, * $p<0.1$.

4.2 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:

$$\mathbf{B}\mathbf{y}_{it} = \mathbf{f}_i + \mathbf{A}(\mathbf{L})\mathbf{y}_{i,t-1} + \mathbf{u}_{it}, \tag{8}$$

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 $E(\boldsymbol{u}_t \boldsymbol{u}_s') = \mathbf{0}_m$ all $s \neq t$.

In our baseline specification, we set:

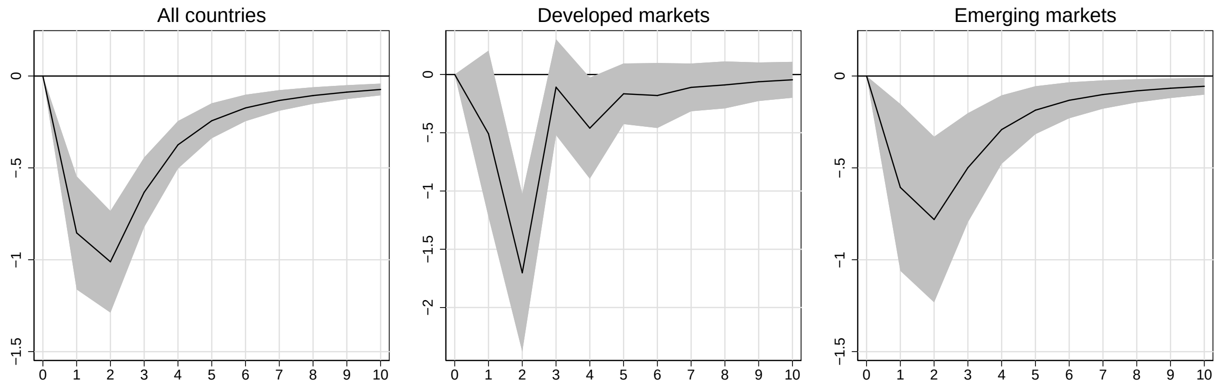
$$\mathbf{y}_{it} = [\Delta ir_{US,t}, \Delta ir_{i,t}, \ln VIX_t, \Delta xbl_{it}, \Delta Dollar_t]', \tag{9}$$

where $\Delta ir_{US,t}$ is the quarterly change in the US dollar policy rate, $\Delta ir_{i,t}$ is the quarterly change in the policy rate in country i, Δxbl_{it} is the quarterly growth rate in dollar-denominated lending (in percent), $\ln VIX_t$ is the log of the VIX index, and $\Delta Dollar_t$ 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 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). The results are robust to alternative ordering of variables.

Figure 5 displays the impulse responses from our SPVAR specification. They reveal that the broad dollar has a negative and strongly statistically significant impact on cross-border bank lending. This is the case for lending to borrowers from all countries, as well as for our distinct subsamples of lending to developed market and emerging market borrowers. The estimated negative impact is quite persistent, remaining statistically significant for up to

Figure 5: Impulse response functions of US dollar denominated cross-border bank lending to a US dollar exchange rate shock



Notes: All figures display the response of changes in cross-border lending to a one standard deviation shock to the broad dollar index (a 2.4% dollar appreciation in the sample). The estimates of our orthogonalized impulse response functions expressed in percent are based on a Cholesky decomposition with five endogenous variables ordered as $[\Delta ir_{US,t}, \Delta ir_{i,t}, \ln VIX_t, \Delta xbl_{it}, \Delta Dollar_t]$. The shaded area denotes 95% confidence intervals, obtained using a Gaussian approximation based on 1000 Monte Carlos draws from the estimated structural panel VAR. The left figure shows the impulse response for all borrowing countries. The middle figure shows the impulse response for the developed markets as borrowing countries. The right figure shows the impulse response for emerging markets as borrowing countries. The sample period is 2000Q1-2017Q2.

ten quarters after the occurrence of the shock. In terms of the magnitude, in response to a one standard deviation increase in the broad dollar index (a 2.4 percent dollar appreciation in the sample), the impulse response peaks at about -1 percent after two quarters, which indicates a 1 percent contraction on average in cross-border lending to all countries.

4.3 Exchange rates and cross-border flows in other currencies

In addition to the US dollar, the BIS locational banking statistics also reports cross-border flows denominated in four other major currencies: the British pound, the euro, the Japanese yen, and the Swiss franc. We now examine the relationship between strength of these major currencies and cross-border bank lending denominated in these other currencies. In particular, we regress the growth rate of the cross-border bank lending denominated in currency j to country i, $\Delta xbl_{it}^{(j)}$, on the change in the nominal effective exchange rate of currency j, $\Delta\overline{NEER}_t^{(j)}$, and the change in the bilateral exchange rate of currency i against j, $\Delta BER_{it}^{(j)}$, together with the log level and the change in VIX:

$$\Delta xbl_{it}^{(j)} = \alpha_i + \beta\Delta\overline{NEER}_t^{(j)} + \gamma\Delta BER_{it}^{(j)} + \delta\ln VIX_t + \eta\Delta\ln VIX_t + \varepsilon_{it}^{(j)}. \qquad (10)$$

Table 9: Panel Regressions of cross-border lending on the broad dollar

	(1)	(2)	(3)	(4)
	CHF	EUR	GBP	JPY
$\Delta\overline{NEER}_t^{(j)}$	-0.134	0.0990	0.208	-0.0823
	(0.191)	(0.0873)	(0.201)	(0.1000)
$\Delta BER_{i,j,t}$	0.0509	-0.0124	0.000397	-0.106***
	(0.0552)	(0.0224)	(0.0673)	(0.0308)
$\ln VIX_t$	-5.256***	-2.299***	-3.063*	-3.518***
	(1.323)	(0.594)	(1.569)	(0.978)
$\Delta\ln VIX_t$	-0.0462*	0.00154	-0.0410*	-0.0218
	(0.0275)	(0.00718)	(0.0208)	(0.0198)
Observations	5,455	5,829	5,554	5,432
R-Squared	0.037	0.033	0.024	0.045

Notes: This table shows results from panel regressions of borrowing-country specific quarterly growth rates in the cross-border bank lending (loans and debt securities) denominated in currency j on quarterly changes in the nominal effective exchange rate of currency i ($\Delta\overline{NEER}_t^{(j)}$), quarterly changes in the the bilateral exchange rate of the currency of the respective borrowing country vis-à-vis currency j ($\Delta BER_{it}^{(j)}$), the log level of VIX ($\ln VIX_t$), quarterly changes in VIX ($\Delta\ln VIX_t$). Columns 1-4 report the results for j equal to the Swiss franc (CHF), the euro (EUR), the British pound (GBP), and the Japanese yen (JPY), respectively. A Country-level fixed effects are included in all regression specifications. Standard errors in parentheses are two-way clustered by quarter and borrowing country. *** p <0.01, ** p<0.05, * p<0.1.

Table 9 shows the regression results. The nominal effective exchange rate of the other major currencies does not enter significantly. The bilateral exchange rate also does not enter significantly except for cross-border flows denominated in the Japanese yen. Together with the results in Section 3.4, we do not find a significantly triangular relationship between the spot exchange rate, cross-currency basis, and cross-border bank lending using other major currencies as the base currency. These results point to the unique role of the US dollar as an international funding currency in affecting leverage and risk taking via fluctuation in exchange rate valuations.

5 A model of the dollar, bank leverage and CIP

So far, we have documented empirically that the strength of the dollar is positively correlated with the price of dollar liquidity, as measured by the magnitude of CIP deviations, and negatively correlated with the quantity of dollar liquidity, as reflected in cross-border flows. In this section, we sketch a model in which a dollar appreciation increases the shadow cost of bank balance sheet capacity, thereby reducing the supply of dollar credit and increasing CIP deviations.

We provide a model of a bank located outside the United States, but with significant US dollar business. The bank's dollar business has two parts. The first is lending in dollars to borrowers in the cash market. The bank has a diversified global loan portfolios, including lending to emerging market corporates withsome currency mismatch on their corporate 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. Therefore, a stronger dollar increases the default risk on the banks' loan book, even though the bank does not have currency mismatch on their balance sheets. 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 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:

$$a_1 + a_2 = e + d \tag{11}$$

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:

$$r = a_1 r_1 + a_2 r_2 \tag{12}$$

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:

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

where $E\left(r\right)$ 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 (11).

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

$$\alpha\sigma_r \leq e \tag{13}$$

We transform the constraint by squaring both sides and dividing by α^2 to give:

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

Then, write the Lagrangean as:

$$\begin{aligned} \mathcal{L} &= E\left(r\right) - \lambda\left(\sigma_r^2 - \left(\frac{e}{\alpha}\right)^2\right) \\ &= E\left(r\right) - \lambda\sigma_r^2 + \lambda\left(\frac{e}{\alpha}\right)^2 \end{aligned} \tag{14}$$

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

The third term in the Lagrangean $\mathcal{L}$ in (14) 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:

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

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:

$$\begin{bmatrix} a_1 \\ a_2 \end{bmatrix} = \frac{1}{2\lambda}\Sigma^{-1} \begin{bmatrix} \mu_1 \\ \mu_2 \end{bmatrix}. \tag{15}$$

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 (15) 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:

$$\lambda = \frac{\alpha}{2e}\sqrt{\mu'\Sigma^{-1}\mu} \tag{16}$$

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

Substituting (16) into the first-order condition (15) allows us to solve for the optimal portfolio of the bank:

$$\begin{bmatrix} a_1 \\ a_2 \end{bmatrix} = \frac{e}{\alpha} \cdot \frac{1}{\sqrt{\mu'\Sigma^{-1}\mu}}\Sigma^{-1}\begin{bmatrix} \mu_1 \\ \mu_2 \end{bmatrix} \tag{17}$$

The optimal portfolio in (17) 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 (17), but in which we have equity for the banking sector as a whole. Specifically, if e_k is the equity of bank k, let:

$$E = \sum_{k \in B} e_k \tag{18}$$

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 (17), the assets of the banking sector as a whole are given by:

$$\begin{bmatrix} A_1 \\ A_2 \end{bmatrix} = \frac{E}{\alpha} \cdot \frac{1}{\sqrt{\mu' \Sigma^{-1} \mu}} \Sigma^{-1} \begin{bmatrix} \mu_1 \\ \mu_2 \end{bmatrix} \tag{19}$$

It remains to solve for μ_1 and μ_2 from the market-clearing condition. Denote by $X_1(\mu_1)$ the demand for dollar loans by EM corporates, which is a decreasing function of μ_1. Denote by $X_2(\mu_2)$ the demand for dollars in the FX swap market, decreasing in μ_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 (19), the market clearing condition can be written:

$$\begin{bmatrix} X_1(\mu_1) \\ X_2(\mu_2) \end{bmatrix} = \frac{E}{\alpha} \cdot \frac{1}{\sqrt{\mu' \Sigma^{-1} \mu}} \Sigma^{-1} \begin{bmatrix} \mu_1 \\ \mu_2 \end{bmatrix} \tag{20}$$

We now consider the comparative statics of an appreciation of the US dollar. A dollar appreciation affects the cross-currency basis in two ways. First,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 E. . Second, a dollar appreciation increases the tail risk on the banks' loan portfolio, resulting in a higher level of Σ. To restore market clearing, both μ_1 and μ_2 increase. For us, it is the increase in μ_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 (16), the shadow value of bank balance sheet capacity increases for two reasons. The first is that the price of credit increases and raises μ. 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.

6 Bank Equities and the Broad Dollar

Finally, consistent with the model outlined in the previous section, we provide empirical support that a strong dollar has a negative impact on bank equities, particularly in currency areas with more negative cross-currency basis. We focus on a sample of 51 internationally active 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 10, 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 2, 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

Table 10: Regressions of bank equity returns on the broad dollar movements

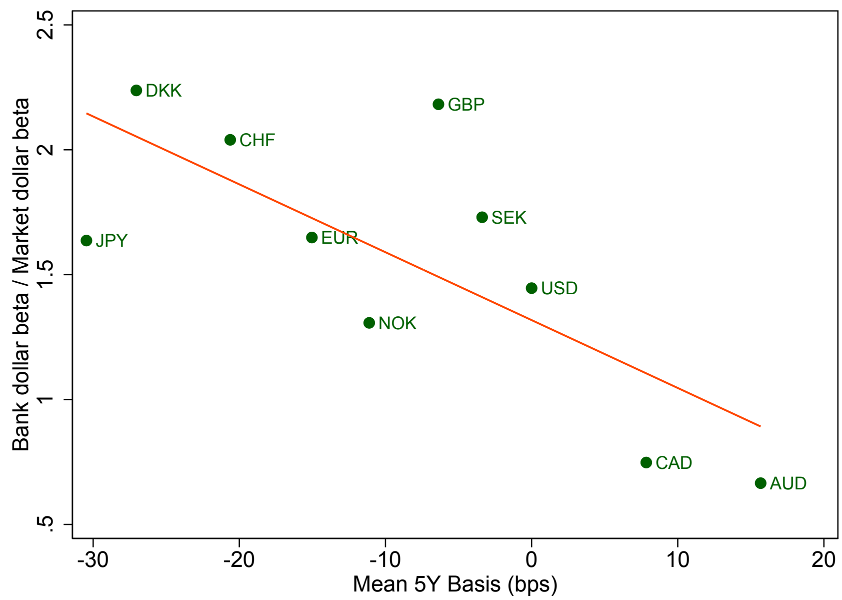
	(1)	(2)	(3)
	Bank Equity Return	Bank Equity Return	Bank Equity Return
$\Delta Broad_t$	-2.016***	-0.268**	-0.0303
	(0.127)	(0.103)	(0.0838)
$\Delta Broad_t \times bs_t$			2.875***
			(0.808)
$\Delta Market_t$		1.246***	1.236***
		(0.0527)	(0.0524)
Constant	-0.00444***	-0.00762***	-0.00728***
	(3.25e-05)	(0.000122)	(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, $^{***}p < 0.01$, $^{**}p < 0.5$ and $^{*}p < 0.1$.

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 6 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

Figure 6: 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.

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.

References

[1] Adrian, T., E. Etula, and T. Muir (2014): "Financial Intermediaries and the Cross-Section of Asset Returns," *Journal of Finance*, 69, 2557–2596.

[2] Adrian, T., and H. S. Shin (2014): "Procyclical Leverage and Value-at-Risk," *Review of Financial Studies*, 27, 373–403.

[3] Baba, N., R. N. McCauley, and S. Ramaswamy (2009): "US Dollar Money Market Funds and Non-US Banks," *BIS Quarterly Review*, pp. 65–81.

[4] Baba, N., F. Packer, and T. Nagano (2008): "The Spillover of Money Market Turbulence to FX Swap and Cross-Currency Swap Markets," *BIS Quarterly Review*, pp. 73–86.

[5] Bernanke, B., and M. Gertler (1989): "Agency Costs, Net Worth, and Business Fluctuations," *American Economic Review*, pp. 14–31.

[6] Borio, C., R. N. McCauley, P. McGuire, and V. Sushko (2016): "Covered interest parity lost: understanding the cross-currency basis," *BIS Quarterly Review*.

[7] Bottazzi, J.-M., J. Luque, M. Pascoa, and S. M. Sundaresan (2012): "Dollar Shortage, Central Bank Actions, and the Cross Currency Basis," *Working Paper*.

[8] Brunnermeier, M. K., and L. H. Pedersen (2009): "Market Liquidity and Funding Liquidity," *Review of Financial studies*, 22(6), 2201–2238.

[9] Brunnermeier, M. K., and Y. Sannikov (2014): "A Macroeconomic Model with a Financial Sector," *American Economic Review*, 104(2), 379–421.

[10] Bruno, V., and H. S. Shin (2015a): "Capital flows and risk-taking channel of monetary policy," *Journal of Monetary Economics*, 71, 119–32.

[11] ——— (2015b): "Cross-Border Banking and Global Liquidity," *Review of Economic Studies*, 82, 535–564.

[12] Coffey, N., W. B. Hrung, and A. Sarkar (2009): "Capital Constraints, Counterparty Risk, and Deviations from Covered Interest Rate Parity," *Federal Reserve Bank of New York Staff Report 393*.

[13] Du, W., A. Tepper, and A. Verdelhan (2016): "Deviations from Covered Interest Rate Parity," *Working Paper*.

[14] Gabaix, X., and M. Maggiori (2015): "International Liquidity and Exchange Rate Dynamics," *Quarterly Journal of Economics*, 130(3), 1369–1420.

[15] Garleanu, N., and L. Pedersen (2011): "Margin-Based Asset Pricing and Deviations from the Law of One Price," *Review of Financial Studies*, 24, 1980–2022.

[16] Greenwood, R., and D. Vayanos (2014): "Bond Supply and Excess Bond Returns," *Review of Financial Studies*, 27, 663–713.

[17] Griffolli, M. T., and A. Ranaldo (2011): "Limits to Arbitrage during the Crisis: Funding Liquidity Constraints and Covered Interest Parity," *Working Paper*.

[18] He, Z., and A. Krishnamurthy (2012): "A Model of Capital and Crises," *The Review of Economic Studies*, 79(2), 735–777.

[19] He, Z., and A. Krishnamurthy (2013): "Intermediary Asset Pricing," *American Economic Review*, 103(2), 732–770.

[20] Holmstrom, B., and J. Tirole (1997): "Financial Intermediation, Loanable Funds, and the Real Sector," *Quarterly Journal of economics*, pp. 663–691.

[21] Ivashina, V., D. S. Scharfstein, and J. C. Stein. (2015): "Dollar Funding and the Lending Behavior of Global Banks," *Quarterly Journal of Economics*, 130(3), 1241–1281.

[22] Liao, G. Y. (2016): "Credit Migration and Covered Interest Rate Parity," *Working Paper, Harvard Business School.*

[23] Miranda-Agrippino, S., and H. Rey (2015): "World Asset Markets and the Global Financial Cycle," *Working Paper, Bank of England and London Business School.*

[24] Rey, H. (2013): "Dilemma not Trilemma: The Global Financial Cycle and Monetary Policy Independence," *Proceedings - Economic Policy Symposium - Jackson Hole, Federal Reserve of Kansas City Economic Symposium*, pp. 285–333.

[25] Rime, D., A. Schrimpf, and O. Syrstad (2017): "Segemented Money Markets and CIP Arbitrage," *Working Paper.*

[26] Sushko, V., C. Borio, R. McCauley, and P. McGuire (2016): "The failure of covered interest parity: FX hedging demand and costly balance sheets," *BIS Working Paper No. 590.*

[27] Vayanos, D., and J.-L. Vila (2009): "A Preferred-Habitat Model of the Term Structure of Interest Rates," *Working Paper.*

[28] Verdelhan, A. (Forthcoming): "The Share of Systematic Risk in Bilateral Exchange Rates," *Journal of Finance.*

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