Covered Interest Parity Deviations: Macrofinancial Determinants

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May 31, 2020

Abstract

This paper studies how several macrofinancial factors are associated over time with the evolution of covered interest parity (CIP) deviations in the decade after the global financial crisis. Changes in a number of risk- and policy-related factors have a significant association with the evolution of CIP deviations. Key measures of FX market liquidty and intermediaries' risk-taking capacity are strongly correlated with the cross-currency basis (the deviation from CIP), and the close relationship between broad U.S. dollar strength and the basis is driven mainly by a common factor depending on other safe-haven currencies' comovements. Post-crisis monetary policies also play a role, as demonstrated by the relationship between CIP deviations, central bank balance sheet, and term premia. Further highlighting the role of bank regulation, we offer evidence that the year-end dynamics of the three-month dollar basis depend on financial regulations targeting global systemically important financial institutions. Data on central bank swap line draws at quarter ends yield a lower-bound estimate of how much regulation-induced dollar funding shortages affect the basis.

JEL classification numbers: F31, G15.

1 Introduction

The principle of covered interest parity (CIP), set out by Keynes (1923) during the floating exchange rate period after World War I, is a fundamental building block of international finance.

*This paper is a substantial revision of the last version, issued as NBER Working Paper 26129 (August 2019). Cerutti: Asia and Pacific Department, International Monetary Fund (IMF). Obstfeld: Department of Economics, University of California, Berkeley; Peterson Institute for International Economics; NBER; and CEPR. Zhou: Department of Economics, Princeton University. An earlier draft was completed while the authors were all at the IMF Research Department. We thank Paul Cashin, Oyakhilome Ibhagui, Gee Hee Hong, Anne-Charlotte Paret-Onorato, Piotr Kopyrski, Roman Lafarguette, and Chris Walker for their comments on the earlier draft. Zhou acknowledges financial support from the International Economics Section at Princeton University. All errors are our own. The opinions expressed herein are solely the responsibility of the authors and should not be interpreted as reflecting the views of the IMF, its Executive Board, IMF management, or the National Bureau of Economic Research.

Absent counterparty risk, CIP is a pure no-arbitrage relationship that equates the premium of a currency's forward over its spot exchange rate (both rates expressed as the price of foreign currency) to its nominal interest-rate advantage over foreign currency. CIP is the most fundamental relationship linking integrated money and foreign exchange markets.

For several decades until the Global Financial Crisis (GFC), CIP appeared to hold quite closely—even as a broad macroeconomic description applying to weekly or even daily data. But as a growing number of studies document, and as we explore further below, the relationship seems to have broken down since the onset of the GFC. That CIP deviations emerged in the turbulence of the GFC is not surprising in view of counterparty fears, and is not unprecedented either. What has been more puzzling is the continuation of CIP deviations – at times larger, at times smaller – well after the GFC, and even for virtually riskless transactions (Du, Tepper and Verdelhan, 2018). This phenomenon is important for at least three reasons. First, it may be evidence of financial-market frictions or unintended policy consequences that potentially entail inefficient resource allocation. Second, it may imply a change in the way macroeconomic policies (especially monetary policies) transmit across borders. Third, CIP deviations may elucidate asset pricing in a world where financial intermediary constraints are stochastic and potentially binding (Du, Hebert and Huber, 2019) – to some degree they capture financial stresses that simultaneously affect a range of markets.[1]

Even before the GFC, CIP seems to have rarely held exactly. Detailed tick-frequency studies such as Akram, Rime and Sarno (2008) were able to detect small and transient – but economically meaningful – departures from CIP. Nonetheless, CIP still provided an excellent guide to the relationship among forward and spot exchange rates and interest rates at the macro level. As Akram, Rime and Sarno (2008, p.238) put it, "the lack of predictability of arbitrage and the fast speed at which arbitrage opportunities are exploited and eliminated imply that a typical researcher in international macro-finance using data at the daily or lower frequency can safely assume that CIP holds." This claim is no longer valid.

The failure of CIP has several policy implications. A first relates to the global financial cycle, and specifically, the claim that even small economies can exercise monetary policy independently of the Federal Reserve's interest rate choice because forward and spot exchange rates will adjust automatically to insulate the domestic monetary policy setting from the Fed's (Bernanke, 2017). Unless CIP holds closely, however, this claim is no longer true: domestic actors may be able to borrow or lend synthetically in domestic currency at a rate that is different from the domestic central bank rate, but dependent on Fed policy. If so, the failure of CIP raises a second macroeconomic policy question: precisely how are monetary policies transmitted across borders and into domestic funding conditions? To know the answer, we need to have a good sense of what drives CIP departures. Finally, the failure of CIP is a *prima facie* argument for the importance of central bank swap lines that allow financial-sector institutions more easily to fund in foreign currencies

[1] Levich (2017) surveys the history of research on CIP and discusses implications of its breakdown.

when necessary (Bahaj and Reis, 2020*a*,*b*).

A growing recent literature tries to rationalize recent CIP deviations. Different authors have stressed a range of often complementary potential drivers, ranging from regulation-induced or other arbitrage limits (Ivashina, Scharfstein and Stein, 2015; Du, Tepper and Verdelhan, 2018; Rime, Schrimpf and Syrstad, 2019; Cenedese, Della Corte and Wang, 2020), to changes in banks' balance-sheet or risk-taking capacity connected with U.S. dollar appreciation (Avdjiev, Du, Koch and Shin, 2019), to interest rate differences across currencies and their impact on the FX swap market (Du, Tepper and Verdelhan, 2018; Borio, Iqbal, McCauley, McGuire and Sushko, 2018; Bräuning and Ivashina, forthcoming). Rime, Schrimpf and Syrstad (2019) argue that CIP deviations are not materially significant for most potential arbitrageurs given their true marginal dollar funding rates, while those few actors with the lowest dollar funding rates, who are in a position to engage in covered interest arbitrage, are constrained by regulatory factors.

This paper documents the evolution of CIP deviations at the "macrofinancial" level referenced by Akram, Rime and Sarno (2008), using different measures to evaluate the importance over time of key drivers proposed in the literature. An advantage of this approach is that it can indicate the factors important enough to have driven macro-level CIP deviations since the GFC, and their potentially changing roles given a shifting macroeconomic environment – comprising (among other things) the euro area crisis, unconventional monetary policies, and key regulatory changes.

The outline and the main findings of the paper are as follows. Section 2 sets out a methodology for investigating correlates of CIP deviations, along with preliminary panel and time-series results across 10 advanced-economy currencies vis-à-vis the U.S. dollar. As in a number of earlier studies, notably Avdjiev, Du, Koch and Shin (2019), we regress the cross-currency LIBOR basis – the deviation from CIP – on potential drivers. We focus on the three-month tenor. To smooth out high-frequency noise in line with our macro focus, we work with monthly averges of daily data. Like Avdjiev, Du, Koch and Shin (2019), we find that CIP deviations emerge abruptly starting with the GFC and that a higher nominal effective U.S. dollar exchange rate is strongly associated over 2010-19 with a more negative basis. Also in line with their findings, the implied volatility of S&P options (the VIX, stressed in some earlier work on global financial cycles as an indicator of financial tightening such as Bruno and Shin (2015) and Miranda-Agrippino and Rey (forthcoming)) is generally not statistically significant. In addition, however, we detect important roles for a measure of exchange-market liquidity and for changes in the U.S. interest rate. Holding the foreign interest rate constant, an increase in the U.S. interest rate leads to a less negative dollar basis in the time series dimension, seemingly in contrast to the longer-term cross-sectional pattern reported and rationalized by Du, Tepper and Verdelhan (2018), and likely reflecting broader financial market effects. Time-series regressions for individual countries also reveal important heterogeneity among currencies, likely related to the issuing countries' differing domestic financial structures. These deserve further research.

Section 3 looks more closely at these regularities and investigates some explicit potential risk-based drivers of the basis, asking if they can displace the measured strong association between the basis and the U.S. dollar. We find that a measure of limited marginal balance-sheet capacity, the leverage ratio of U.S. primary dealers, adds significantly to raising the cost of synthetic dollar funding relative to that of direct dollar funding. The section also looks more deeply into the U.S. dollar's role, distinguishing between a strong dollar's general negative impact on balance sheet capacity, as posited by Avdjiev, Du, Koch and Shin (2019), and the role of broad dollar appreciation as an indication of a more general global flight into safe haven currencies. Alternative methodologies for identifying the safe haven component of broad dollar swings reveal an important role of safe haven currencies' comovement in driving the U.S. currency's impact on the basis, and a much more tenuous role of the residual dollar movement.

A low interest rate environment and unconventional monetary policies are among the drivers of global capital flows post-crisis, and thus have the potential to affect deviations from CIP through portfolio rebalancing, hedged dollar borrowing, and international financial flows. In Section 3, we show evidence supporting a relation between central banks' balance sheets and the dollar basis over the last decade. Moreover, an important metric to evaluate the profitablity of hedged dollar investment – the relative term premium across currencies – is a significant correlate of CIP deviations after 2014. This term premium effect may be driven by supply-side factors and is complementary to the safe-haven dollar effect. Along with the loss of statistical significance of primary dealers' leverage ratio after 2014 and a seeming weakening in the influence of dollar swings, our findings suggest that the underlying drivers of post-crisis CIP deviations have varied over time.

Section 4 extends the findings of Du, Tepper and Verdelhan (2018) on the dynamics of the dollar basis near regulatory reporting dates – findings that they characterized as "smoking gun" evidence on the role of regulatory constraints on potential arbitrageurs' balance sheets. We show that the capital surcharge for globally systemically important banks (GSIBs), introduced on January 1, 2016 and fully implemented by January 1, 2019, has a notably strong effect in driving three-month dollar bases in the fourth quarter, when U.S. and euro area regulators evaluate GSIB balance sheets. Finally, as period-ends offer a unique opportunity to investigate the role of imbalance in dollar demand and supply in driving deviations from CIP, we exploit central bank swap lines' role in bridging dollar funding shortfalls (Bahaj and Reis, 2020*a*,*b*) at quarter-ends to infer the response of the one-week dollar basis to regulation-induced dollar shortages.

Section 5 concludes.

2 The evolution of CIP deviations: A regression approach

As many authors have noted, CIP held fairly well up until the Global Financial Crisis, even based on indicative LIBOR rates of interest (see Figure 1). The relationship broke down (understandably) during the height of the crisis, but (more surprisingly), has not been re-established afterward, and for many currencies, in particular the euro and the yen, the basis against the U.S.

dollar has generally been negative. This change has given rise to a large literature. Generally, a negative dollar basis is ascribed to a need by globally active financial institutions to hedge or fund dollar investments, coupled with limits to even short-term arbitrage that have become tighter in the inter-crisis years. These limits are in the sprit of Keynes (1923), who wrote that, "the floating capital normally available, and ready to move from center to center for the purpose of taking advantage of moderate arbitrage profits between spot and forward exchange, is by no means unlimited in amount, and is not always adequate to the market's requirements (Keynes, 1923, p.129)."

For example, a euro area bank that cannot access the cheapest direct dollar funding at rate r, but needing to repay USD 1, could instead borrow EUR S at an interest rate of r^*, where S is the spot euro price of dollars; buy a dollar in the spot market and repay its debt; and then buy $S(1+r^*)$ euros in the forward market for a promise of $S(1+r^*)/F$ dollars, where F is the forward euro/dollar rate. Next period the bank will owe USD $S(1+r^*)/F$ rather than the USD $1+r$ it would have owed had it been able to borrow dollars directly, but it can repeat the process to obtain the dollars it will then need. If the unavailability of direct dollar credit is a binding constraint, then we would expect a negative basis, that is, that the cost of synthetic dollar borowing exceeds that of direct borrowing, or $S(1+r^*)/F > 1+r$.

Given this demand side effect for forward euros, why is there not a corresponding supply from those who can borrow dollars cheaply, and thus could engage in CIP arbitrage? The emerging answer in the literature focuses on limited balance sheet capacity, driven by financial frictions including regulatory constraints that have intensified in the 2010s. We provide further evidence on these in this paper.

Interestingly, experience of the last decade shows that older accounts of the joint determination of forward and spot exchange rates, once thought to be outdated, may have regained relevance. Tsiang (1959) (who reported the quotation from Keynes repeated above) presented a classic analysis that more recent theoretical work, such as Gabaix and Maggiori (2015), echoes. Tsiang's analysis classifed market participants as (1) those needing to hedge trade receipts; (2) those speculating on exchange rate changes – most dramatically, possible parity changes within the Bretton Woods system, though possibly also exchange movements within its allowed fluctuation bands; and (3) those arbitraging covered interest differentials. In the modern world of massive two-way financial flows, trade motives seem swamped by financial motives, and among those, covered return differentials are likely most important, given the near random walk behavior of floating exchange rates. These considerations justify the focus on financial factors in understanding current departures from CIP.[2]

[2]Obstfeld (1983) developed a model of the dollar-deutschemark exchange rate based on covered interest differentials, with some empirical success.

2.1 Measurement, data and empirical strategy

For a given foreign currency and the U.S. dollar, a deviation from covered interest rate parity refers to the wedge between two differentials: (i) the difference between the n-period forward exchange rate and spot exchange rate, which we denote by $f_{t,t+n} - s_t$, annualized and with both exchange rates expressed in units of foreign currency per dollar; and (ii) the difference in the nominal interest rates earned by holding the currencies, which we denote by $r^*_{t,t+n} - r_{t,t+n}$, the n-period annualized interest rate difference between foreign currency (with an asterisk) and U.S. dollar interest rates. In the absence of financial frictions, an arbitrageur could take advantage of a deviation from covered interest parity and earn a riskless profit. Alternatively, and equivalently if there are no frictions, no one would borrow dollars if it were cheaper to borrow foreign currency, buy dollars with the proceeds, and sell the dollars n periods forward for foreign currency (as in a foreign exchange swap) to repay the initial foreign-currency loan. In frictionless financial markets, therefore, the CIP deviation for any horizon n, $x_{t,t+n}$, also known as n-period cross-currency basis and shown in equation (1) below, should equal zero:

$$x_{t,t+n} = r_{t,t+n} - [r^*_{t,t+n} - (f_{t,t+n} - s_t)]. \tag{1}$$

The sign of $x_{t,t+n}$ reflects the direction of CIP deviations. We call the deviation "a negative dollar basis" if $x_{t,t+n} < 0$, as a negative deviation suggests that direct dollar funding is cheaper than synthetic dollar funding that works by borrowing foreign currency and swapping it into dollars.[3]

The evolution of the cross-currency dollar basis exhibits clear deviations from CIP after the 2008-09 global financial crisis (GFC). Figure 1 plots the basis computed from indicative interbank interest rates (henthforth referred to as "Libor basis"). (Here, and throughout our empirical analysis, we will express the basis in terms of basis points of annualized returns.) Before the GFC, CIP deviations were very small and fluctuated around zero. This feature is in line with the findings of Akram, Rime and Sarno (2008), as described above.[4] Starting with the GFC, however, CIP broke down as a sizable unexploited cross-currency wedge opened. During the GFC, the dollar basis reached levels of about -200 basis points, and experienced another dip during the height of the Eurozone debt crisis. While most three-month dollar bases had been steadily reverting to near zero through 2013, they widened again after mid-2014. Most currencies have a negative dollar basis, implying a cost advantage for direct dollar funding, were it available at a marginal cost near Libor. "Carry" currencies such as the Australian and New Zealand dollars, on the other hand, display positive bases against the U.S. dollar (that is, $x_{t,t+n} > 0$). The positive sign indicates that direct U.S. dollar funding is costlier than synthetic funding based on swapping AUD or NZD borrowings into U.S. currency. Nonetheless, financial institutions in Australia and New

[3]To see why, note that by (1), $x_{t,t+n} < 0$ is equivalent to $r_{t,t+n} < r^*_{t,t+n} + (s_t - f_{t,t+n})$ where $s_t - f_{t,t+n}$ is the cost of swapping into dollars (which augments the borrowing-cost component captured by the foreign interest rate).

[4]See McCormick (1979) and Clinton (1988) for earlier empirical evidence supporting CIP.

Zealand raise a considerable proportion of wholesale domestic-currency funding from hedged foreign-currency denominated issuances (principally U.S. dollar, yen, and euro) in light of the relatively limited sizes of their local domestic-currency funding bases (Arsov, Moran, Shanahan and Stacey, 2013; Callaghan, 2017).

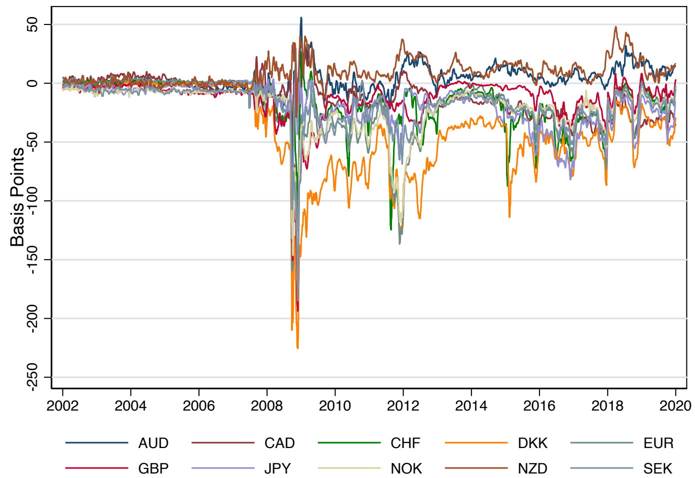


Figure 1: Three-month Libor basis: 2002-2019

Note: Figure 1 plots 10-day averages of three-month dollar basis, based on IBOR rates for G10 curencies from 2002 to 2019.

Our baseline empirical specification builds on Equation (1). If CIP holds, $x_{t,t+n} = 0$. In that case, regressing the forward premium $f_{t,t+n} - s_t$ on the interest rates $r^*_{t,t+n}$ and $r_{t,t+n}$, plus a constant, should generate estimated coefficients of 1 for foreign interest rate, -1 for the U.S. interest rate, and 0 for the constant, with an R^2 of 1. In the presence of CIP deviations ($x_{t,t+n} \neq 0$), however, the regression equation

$$f_{t,t+n} - s_t = \alpha + \beta^* r^*_{t,t+n} - \beta r_{t,t+n} + \varepsilon_t$$

may have coefficients β^* and β different from 1, and a constant term α different from 0. Equivalently, subtracting $r^*_{t,t+n} - r_{t,t+n}$ from (1) yields the regression specification

$$x_{t,t+n} = \alpha + \gamma^* r^*_{t,t+n} - \gamma r_{t,t+n} + \varepsilon_t, \tag{2}$$

in which α may be nonzero and the coefficients $\gamma^* = \beta^* - 1$ and $\gamma = \beta - 1$ potentially are nonzero as well. To avoid possible unit roots and for consistency with prior literature (Avdjiev, Du, Koch and Shin, 2019), our preferred specification is (2) in first differences:

$$\Delta x_{t,t+n} = \alpha + \gamma^* \Delta r^*_{t,t+n} - \gamma \Delta r_{t,t+n} + \eta_t, \tag{3}$$

where $\eta_t = \Delta\varepsilon_t$. We will sequentially augment the equation with additional regressors to assess their correlations with changes in the basis.

The data that we use are changes in monthly averages of Libor bases, interest rates, and additional potential explanatory variables. By using monthly averages, our regressions aim to highlight drivers of CIP deviations at a relatively lower frequency, at the same time alleviating issues related to period-end jumps in the bases.[5] Our sample begins in January 2002 and ends in December 2019. We largely follow Du, Tepper and Verdelhan (2018) to construct our measure of the Libor basis. The data appendix contains more details on data sources.

2.2 Explaining CIP deviations: Interest rates

Table 1 presents an initial panel regression based on the specification in (3).[6] The findings cover three periods, pre-GFC (2002-06), GFC (2007-09), and post-GFC (2010-2019); they examine both the Libor and Treasury bases; and they include currency fixed effects. The table shows that for interbank rates of interest, they are economically or statistically insignificant correlates of the basis, apart from the market disruptions of 2007-09. For Treasury rates, as is evident in the raw data, there are significant departures from CIP in every period, consistent with the idea that Treasurys yield an additonal liquidity return, as modeled by Jiang, Krishnamurthy and Lustig (2019) and Engel and Wu (2020).

The individual currency results in Table 2, which look only at the Libor basis, show considerable herogeneity in some periods. For the pre-GFC sample, the results largely mirror those in the panel regressions of Table 1. The same is largely true for the GFC years, with the exception of the Japanese yen, where the coefficient on the change in the Japanese interest rate is large and positive rather than negative. This sign pattern indicates that over time, a rise in the Japanese interest rate makes the dollar basis more positive in the 2007-09 sample, paradoxically *lowering* the incentive for covered interest arbitrage from dollars into yen.

Du, Tepper and Verdelhan (2018) showed that for the post-GFC period, there is a similar cross-sectional relationship between long averages of the basis and the interest differential $r_{USD} - r_i^*$, where i runs over the G10 currencies: Across i, the higher is the interest difference $r_{USD} - r_i^*$, the more negative is the dollar basis x_i. They reason that a lower interest rate r_i^* compared with the r_{US} will induce more synthetic dollar funding in currency i and more flows from currency i into hedged long-term dollar assets. The resulting forward dollar sales, however, create an imbalance for swap dealers (as also argued by Rime, Schrimpf and Syrstad (2019)). As dealers rebalance order flows, the forward premium on currency i must rise by even more than the rise in the USD-currency i interest difference (a decline in $f - s$). The more negative basis increases the incentive for CIP arbitrage by institutions that can obtain cheap dollar funding, allowing the associated flow of forward foreign-currency sales to rebalance the swap market.

[5]In Section 4.1, we offer evidence that in recent years, longer-tenor CIP deviations (such as three-month dollar bases) are affected by year-end spikes, analogous to the quarter-end spikes visible for one-week and one-month tenors.

[6]For all panel regressions, we report Driscoll and Kraay (1998) standard errors. The estimated standard errors barely change if we use the fixed-b estimator proposed by Kiefer and Vogelsang (2005).

If this cross-sectional pattern held in the time series, then in panel (c) of Table 2 (covering the post-GFC period), we would expect to see positive coefficients on Δr^* and negative coefficients on Δr. For the coefficient on Δr^*, this pattern indeed holds for the Swiss franc, Danish krone, and Japanese yen, but not clearly for the other currencies. These differences deserve further exploration. For the change in the USD rate, Δr, the coefficient is uniformly positive, and in half the cases statistically and economically significant. This finding – that a rise in the dollar interest rate makes the dollar cross-currency basis less negative – contradicts the cross-sectional result and suggests that changes in dollar interest rates may well have different effects on the basis than changes in other interest rates, perhaps because they are associated with broader financial-market effects. For example, if a rise in the dollar interest rate compresses the global demand for dollar funding, that change could be associated with fewer forward dollar sales by synthetic dollar borrowers, and thus lower equilibrium purchases of forward dollars by covered interest arbitrageurs.

	IBOR basis			**Treasury basis**		
	(1)	(2)	(3)	(4)	(5)	(6)
Δx	02-06	07-09	10-19	02-06	07-09	10-19
Δr^*	-0.01**	-0.20***	0.06	-0.10**	-0.22**	0.07
	(0.01)	(0.06)	(0.09)	(0.04)	(0.10)	(0.10)
Δr	0.00	0.06	0.13	0.21**	0.55***	0.25**
	(0.01)	(0.06)	(0.09)	(0.09)	(0.18)	(0.11)
N	590	360	1200	590	360	1200
R^2	0.007	0.113	0.014	0.075	0.220	0.027

Table 1: 3-month dollar basis and interest rates

Note: This table reports the results of simple panel regressions of monthly changes in 3-month dollar basis (IBOR/treasury) on corresponding interest rates. The panel consists of G10 currencies against US dollar. Samples are split to before (02-06), during (07-09), and after (10-19) the financial crisis. Monthly averages are used. Driscoll and Kraay (1998) standard errors are reported: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Δx	AUD	CAD	CHF	DKK	EUR	GBP	JPY	NOK	NZD	SEK
Δr^*	-0.01	-0.04**	-0.01	-0.03*	-0.02	-0.00	-0.01	-0.00	-0.01	-0.01
	(0.01)	(0.02)	(0.01)	(0.02)	(0.02)	(0.02)	(0.04)	(0.00)	(0.02)	(0.01)
Δr	0.01	0.01	-0.00	0.01	-0.01	-0.02***	0.02	0.00	-0.00	0.01
	(0.01)	(0.01)	(0.01)	(0.02)	(0.01)	(0.01)	(0.02)	(0.01)	(0.02)	(0.01)
Constant	-0.05	-0.03	0.03	-0.04	0.05	0.09	-0.07	-0.05	0.06	-0.13
	(0.16)	(0.18)	(0.10)	(0.16)	(0.15)	(0.08)	(0.19)	(0.12)	(0.14)	(0.08)
N	59	59	59	59	59	59	59	59	59	59
R^2	0.008	0.052	0.007	0.028	0.066	0.050	0.015	0.003	0.004	0.007

(a) Pre-crisis (2002-2006)

Δx	AUD	CAD	CHF	DKK	EUR	GBP	JPY	NOK	NZD	SEK
Δr^*	-0.12***	-0.14**	-0.24*	-0.49***	-0.26***	-0.22**	0.52*	-0.22***	-0.09	-0.20***
	(0.02)	(0.07)	(0.14)	(0.08)	(0.06)	(0.09)	(0.31)	(0.06)	(0.06)	(0.06)
Δr	0.07	0.03***	0.17	0.06	-0.00	0.14	-0.10***	-0.02	0.19***	0.07
	(0.06)	(0.01)	(0.11)	(0.05)	(0.05)	(0.12)	(0.04)	(0.04)	(0.05)	(0.06)
Constant	0.11	-1.36	0.42	-4.53	-3.20	-0.98	-1.74	-1.95	1.71	-1.51
	(0.69)	(1.33)	(1.15)	(3.24)	(2.09)	(2.25)	(1.19)	(2.97)	(1.25)	(2.06)
N	36	36	36	36	36	36	36	36	36	36
R^2	0.114	0.080	0.083	0.417	0.231	0.084	0.095	0.269	0.324	0.144

(b) Crisis (2007-2009)

Δx	AUD	CAD	CHF	DKK	EUR	GBP	JPY	NOK	NZD	SEK
Δr^*	-0.08**	0.01	0.70**	0.70***	-0.22	-0.24*	2.51***	-0.40***	-0.12***	0.16
	(0.04)	(0.10)	(0.31)	(0.21)	(0.30)	(0.14)	(0.57)	(0.13)	(0.05)	(0.16)
Δr	0.13***	0.13*	0.23**	0.17	0.06	0.23***	0.22**	0.07	0.27***	0.10
	(0.05)	(0.08)	(0.09)	(0.13)	(0.18)	(0.08)	(0.11)	(0.15)	(0.09)	(0.10)
Constant	-0.23	-0.30	0.36	1.26	-0.09	-0.22	0.39	-0.06	-0.51	0.16
	(0.33)	(0.36)	(0.51)	(0.85)	(0.54)	(0.40)	(0.66)	(0.63)	(0.44)	(0.52)
N	120	120	120	120	120	120	120	120	120	120
R^2	0.044	0.032	0.103	0.163	0.013	0.055	0.177	0.156	0.151	0.049

(c) Post-crisis (2010-2019)

Table 2: Libor basis and interest rates: Time-series evidence

Note: This table reports the results of simple time-series regressions of monthly change in IBOR basis on IBOR rates. The panel consists of G10 currencies against US dollar. Samples are split to before (02-06), during (07-09), and after (10-19) the financial crisis. Monthly averages are used. Autocorrelation-robust standard errors with lag selection according to Newey and West (1994) are reported. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

2.3 Explaining CIP deviations: The U.S. dollar and other correlates

We next turn to other correlates of the dollar basis.

Table 3 examines the relationship in a panel regression of the dollar basis on three potential indicators of stresses in financial markets. We focus on the Libor basis, although we also give results for the Treasury basis for comparison.

Writers such as Bruno and Shin (2015) have noted the role of the U.S. dollar's stength in foreign exchange markets as an indicator of global financial tightness and in particular, risk-off sentiment. Avdjiev, Du, Koch and Shin (2019) document that a increases in a broad index of nominal dollar value are associated with more negative dollar bases, and they present evidence that dollar strength discourages cross-border dollar lending by global banks. Column (3) in Table 3 strongly reaffirms this result for 2010-19: the coefficient on the broad dollar index is economically important and startisticlaly significant at the 1 percent level. Notwithstanding this strong effect of the dollar, the significant positive impact of changes in U.S. interest rates remains in column (3).

Bruno and Shin (2015) also posited a link between bank leverage and the VIX, the implied volatility of S&P 500 index options, which is often taken as an indicator of risk aversion in financial markets. Table 3 suggests, however, that the role of the VIX is statistically insignificant, although the estimated coefficients on changes in the VIX are large and negative, indicating that VIX increase are correlated with a more negative basis.[7]

	IBOR basis			**Treasury basis**		
	(1)	(2)	(3)	(4)	(5)	(6)
Δx	02-06	07-09	10-19	02-06	07-09	10-19
Δr^*	-0.01**	-0.22***	0.02	-0.10**	-0.25***	0.03
	(0.01)	(0.07)	(0.08)	(0.04)	(0.06)	(0.11)
Δr	0.00	0.12*	0.22**	0.22**	0.34**	0.27***
	(0.01)	(0.07)	(0.09)	(0.09)	(0.15)	(0.10)
ΔBroad dollar	-0.03	-2.43**	-1.38***	-1.27*	-1.87	-0.42
	(0.07)	(0.93)	(0.51)	(0.66)	(2.95)	(0.50)
ΔLog VIX	-0.03	0.53	-7.25	2.83	-49.93	-6.31*
	(0.98)	(8.47)	(5.03)	(7.46)	(38.47)	(3.77)
ΔFwd bid-ask	0.00	-1.07***	-0.29***	0.11*	-1.36**	-0.22***
	(0.02)	(0.22)	(0.08)	(0.06)	(0.55)	(0.07)
N	590	360	1200	590	360	1200
R^2	0.008	0.276	0.109	0.104	0.353	0.053

Table 3: Explaining 3-month CIP deviations: Monthly panel regressions with controls

Note: This table reports the results of panel regressions of monthly changes in dollar basis (IBOR/treasury) on interest rates along with a number of control variables. The panel consists of G10 currencies against US dollar. Samples are split to before (02-06), during (07-09), and after (10-19) the financial crisis. Monthly averages are used. Driscoll and Kraay (1998) standard errors are reported: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

[7] An alternative measure – the 10-year Treasury note volatility futures (TYVIX) – also has an insignificant but negative coefficient, with the size of the coefficient comparable to that of the VIX in column (3) of Table 3.

The increase in the forward exchange bid-ask spread is an indicator of illiquidity and volatility in foreign exchange markets (Bessembinder, 1994), typically associated with heightened risk aversion. Table 3 shows that a rise in bid-ask spreads makes the basis more negative over the post-GFC period, with an effect that is statistically very significant. We stress again that the change in the spread is a significant correlate notwithstanding the inclusion of the change in US interest and the change in the broad dollar index, so in some sense, these different indicators of financial tightening must capture different effects, which future research could usefully illuminate. For example, the bid-ask spread directly impacts the return to CIP arbitrage, so it is not surprising that an increase leads to a more negative basis.

Table 4, which shows how the effects in Table 3 vary across tenors, underscores the last interpretation of the bid-ask spread's role. A given change in the spread represents a bigger effective transcation cost the short the tenor of the trade, and consistent with this hypothesis, Table 4 shows that the spread's correlation with the basis becomes less strongly negative as the tenor rises. This pattern is less pronounced once period-end observations are dropped from the sample before taking the monthly average of daily observations. The dollar relationship seems more pronounced at longer tenors, while the VIX remains largely statistically insignificant across tenors, but its correlation seems most important at the one-week tenor in a sample that omits period ends.

	Include period-ends					Exclude period-ends		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Δx	1-week	1-month	3-month	6-month	1-year	1-week	1-month	3-month
Δr^*	-0.03	0.10	0.02	0.03	0.09	0.05	0.12	0.03
	(0.06)	(0.12)	(0.08)	(0.07)	(0.09)	(0.05)	(0.12)	(0.08)
Δr	-0.65	-0.78**	0.22**	0.17**	0.12	-0.13*	-0.92***	0.22**
	(0.42)	(0.32)	(0.09)	(0.08)	(0.08)	(0.07)	(0.34)	(0.09)
ΔBroad Dollar	-2.05	-1.98	-1.38***	-1.34***	-1.44***	0.33	-1.90	-1.38***
	(1.83)	(1.42)	(0.51)	(0.43)	(0.45)	(0.39)	(1.44)	(0.52)
ΔLog VIX	0.12	-3.78	-7.25	-6.44	-6.58	-7.94*	-3.09	-7.39
	(9.32)	(7.87)	(5.03)	(5.32)	(5.48)	(4.74)	(8.24)	(5.08)
ΔFwd bid-ask	-12.39***	-1.79*	-0.29***	-0.04	-0.01	-1.83**	-1.80*	-0.29***
	(2.83)	(0.91)	(0.08)	(0.04)	(0.02)	(0.77)	(0.94)	(0.08)
N	960	1200	1200	1200	840	960	1200	1200
R^2	0.185	0.113	0.109	0.100	0.107	0.055	0.122	0.108

Table 4: Dollar effect across tenors: Panel regressions

Note: This table reports panel regressions output of Libor basis on a set of regressors as in the baseline specification of Table 2. Tenors of forward premia (and thus tenors of regressors) from 1-week to 1-year are considered. Sample period is 2010M1-2019M12. The last three columns report regressions results on 1-week to 3-month tenor on the sample excluding period-ends. The restricted sample is obtained by first dropping all observations in February, May, August, September and November such that forward settlement date are in a different quarter (1-week and 1-month tenor) or year (3-month tenor) than spot settlement. For one-year tenor, SEK is excluded due to lack of data. For one-week tenor, CAD and NZD are excluded. Driscoll and Kraay (1998) standard errors are reported: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

3 Unpacking the dollar effect

As we have noted, the finding in Section 2.3 – that variation in the dollar exchange rate against a basket of currencies explains changes in the three-month dollar basis – is consistent with Avdjiev, Du, Koch and Shin (2019) (henthforth ADKS), who emphasize the close connection between dollar strength, cross-border dollar bank lending, and CIP deviations. In this telling, broad U.S. dollar appreciation reduces intermediaries' risk-taking capacity, limiting funds available for active CIP arbitrage and making the dollar basis more negative.

Dollar index movements are highly endogenous to changes in macrofinancial conditions, however. An emerging literature has identified a number of variables that could explain dollar fluctuations, at least within the post-GFC period financial. Shifts in risk sentiment and the associated "flight to safety" may also contribute to dollar appreciation and tighter dollar funding conditions. In this section, we build on the insight of ADKS and further investigate the dollar's role by directly assessing the additional impact of diffferent measures of global risk aversion, leverage constraints, and relative bond returns. We find that the asociation of the broad dollar index with the three-month Libor basis remains important when controlling directly for indicators of balance-sheet stress and long-term bond returns, but seems to be driven most strongly by a common factor that depends on safe-haven currencies' comovement.

Regarding bond returns, unconventional monetary policies after the GFC may have a material impact on the cross-currency basis, either directly, through a portfolio rebalancing effect on bond returns, or more indirectly, by affecting the relative strength of currencies. We find evidence that larger balance sheets of foreign central banks relative to the Fed leads to a more negative basis. On the other hand, when we look more directly at asset prices, we find that fluctuations in the term premium differential, an important metric of the attractiveness of currency-hedged long-term dollar investment, seems to be an important driver of the basis after 2014, complementary to the effect of the spot dollar exchange rate.

3.1 CIP deviations and post-GFC exchange rate determinants

Several recent studies have shown that macrofinancial fundamentals connected with global risk appetite can help to explain and predict exchange rates during the post-GFC period. In particular, Lilley, Maggiori, Neiman and Schreger (2019) demonstrate that movement in the broad U.S. dollar index has been closely related to private U.S. purchases of foreign bonds after the financial crisis. This correlation, most significant before 2013, is connected with the risk appetite of global investors, with various indicators of risk appetite exhibiting significant explanatory power for the dollar.[8] These findings suggest that similar risk-preference indicators could help in accounting

[8]There are several other examples in this vein. Greenwood, Hanson, Stein and Sunderam (2019) develop a theory of term premia and exchange rates and find some empirical support. Jiang, Krishnamurthy and Lustig (2019), Engel and Wu (2020), and Valchev (2020) argue that bonds have differential convenience yields that are significant in explaining U.S. dollar movements.

for deviations from CIP.

Table 5 asks if global financial cycle measures that are more tightly focused than the VIX significantly substitute for – or complement – the dollar effect on CIP deviations. We concentrate on two particular variables: (1) the Miranda-Agrippino and Rey (forthcoming) (henthforth MR) global asset-price factor extended by Miranda-Agrippino, Nenova and Rey (2020); and (2) the He, Kelly and Manela (2017) (henceforth HKM) squared leverage ratio of primary dealers. Both measures are expressed in units of standard deviations.

Extracted from a large set of world risky asset prices, the MR factor can explain a sizable fraction of global asset price comovement. A lower level of the factor reflects lower risk appetite on the part of global investors. The HKM squared leverage ratio measure is the squared inverse of U.S. primary dealer sector's aggregate capital ratio. This leverage measure is strongly countercyclical, is therefore positively correlated with intermediaries' marginal value of wealth, and is shown by HKM to perform well in pricing a wide range of asset classes.[9]

Lilley, Maggiori, Neiman and Schreger (2019) demonstrate that regressions of the broad dollar on the MR factor or on the HKM value-weighted return to a portfolio of New York Fed primary dealers' holding companies (which is high when the HKM leverage ratio is high) generate comparatively high rolling R^2s over the 2007-12 period. While this explanatory power suggests that both the MR and HKM financial cycle measures are important from a macrofinancial standpoint, it does not preclude that they influence the basis independently of the dollar. In our application, we expect the basis to react positively to an increase in the MR factor and negatively if primary dealers' leverage ratio increases: the former tends to increase during periods of high global risk appetite, whereas the latter is countercyclical, rising during periods of financial tightening, when risk bearing capacity is most stretched.

Table 5 reports findings for individual currencies and the ten-currency panel. Panel (a) shows that, omitting dollar changes, increases in the MR asset-price factor (indicative of a more ebullient global financial cycle) make the dollar basis less negative across all currencies, as expected. The effect is sometimes large and statistically very significant. In panel (b) the a higher HKM squared leverage ratio makes the basis more negative for eight out of ten currencies, in some cases with very large effects. In all of these regressions a higher dollar interest rate is associated with a less negative basis, contrasting with the cross-sectional finding of Du, Tepper and Verdelhan (2018).

[9]The HKM capital ratio is computed as the ratio of market value of equity to the sum of market value of equity and the book value of debt. Market value of equity is constructed from equity prices and the measure is thus available at daily frequency, consistent with our methodology of taking monthly averages of daily observations. We use the squared leverage ratio measure, which is shown by HKM to reflect time-varying risk premia in intermediary asset pricing frameworks such as He and Krishnamurthy (2012). Du, Hebert and Huber (2019) use the HKM return on equity issued by primary dealers to proxy for intermediary wealth returns in their asset pricing framework. In a recent paper, Augustin, Chernov, Schmid and Song (2020) estimate a no-arbitrage model of forward premium and dollar basis determination, and show that both the broad dollar index and the HKM capital ratio can significantly explain pricing errors implied by the model.

$\Delta(f-s)$	AUD	CAD	CHF	DKK	EUR	GBP	JPY	NOK	NZD	SEK
Δr^*	-0.09**	-0.01	0.77***	0.63***	-0.23	-0.26*	2.46***	-0.41***	-0.11**	0.11
	(0.04)	(0.09)	(0.18)	(0.23)	(0.30)	(0.16)	(0.44)	(0.10)	(0.05)	(0.14)
Δr	0.21***	0.21***	0.50***	0.33**	0.31*	0.33***	0.32***	0.27*	0.35***	0.26**
	(0.07)	(0.08)	(0.10)	(0.16)	(0.17)	(0.09)	(0.11)	(0.14)	(0.08)	(0.11)
ΔAsset price fator	4.67*	1.86	8.89**	18.93***	16.83***	4.62*	7.98***	12.47***	2.29	12.32***
	(2.45)	(2.07)	(3.82)	(6.67)	(6.33)	(2.40)	(2.49)	(4.05)	(1.61)	(3.45)
ΔFwd bid-ask	-3.31*	-1.12	-11.78***	-0.29**	-17.01***	-1.40*	-4.45	-0.17	-0.43	-0.17***
	(1.99)	(1.93)	(4.45)	(0.13)	(3.69)	(0.78)	(4.86)	(0.15)	(1.43)	(0.03)
Constant	-0.41	-0.53**	-0.16	1.01	-0.52	-0.57	0.19	-0.58	-0.84*	-0.14
	(0.34)	(0.23)	(0.74)	(1.00)	(0.67)	(0.46)	(0.42)	(0.66)	(0.43)	(0.62)
N	112	112	112	112	112	112	112	112	112	112
R^2	0.111	0.071	0.363	0.285	0.249	0.104	0.221	0.306	0.200	0.188

(a) 3-month Libor basis and MR asset price factor: Time-series regressions

$\Delta(f-s)$	AUD	CAD	CHF	DKK	EUR	GBP	JPY	NOK	NZD	SEK
Δr^*	-0.10**	0.03	0.67***	0.52**	0.03	-0.25*	2.31***	-0.26***	-0.11**	0.13
	(0.04)	(0.07)	(0.14)	(0.25)	(0.29)	(0.15)	(0.52)	(0.07)	(0.05)	(0.12)
Δr	0.20***	0.21**	0.45***	0.23**	0.23*	0.27***	0.30***	0.18	0.29***	0.12
	(0.07)	(0.08)	(0.10)	(0.11)	(0.12)	(0.09)	(0.09)	(0.13)	(0.08)	(0.09)
ΔLeverage ratio^2	-7.75***	2.57	-23.19***	-36.42***	-36.86***	-4.49*	-20.68***	-27.75***	1.34	-16.09***
	(2.33)	(2.57)	(5.46)	(5.16)	(6.83)	(2.33)	(2.98)	(3.85)	(1.55)	(3.33)
ΔFwd bid-ask	-4.47***	-1.05	-11.17***	-0.34**	-17.49***	-1.49*	-4.70	-0.16	-0.77	-0.18***
	(1.71)	(1.93)	(4.11)	(0.16)	(3.75)	(0.76)	(4.35)	(0.13)	(1.62)	(0.02)
Constant	-0.48	-0.65**	-0.60	0.44	-0.74	-0.59	-0.17	-0.75	-0.71	-0.17
	(0.38)	(0.25)	(0.72)	(0.69)	(0.71)	(0.47)	(0.52)	(0.52)	(0.44)	(0.50)
N	107	107	107	107	107	107	107	107	107	107
R^2	0.130	0.086	0.405	0.375	0.411	0.076	0.301	0.454	0.163	0.161

(b) 3-month Libor basis and HKM intermediary leverage: Times-series regressions

	Asset price factor			**Intermediary leverage ratio^2**			**Both**
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
$\Delta(f-s)$	No dollar	With dollar	With dollar: 14-19	No dollar	With dollar	With dollar: 14-18	With dollar
Δr^*	0.04	0.03	0.20**	0.06	0.04	0.20**	0.04
	(0.09)	(0.09)	(0.09)	(0.09)	(0.09)	(0.10)	(0.08)
Δr	0.26***	0.30***	0.30***	0.21**	0.26***	0.26**	0.26***
	(0.09)	(0.09)	(0.08)	(0.10)	(0.09)	(0.10)	(0.09)
ΔBroad Dollar		-1.33**	-1.38*		-1.11*	-1.11*	-1.24**
		(0.65)	(0.73)		(0.56)	(0.61)	(0.62)
ΔLog VIX		-6.95*	-3.38		-5.66	-2.86	-6.97*
		(4.13)	(4.22)		(4.65)	(5.48)	(4.04)
ΔFwd bid-ask	-0.32***	-0.29***	-0.23***	-0.33***	-0.31***	-0.26***	-0.31***
	(0.08)	(0.08)	(0.07)	(0.08)	(0.09)	(0.08)	(0.0861)
ΔAsset price factor	10.55***	3.17	-3.26				-2.88
	(3.38)	(4.49)	(7.78)				(4.11)
ΔLeverage ratio^2				-19.50***	-14.02***	-1.84	-15.61***
				(3.17)	(3.91)	(12.28)	(4.48)
N	1120	1120	640	1070	1070	590	1070
R^2	0.098	0.133	0.174	0.141	0.178	0.165	0.180

(c) 3-month Libor basis and risk measures: Panel regressions

Table 5: Libor basis and risk measures: Time-series and panel evidence

Note: This table presents time-series and panel regressions results on correlations between 3-month Libor basis and risk measures. For each currency, Panel A and B report results from time-series regression controlling only for interest rates, risk measures and forward bid-ask spread. Asset price factor refers to the "global financial cycle" estimates from Miranda-Agrippino, Nenova and Rey (2020). Data on intermediary leverage ratio (squared) is from data on primary dealer sector's capital ratio (He, Kelly and Manela, 2017). Both measures are demeaned and rescaled by its standard deviation. In all regressions, daily data are taken monthly averages before each regression. Samples for all regressions start at 2010M1 (or 2014M1). Samples end at 2019M4 for regressions involving equity price factors and 2018M11 for regressions including intermediary leverage. Driscoll and Kraay (1998) (panel) and Newey and West (1994) standard errors are reported. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Panel (c) looks at these results through the lens of panel regressions. Over the limited 2014-18(19) sample, the roles of the MR and HKM indicators seem both to be attenuated. In both of these regressions, the dollar is also only marginally significant. The result could reflect more tranquil market conditions following the euro crisis and domestic brinksmanship over the U.S. federal debt limit. While broadly consistent with the finding of Lilley, Maggiori, Neiman and Schreger (2019) that financial-market factors have less explanatory power for the multilateral dollar exchange rate after 2013 or so, it is puzzling that the risk indicators seem less influential in a period when several financial regulations on intermediaries had been more fully implemented. We will encounter this finding again below, and it is possibly related to the relatively lower variability of the HKM variable over 2014-2019 (see Figure 2).

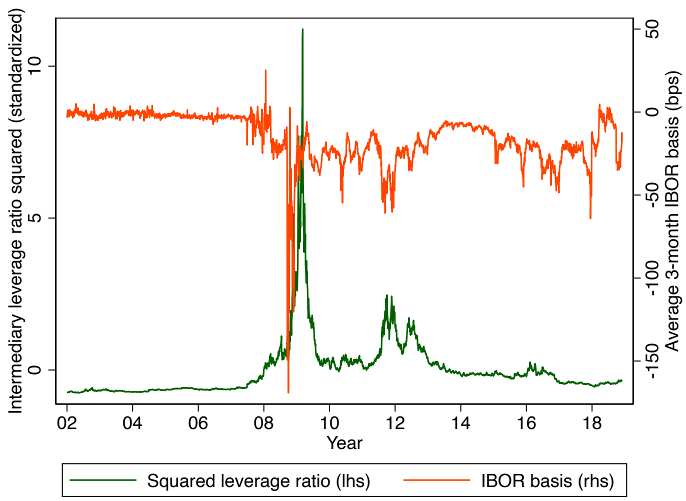


Figure 2: Standardized intermediary squared leverage ratio and three-month dollar basis
Note: Figure 2 plots daily standardized level of He, Kelly and Manela (2017) intermediary squared leverage ratio, against average three-month dollar basis across G-10 currencies.

Over the entire 2010-19 sample, however, the HKM variable is quite significant and economically important. In column (5), for example, which includes the dollar, a one standard deviation rise in the squared liquidity ratio is asociated with a fall in the annualized dollar basis of 14.02 basis points. Keeping both the asset-price factor and the squared leverage ratio in the regression, the dollar change becomes significant but the MR asset-price factor is not (column 7). In all specifications, once again, a rise in US interest rates plays an important role in making the basis less negative. The conclusion is that over the entire 2010-19 sample, there are a number of key monetary and financial drivers of the basis complementary with the broad dollar exchange rate, and some of these directly reflect risk-taking capacity and (in the case of the bid-ask spread) exchange-market liquidity.

3.2 Dollar effects and safe-haven flows

We next seek to understand better the mechanism through which movements in the broad dollar index connect to the dollar basis. A strong dollar could potentially induce a more negative basis through two distinct channels. First, as much of the literature posits, a strong dollar reflects and induces a reduction in intermediaries' risk-taking capacity (e.g., by raising the value of dollar-denominated balance sheet liabilities). But second, a strong dollar could simply reflect safe-haven demand stemming from a general drop in risk appetite – a development that would also lead to a more negative basis. Our simple intuition is that risk-off shocks that discourage CIP arbitrage and promote the flight of cross-border capital to safety should simultaneously put upward pressure on other safe-haven currencies.

If global risk-off episodes dominate the basis and these are reflected in a stronger multilateral dollar, then we would expect that common comovement in the safe haven currencies will have good explanatory power compared with the residual component of the dollar index, which would capture other, orthogonal, mechanisms through which a strong dollar could be associated with financial tightening (for example, a more restrictive U.S. monetary policy).

We try to measure the safe-haven component of dollar movements in two ways. Our first measure comes from a simple linear regression of the broad dollar exchange rate on levels of multilateral effective nominal exchange rates of the Swiss franc and Japanese yen. We regress the change in the basis on changes in both the residuals and the fitted value from this regression (after taking monthly averages) – the latter reflecting the safe haven component of dollar movements – and check if the residuals remain significant. Ranaldo and Soderlind (2010) show that the Swiss franc and Japanese yen tend to appreciate against the dollar when U.S. stock prices fall, and when U.S. bond prices and foreign exchange market volatility rise. Thus, these curencies indeed strengthen in conditions of market stress. Lilley, Maggiori, Neiman and Schreger (2019) show that alongside the U.S. dollar, the Japanese yen and Swiss franc also have significant loadings on U.S. purchases of foreign bonds, possibly suggesting that all three currencies load on the same global risk factor.

These last findings suggest a second approach to quantifying the safe-haven component of dollar movements. We use a simple static factor model to extract a single principal component from these three currencies, and decompose the raw broad dolar index into the common factor and a residual.

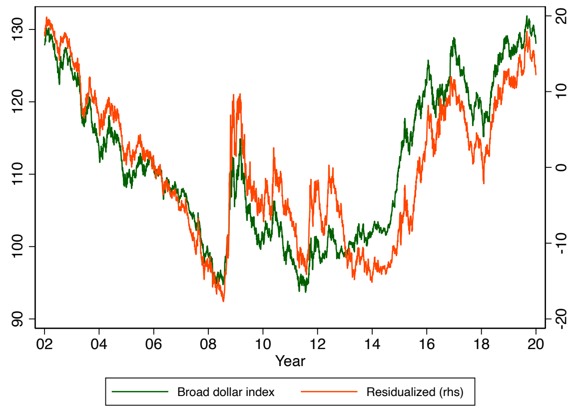
Figure 3 plots the residuals and the factors generated by this exercise. Perhaps surprisingly, the estimated residual components of the dollar index are highly correlated with the original series. The correlation is remarkably high for the regression-based residuals: close to 0.9 (Figure 3a). The correlation is less striking, but still substantial, for the principal-component-based residual series: close to 0.5 (Figure 3b). The safe haven common factor can explain 45 percent of the total variation of the effective exchange rates of the three currencies, comoves closely with the dollar (Figure 3c), but does not correlate strongly with the VIX index (Figure 3d).

Table 6 reports the findings based on the regression-based proxies for the safe-haven and residual components of the dollar. In the panel regressions of panel (a), both the dollar components and the VIX are significant over 2010-18 before the squared leverage ratio is included (column (1)). However, the fitted value of the regression on the franc and the yen has a stronger estimated effect, despite the high correlation of the residual with the raw exchange rate. Once leverage is added to the regression, however, the VIX and the residual become much less significant (column (2)). Over 2014-18, as above, the leverage ratio becomes insignificant, and the contrast between the effects of the two dollar components is smaller. In comparison with Table 5, panel (c), column (5), for example, the effect of the safe-haven component of dollar movements is much more evident in Table 6, panel (a), column (2) than that of raw dollar movements, whereas the residual component is not highly significant.

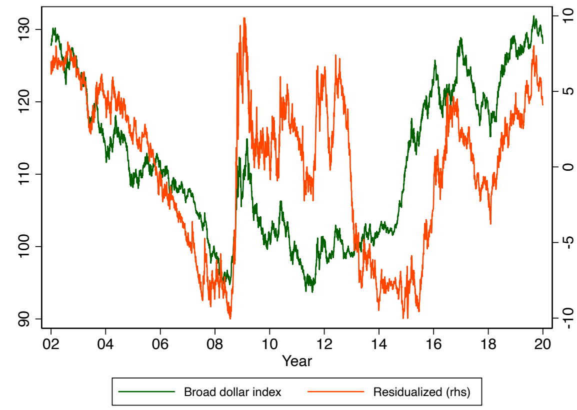
Panel (b) of Table 6 shows results by currency over 2010-18. For the majority of currencies, the findings are reasonably consistent with the panel results in panel (a).

Table 7 replicates Table 6, but uses the principal component methodology to isolate the part of dollar movements driven by safe safe-haven demand. The findings in the top panel on the whole echo those of Table 6, with the leverage variable again dominating the VIX and the safe-haven dollar component having a much lower p-value than the raw dollar in the comparable Table 5 results. The individual-currency results in the lower panel are generally consistent with the panel regressions, despite some hetrerogeneity across currencies. We note that the insignificance of the dollar residual is perhaps less surprising than in Table 6, owing to its lower correlation with the raw dollar than that of the regression-based residual.

Taken together, the results of this section so far suggest that the broad dollar's role may be mainly as an inverse indicator of global risk appetite – with appreciations asociated with greater risk aversion – while the squared leverage ratio is a strong indicator of pressure on intermediaries' risk-taking capacity.

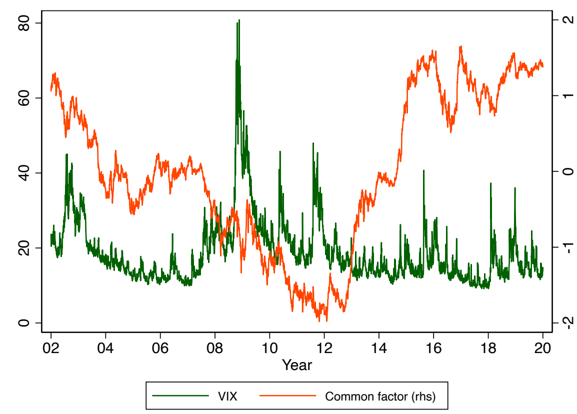


(a) Residualized dollar



(b) Residual after common factor extraction

(c) Safe haven common factor



(d) Safe haven common factor and VIX

Figure 3: Broad dollar index, common factor, and residuals

Note: Figure 3 plots various measures of residualized dollar and safe-haven currency common factor against original time-series of broad dollar index and VIX. In Figure 3a, the residualized dollar measure (axis on the RHS) is obtained from regressing broad dollar index on nominal effective exchange rates of Japanese yen and Swiss franc. In Figure 3b, the residualized dollar measure (axis on the RHS) comes from extracting one common principal component of broad dollar index and NEER of Japanese yen and Swiss franc. In Figure 3c and 3d, the common factor is the principal component extracted from the three original effective exchange rate indices.

Δx	10-18 (1)	(2)	14-18 (3)	(4)
Δr^*	0.02	0.05	0.20**	0.20**
	(0.09)	(0.08)	(0.10)	(0.10)
Δr	0.22**	0.22**	0.25**	0.25**
	(0.09)	(0.09)	(0.10)	(0.10)
ΔFitted broad dollar	-2.07**	-2.71***	-1.53*	-1.66*
	(0.80)	(0.82)	(0.79)	(0.85)
ΔResid. broad dollar	-1.43***	-1.04*	-1.06	-1.04
	(0.54)	(0.54)	(0.65)	(0.63)
ΔLog VIX	-11.30**	-6.66	-3.72	-3.29
	(5.57)	(4.39)	(5.68)	(5.59)
ΔFwd bid-ask	-0.32***	-0.31***	-0.26***	-0.26***
	(0.09)	(0.08)	(0.07)	(0.07)
ΔLeverage ratio^2		-17.89***		-5.43
		(3.82)		(10.69)
N	1070	1070	590	590
R^2	0.139	0.200	0.166	0.166

(a) Panel regressions

Δx	(1) AUD	(2) CAD	(3) CHF	(4) DKK	(5) EUR	(6) GBP	(7) JPY	(8) NOK	(9) NZD	(10) SEK
Δr^*	-0.09**	-0.03	0.56***	0.56***	-0.02	-0.24*	2.29***	-0.26***	-0.10**	0.07
	(0.04)	(0.07)	(0.12)	(0.21)	(0.22)	(0.14)	(0.35)	(0.05)	(0.05)	(0.12)
Δr	0.19***	0.23**	0.44***	0.23**	0.24**	0.31***	0.32***	0.20*	0.32***	0.16*
	(0.06)	(0.09)	(0.09)	(0.11)	(0.11)	(0.07)	(0.07)	(0.12)	(0.08)	(0.08)
ΔFitted broad dollar	-0.73	-2.00***	-3.18*	-4.93***	-3.70***	-1.07	-2.63**	-2.17***	-0.28	-2.76**
	(0.69)	(0.59)	(1.68)	(1.77)	(1.15)	(0.68)	(1.21)	(0.63)	(0.59)	(1.20)
ΔResid. broad dollar	0.20	-0.69***	-0.41	-1.59*	-1.88***	-1.12**	-1.32**	-1.37***	-0.16	-1.33**
	(0.34)	(0.23)	(1.34)	(0.88)	(0.58)	(0.44)	(0.58)	(0.40)	(0.34)	(0.53)
ΔLog VIX	-4.93	-5.54**	-16.35	-7.53	-1.87	-4.45	-4.25	-0.18	-5.31	-6.94
	(4.27)	(2.73)	(11.76)	(7.00)	(8.65)	(6.20)	(4.68)	(4.19)	(3.80)	(6.67)
ΔFwd bid-ask	-4.69**	-1.11	-8.97***	-0.27*	-16.04***	-1.05	-3.12	-0.14	-0.21	-0.16***
	(1.89)	(1.92)	(3.37)	(0.16)	(3.44)	(0.84)	(3.07)	(0.11)	(1.61)	(0.02)
ΔLeverage ratio^2	-8.02***	3.61	-24.04***	-37.30***	-35.80***	0.46	-18.94***	-26.37***	3.83**	-12.24***
	(1.65)	(2.23)	(7.37)	(6.66)	(7.37)	(3.16)	(4.74)	(4.09)	(1.70)	(3.95)
Constant	-0.38	-0.30	-0.33	1.23	-0.13	-0.38	0.26	-0.36	-0.69*	0.18
	(0.43)	(0.27)	(0.80)	(0.88)	(0.72)	(0.48)	(0.43)	(0.50)	(0.41)	(0.58)
N	107	107	107	107	107	107	107	107	107	107
R^2	0.171	0.187	0.448	0.445	0.479	0.149	0.363	0.509	0.193	0.250

(b) Time series (controlling for intermediary leverage)

Table 6: Three-month Libor basis, safe-haven currency comovement and residualized dollar index

Note: This table reports regressions involving fitted and residualized dollar index, obtained from regressing the broad dollar index on BIS nominal effective exchange rate indices of Swiss Franc and Japanese Yen. Data on intermediary leverage ratio (squared) is from data on primary dealer sector's capital ratio (He, Kelly and Manela, 2017), demeaned and rescaled by its standard deviation. Daily data are taken monthly averages before each regression. Samples for regressions in Panel (a) start at 2010M1 (or 2014M1) and end at 2018M11. Samples for regressions in Panel (b) start at 2010M1. For panel regressions, Driscoll and Kraay (1998) standard errors are reported. For time-series regressions, autocorrelation-robust standard errors with lag selection according to Newey and West (1994) are reported. $^* p < 0.1$, $^{**} p < 0.05$, $^{***} p < 0.01$.

	10-18		14-18	
Δx	(1)	(2)	(3)	(4)
Δr^*	0.02	0.05	0.20**	0.20**
	(0.09)	(0.08)	(0.10)	(0.10)
Δr	0.22**	0.23***	0.26**	0.26**
	(0.09)	(0.09)	(0.10)	(0.10)
ΔSafe haven factor	-14.90***	-14.82***	-11.76**	-12.23**
	(5.47)	(5.14)	(5.46)	(5.84)
ΔResid. Broad dollar	-1.14*	-0.19	-0.72	-0.57
	(0.63)	(0.75)	(0.99)	(0.93)
ΔLog VIX	-11.33**	-7.09	-4.04	-3.54
	(5.71)	(4.55)	(5.89)	(5.72)
ΔFwd bid-ask	-0.32***	-0.31***	-0.26***	-0.26***
	(0.09)	(0.08)	(0.07)	(0.07)
ΔLeverage ratio^2		-17.77***		-7.14
		(3.72)		(10.85)
N	1070	1070	590	590
R^2	0.138	0.198	0.167	0.168

(a) Panel regressions

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Δx	AUD	CAD	CHF	DKK	EUR	GBP	JPY	NOK	NZD	SEK
Δr^*	-0.09**	-0.02	0.60***	0.56**	-0.02	-0.24*	2.28***	-0.27***	-0.10**	0.06
	(0.04)	(0.07)	(0.12)	(0.22)	(0.22)	(0.14)	(0.34)	(0.05)	(0.05)	(0.12)
Δr	0.19***	0.23**	0.46***	0.25**	0.25**	0.31***	0.32***	0.21*	0.32***	0.16**
	(0.06)	(0.09)	(0.09)	(0.11)	(0.11)	(0.07)	(0.06)	(0.12)	(0.08)	(0.08)
ΔSafe haven factor	-1.03	-10.77***	-11.20	-24.97***	-23.32***	-10.36**	-16.51**	-15.29***	-1.97	-17.45**
	(3.20)	(3.00)	(11.76)	(9.07)	(6.82)	(4.71)	(6.54)	(4.24)	(3.70)	(6.99)
ΔResid. Broad Dollar	0.67	0.06	0.87	0.08	-0.90*	-1.11**	-0.59	-0.93**	-0.07	-0.49
	(0.58)	(0.39)	(1.86)	(1.39)	(0.49)	(0.44)	(0.76)	(0.39)	(0.33)	(0.53)
ΔLog VIX	-5.16	-6.00**	-16.56	-8.20	-2.42	-4.51	-4.73	-0.43	-5.37	-7.52
	(4.45)	(2.83)	(12.03)	(7.19)	(8.78)	(6.34)	(4.88)	(4.24)	(3.97)	(6.78)
ΔFwd bid-ask	-4.75**	-1.16	-9.21***	-0.29*	-16.08***	-1.04	-2.98	-0.13	-0.23	-0.16***
	(1.90)	(1.92)	(3.41)	(0.16)	(3.37)	(0.84)	(2.93)	(0.11)	(1.57)	(0.03)
ΔLeverage ratio^2	-7.93***	3.39*	-22.84***	-36.99***	-35.83***	0.27	-19.07***	-26.40***	3.76**	-12.55***
	(1.73)	(2.05)	(7.51)	(6.52)	(7.13)	(3.05)	(4.64)	(3.96)	(1.62)	(3.82)
Constant	-0.42	-0.35	-0.43	1.10	-0.20	-0.37	0.21	-0.39	-0.69	0.15
	(0.41)	(0.28)	(0.75)	(0.88)	(0.71)	(0.47)	(0.40)	(0.50)	(0.42)	(0.58)
N	107	107	107	107	107	107	107	107	107	107
R^2	0.168	0.191	0.442	0.440	0.479	0.149	0.363	0.510	0.193	0.254

(b) Time series regressions (controlling for intermediary leverage)

Table 7: Libor basis, safe haven factor and residual: Time-series and panel evidence

Note: This table reports the regression results investigating the relationship between 3-month Libor basis, safe haven currency factor and residuals. Safe haven currency factor is the first principal component of daily level of broad USD index, Japanese yen index and Swiss franc index. Broad dollar residual refers to the residual for the USD equation controlling for the common factor. Data on intermediary leverage ratio (squared) is from data on primary dealer sector's capital ratio (He, Kelly and Manela, 2017), demeaned and rescaled by its standard deviation. In all regressions, daily data are taken monthly averages before each regression. Samples for regressions in Panel (a) start at 2010M1 (or 2014M1) and end at 2018M11. Samples for regressions in Panel (b) start at 2010M1. For panel regressions, Driscoll and Kraay (1998) standard errors are reported. For time-series regressions, autocorrelation-robust standard errors with lag selection according to Newey and West (1994) are reported. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

3.3 Dollar supply-demand and CIP deviations: Central bank balance sheets and the term premium channel

To close this section, we study more closely supply-demand forces that underpin the relationship established by ADKS between dollar strength, the dollar basis, and cross-border capital flows. Persistently low global interest rates, asymmetric recovery from the financial crisis, and the unconventional monetary policies of advanced-economy central banks may give rise to lending and borrowing patterns that take advantage of interest-rate differentials across borders. A "low-for-long" interest rate environment encourages reach-for-yield behavior by domestic financial institutions in the form of higher overseas investment. For example, Ammer, Tabova and Wroblewski (2016) find some reallocation toward U.S. and U.K. bond investments by euro-area investors in response to widening bond yield differentials. Japanese insurers, facing massive domestic monetary easing themselves, have substantially increased their exposure to dollar-denominated portfolio investment in recent years (Bank of Japan, 2020). Because foreign investors tend to hedge their FX exposures, the resulting demand pressure for FX hedging would need to be absorbed through adjustment in the dollar basis.[10]

Against this backdrop, we focus on two variables that may offer a perspective distinct from from the risk-based explanations of the drivers of short-term CIP deviations that we explored above.

One is euro bond purchases by foreign central banks. Central bank balance-sheet operations may affect the dollar basis through a portfolio rebalancing channel. For example, by removing euro-denominated bonds from circulation, the ECB's quantitative easing operations may lead to excess demand for future promised euro payments, and thus, appreciation of the forward euro. If euro area quantitative easing puts upward pressure on asset prices, the associated reduction in funding cost may attract foreign issuance in euros and higher hedging demand in dollars, resulting in a more negative dollar basis (Liao, forthcoming).

A second variable we will look at is a metric of the relative profitability of hedged investments in long-term dollar bonds: the relative dollar term premium. Of course, a rise in the relative dollar term premium could result from ECB purchases of euro area bonds, as in the last paragraph. Thus, our regressions below, in which we estimate the role of central bank balance sheets, could be viewed as throwing indirect light on relative term premium effects, which we will also investigate directly. There is an ambiguity in assessing how a relative term premium change will affect the basis, however: the outcome can depend on whether the shock moving the term premium comes from a change in bond supplies – as in the previous paragraph – or a

[10] Borio, Iqbal, McCauley, McGuire and Sushko (2018) estimate demand for dollar hedges by computing the gap between dollar assets and liabilities of international banks, and find this funding gap measure is closely asaociated with the level of CIP deviations. Liao (forthcoming) associates the movement in long-term CIP deviations with offshore foreign-currency issuance of international firms. Amador, Bianchi, Bocola and Perri (forthcoming) study exchange rate policies with a zero lower bound constraint that may inflict carry costs on monetary authorities in the form of CIP deviations.

change in bond demand – for example, a rise in global risk aversion that prompts haven flows into dollar assets. It is in the former case (a supply shock) that a rise in the relative dollar term premium will lead to a more negative dollar basis.

To illustrate this point, imagine that a rise in the relative supply of dollar bonds outstanding leads to a rise in the U.S. relative to foreign term premium. A Japanese insurance company with an overseas portfolio may wish, as a result, to raise its holdings of five-year U.S. Treasury bond and to hedge this additonal dollar exposure by entering into a cross-currency basis swap with a counterparty. To see why there might be additional demand out of a rising relative term premium, assuming it holds the added securities to maturity and the swap spread is zero, the insurance company would receive a fixed long-term rate for the investment, but is exposed to floating short-term rates by paying the dollar Libor rate and receiving the Japanese yen Libor rate every three months during the investment.[11] Ignoring the yen side for simplicity, the expected profit from this investment, as a result, is the expected term premium on the five-year Treasury bond.[12] Non-U.S. investors may respond to a lower U.S. term premium driven by Federal Reserve quantitative easing (Greenwood, Hanson, Stein and Sunderam, 2019; Chari, Dilts Stedman and Lundblad, forthcoming) by cutting back their dollar exposures and unwinding currency hedges, which would reduce the demand for forward foreign currency and reduce downward pressure on the dollar basis. These developments would also weaken the dollar in the spot market. An alternative contractionary shock to the outstanding U.S. bond supply would be forward guidance of lower for longer future U.S. short-term interest rates (see Bundick, Herriford and Smith (2019)), which can raise expectations of future Fed bond purchases.

A lower relative U.S. term premium could, however, result from demand-side developments, such as an exogenous risk-off rise in hedged dollar demand. Such a development would have different effects on the dollar basis and the spot dollar than an expansion of the Fed's QE. In the case of a rise in demand for dollar bonds, some of which comes from non-U.S. residents who hedge in the forward market, the dollar term premium would fall, forward dollar sales might nonetheless rise – leading to a more negative basis – and the spot dollar would appreciate.

In recent years, movements in the Treasury term premium and the dollar exchange rate seem to be closely associated. Greenwood, Hanson, Stein and Sunderam (2019) show empirically that a higher foreign term premium relative to the U.S. is associated with U.S. dollar depreciation and foreign currency appreciation. One implication of their findings is that relative supply changes in bond markets may dominate the correlation between relative term premia and the basis.[13] Because we will additonally control for the safe-haven component of dollar movements in the

[11] Baba, Packer and Nagano (2008) provide more details on the working of a cross-currency basis swap.

[12] With CIP deviations, the investment would be more costly as the insurer would pay an additional spread on the cross-currency basis swap, with the dollar basis being typically negative.

[13] Cœuré (2017) also observe a close comovement between the euro-dollar exchange rate and the relative term premium. On the relationship of the term premium to capital flows, Chari, Dilts Stedman and Lundblad (forthcoming) show that a lower term premium on U.S. Treasury bonds during periods of quantitative easing leads to higher U.S. holdings of emerging market assets, and the opposite occurs during the taper tantrum period.

regressions that follow, we would expect that a measure of the foreign term premium relative to the U.S. dollar term premium, because it lowers the relative global demand for long-dated dollar assets and hence forward hedging purchases of foreign currencies against forward dollars, would make the dollar basis less negative.

Term premia are unobservable and estimates of term premia are model-dependent. Following Hanson and Stein (2015) and Greenwood, Hanson, Stein and Sunderam (2019), we proxy movements in term premia by changes in the nine-year forward yield of one-year bonds, computed from zero-coupon yield curves. A big advantage of this approach is that we do not have to take a stand on the exact term-structure model that generates the term premium estimates. Under the assumption that there is typically little news on expected short rates in the distant future, innovations in forward rates are largely driven by movements in term premia. In the case of the United States, the one-year yield (nine years forward) computed by Gürkaynak, Sack and Wright (2007) is highly correlated with canonical term premium estimates such as Adrian, Crump and Moench (2013). Moreover, as zero-coupon yield curves are readily available for six out of the ten currencies that we consider, in addition to U.S. dollar, the sample coverage of our term premium proxies is satisfactory.

Table 8's estimates cover the 2010-18 period. Panel (a) includes monthly changes in relative balance-sheet size for major central banks that engaged in balance-sheet expansion. The relative balance-sheet size variable is defined as the foreign central bank's total assets, measured in local currency and normalized by domestic M2 stock, relative to the same variable for the Federal Reserve's balance sheet.[14] Panel (b) adds the change in our measure of the foreign-U.S. relative term premium, denoted $tp^* - tp$. We find that over 2010-18, the relative balance sheet term performs as expected, and significantly so, with a larger foreign relative balance sheet making the basis more negative. In contrast, the relative term premium contributes little. The effects of other variables are largely unchanged.

In earlier results we found a reduced role for the HKM squared leverage variable post 2014. This result persists in Table 8, and strong-dollar effects are much reduced (as was also true in Table 6). However, over 2014-18, the relative term premium variable is highly significant, and conforms with the theoretical prediction that a rise in ther relative foreign terms premium makes the dollar basis less negative. The term premium effect also appears to be important for the Swiss franc, the euro, and sterling, in addition to the panel of six currencies.

[14] Results are very close if we do not normalize by M2, as in the study of QE policies by Dedola, Georgiadis, Gräb and Mehl (2020).

Δx	(1) CHF	(2) EUR	(3) GBP	(4) JPY	(5) Panel
Δr^*	0.50***	-0.17	-0.26*	2.31***	0.12
	(0.11)	(0.23)	(0.15)	(0.34)	(0.20)
Δr	0.52***	0.35***	0.33***	0.29***	0.36***
	(0.12)	(0.10)	(0.08)	(0.07)	(0.11)
ΔDollar factor	-11.96	-22.70***	-10.52**	-16.87**	-16.02***
	(9.69)	(6.30)	(4.70)	(6.64)	(5.77)
ΔDollar residual	1.01	-0.65	-1.08**	-0.46	-0.15
	(1.60)	(0.49)	(0.43)	(0.67)	(0.80)
ΔLog VIX	-10.51	-3.93	-4.71	-2.64	-6.99
	(7.89)	(8.68)	(6.25)	(4.41)	(5.33)
ΔFwd bid-ask	-7.49**	-15.97***	-1.06	-3.67	-6.77***
	(3.01)	(3.60)	(0.84)	(2.95)	(2.37)
ΔRelative balance sheet/M2	-0.89***	-0.62**	-0.20*	-0.52**	-0.71***
	(0.13)	(0.26)	(0.11)	(0.26)	(0.15)
ΔLeverage ratio^2	-14.63*	-31.54***	-0.22	-18.53***	-19.00***
	(8.09)	(6.71)	(2.85)	(4.06)	(4.44)
Constant	0.11	-0.29	-0.28	0.85*	
	(0.76)	(0.56)	(0.45)	(0.44)	
N	107	107	107	107	428
R^2	0.529	0.506	0.159	0.392	0.371

(a) Libor basis and central bank balance sheets: 2010-2018

	AUD	CAD	CHF	EUR	GBP	JPY	Panel
Δr^*	-0.10***	-0.03	0.60***	-0.03	-0.24*	2.28***	0.03
	(0.03)	(0.08)	(0.12)	(0.23)	(0.13)	(0.30)	(0.10)
Δr	0.21***	0.25***	0.46***	0.25**	0.31***	0.32***	0.27***
	(0.06)	(0.09)	(0.09)	(0.11)	(0.08)	(0.07)	(0.09)
$\Delta(tp^* - tp)$	6.22***	2.71	-1.47	-3.00	-0.28	-0.09	0.55
	(2.38)	(3.84)	(7.33)	(7.92)	(4.80)	(3.18)	(3.05)
ΔDollar factor	-1.46	-10.51***	-11.48	-23.79***	-10.38**	-16.52**	-12.77**
	(3.21)	(2.70)	(11.54)	(7.45)	(4.65)	(6.49)	(4.92)
ΔDollar residual	0.80	0.05	0.86	-0.96*	-1.11***	-0.59	0.00
	(0.57)	(0.37)	(1.86)	(0.53)	(0.40)	(0.73)	(0.76)
ΔLog VIX	-5.54	-6.16**	-16.54	-2.02	-4.50	-4.73	-7.90*
	(4.87)	(2.97)	(11.95)	(9.29)	(6.39)	(5.00)	(4.67)
ΔFwd bid-ask	-5.22**	-1.27	-9.14***	-15.93***	-1.02	-2.97	-6.39***
	(2.09)	(2.02)	(3.38)	(3.69)	(0.88)	(2.99)	(2.13)
ΔLeverage ratio^2	-10.50***	2.32	-22.14***	-34.66***	0.37	-19.01***	-15.27***
	(2.20)	(1.83)	(8.19)	(6.48)	(3.45)	(5.55)	(3.20)
Constant	-0.46	-0.38	-0.41	-0.23	-0.37	0.21	
	(0.40)	(0.27)	(0.79)	(0.66)	(0.49)	(0.38)	
N	107	107	107	107	107	107	642
R^2	0.191	0.195	0.443	0.480	0.149	0.363	0.228

(b) Libor basis and term premium differentials: 2010-2018

Table 8: Libor basis, central bank balance sheets and term premia: 2010-2018

Note: Table 8 considers the relationship between three-month Libor basis, central bank balance sheets, and term premium. Table 8a reports the relationship between three-month Libor basis and various measures of central bank balance sheets. "ΔRelative balance sheet/M2" refers to 100 times log point changes in the monthly ratio of balance sheets over M2 between foreign (CHF, EUR, GBP, JPY) central banks and the Fed. Sample period is 2010M1 to 2018M11. Table 8b reports the relationship between three-month Libor basis and term premia differential, controlling for safe-haven common factors and residuals. Changes in term premia differential ($\Delta tp^* - tp$) is proxied by changes in one-year yield (nine year forward) differential between foreign and US. Sample period for both panels is from 2010M1 to 2018M11. Term premia differential is in unit of percentage points. For panel regressions, Driscoll and Kraay (1998) standard errors are reported. For time-series regressions, autocorrelation-robust standard errors with lag selection according to Newey and West (1994) are reported. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Δx	(1) CHF	(2) EUR	(3) GBP	(4) JPY	(5) Panel
Δr^*	0.52***	0.19	-0.11	2.60***	0.44***
	(0.13)	(0.29)	(0.22)	(0.44)	(0.09)
Δr	0.43***	0.40***	0.40***	0.35***	0.38***
	(0.15)	(0.12)	(0.12)	(0.09)	(0.13)
ΔDollar factor	-12.68	-14.98**	-8.09	-15.09*	-13.54*
	(10.64)	(7.25)	(6.11)	(7.73)	(7.22)
ΔDollar residual	-0.01	-0.76	-1.25	-1.52***	-0.68
	(1.69)	(0.95)	(1.20)	(0.57)	(1.25)
ΔLog VIX	-3.31	-5.79	-3.95	-1.30	-4.70
	(9.80)	(9.45)	(7.27)	(6.31)	(7.93)
ΔFwd bid-ask	-6.29**	-19.24***	-1.39	-1.67	-5.87**
	(2.46)	(3.11)	(1.82)	(3.52)	(2.54)
ΔRelative balance sheet/M2	-0.50	-0.09	-0.72	-0.27	-0.52
	(0.76)	(0.26)	(0.44)	(0.27)	(0.36)
ΔLeverage ratio^2	-15.04	-1.76	-6.70	0.56	-12.15
	(18.50)	(15.91)	(11.94)	(15.64)	(13.11)
Constant	-0.68	-1.31	-0.63	0.29	
	(1.07)	(0.89)	(0.77)	(0.73)	
N	59	59	59	59	236
R^2	0.336	0.396	0.168	0.391	0.253

(a) Libor basis and central bank balance sheets: 2014-2018

	AUD	CAD	CHF	EUR	GBP	JPY	Panel
Δr^*	-0.01	-0.06	0.60***	-0.05	-0.21	2.55***	0.15
	(0.05)	(0.09)	(0.14)	(0.24)	(0.13)	(0.34)	(0.09)
Δr	0.10**	0.21	0.47***	0.42***	0.42***	0.37***	0.31***
	(0.04)	(0.13)	(0.11)	(0.08)	(0.09)	(0.10)	(0.10)
$\Delta(tp^* - tp)$	4.87	7.31	29.04*	19.34**	11.96**	2.11	10.70**
	(3.22)	(10.07)	(15.99)	(7.84)	(6.02)	(4.70)	(4.60)
ΔDollar factor	0.86	-9.73***	-5.46	-12.82*	-7.46	-14.67**	-10.04*
	(1.62)	(2.75)	(9.12)	(6.55)	(6.55)	(7.48)	(5.15)
ΔDollar residual	-0.03	-0.35	-0.28	-0.32	-0.80	-1.75**	-0.34
	(0.41)	(0.74)	(1.79)	(0.81)	(0.80)	(0.71)	(0.99)
ΔLog VIX	2.16	-6.08	-0.65	-5.88	-3.17	-1.10	-3.47
	(2.83)	(4.21)	(8.95)	(10.41)	(9.19)	(6.04)	(5.37)
ΔFwd bid-ask	-3.38**	-5.26	-8.91***	-19.95***	-1.73	-1.21	-5.80***
	(1.70)	(3.36)	(3.42)	(2.72)	(1.14)	(3.68)	(2.17)
ΔLeverage ratio^2	-11.80*	22.04*	-17.11	1.86	-4.39	-0.84	-10.27
	(6.29)	(11.38)	(13.83)	(13.26)	(8.93)	(15.36)	(10.34)
Constant	-0.24	-0.68	-1.46	-1.59**	-1.25	-0.28	
	(0.38)	(0.62)	(0.99)	(0.71)	(0.82)	(0.54)	
N	59	59	59	59	59	59	354
R^2	0.092	0.256	0.372	0.465	0.156	0.391	0.202

(b) Libor basis and term premium differentials: 2014-2018

Table 9: Libor basis, central bank balance sheets and term premia: 2014-2018

Note: Table 9 considers the relationship between three-month Libor basis, central bank balance sheets, and term premium using 2014M1-2018M11 sample. Table 8a reports the relationship between three-month Libor basis and various measures of central bank balance sheets. "ΔRelative balance sheet/M2" refers to 100*log point changes in the monthly ratio of balance sheets over M2 between foreign (CHF, EUR, GBP, JPY) central banks and the Fed. Sample period is 2010M1 to 2018M11. Table 8b reports the relationship between three-month Libor basis and term premia differential, controlling for safe-haven common factors and residuals. Changes in term premia differential ($\Delta tp^* - tp$) is proxied by changes in one-year yield (nine year forward) differential between foreign and US. Term premia differential is in unit of percentage points. For panel regressions, Driscoll and Kraay (1998) standard errors are reported. For time-series regressions, autocorrelation-robust standard errors with lag selection according to Newey and West (1994) are reported. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

4 Dollar supply-demand imbalance through the lens of period-end dynamics

Given interest rates, movements in the dollar basis can be understood intuitively as a result of supply-demand imbalances in the market for dollar swaps. In this section, we focus on period ends, when such imbalances becomes particularly large, to understand better the role of regulatory factors in allowing deviations from CIP. We first extend the analysis of Du, Tepper and Verdelhan (2018) and show that recent regulatory measures focused on systemically important banks have exacerbated dollar funding pressure at year ends, as evidenced by a notable spike in three-month synthetic funding costs. Then, we use the volume of period-end swap line draws by European banks to infer the size of excess dollar funding demand, and provide ballpark estimates of the response of the short-tenor dollar basis to such excess demand.

4.1 G-SIB window-dressing and CIP deviations

Implementation of post-GFC regulatory reforms has raised the shadow price of balance-sheet capacity and thus constrained more tightly the banking sector's ability to conduct balance-sheet costly CIP arbitrage. Short-tenor (one-week and one-month) CIP deviations tend to widen around quarter-ends as banks make financial reports and disclose leverage ratios. Differences in the reference period used to compute different regulatory indicators could lead to different levels of balance sheet pressures around period-ends. In particular for Europe, a quarter-end balance sheet snapshot is used, resulting in European banks sharply retreating from CIP arbitrage around quarter-ends.[15]

The G-SIB surcharge introduced at the start of 2016 may have imposed additional pressure on swap markets at period ends, raising the relative cost of synthetic dollar funding. The surcharge is assessed based on previous-year measures of banks' systemic importance, with the notional amount of OTC derivates explicitly considered under the "complexity" category of the sytemic risk indicators.[16] Based on year-end balance sheets (according to Correa, Du and Liao (2020) for the United States and Behn, Mangiante, Parisi and Wedow (2019) for Europe), this regulatory arrangement motivates window-dressing behaviors aimed at reducing the size of balance sheets toward year ends to avoid being assessed into a higher bucket of surcharges.[17] Berry, Khan and Rezende (2020) demonstrate that U.S. G-SIBs lower the amount of OTC derivatives during the fourth quarter of the year, while Behn, Mangiante, Parisi and Wedow (2019) offer similar

[15] See Du, Tepper and Verdelhan (2018) for a summary of regulatory measures that contribute to rising balance sheet constraints on banks, which can be passed forward to unregulated clients such as hedge funds.

[16] See Basel Committee on Banking Supervision (2018) and Berry, Khan and Rezende (2020) for more details regarding the institutional background and the G-SIB assessment methodology.

[17] In the U.S., Form FR Y-15 is used to construct systemic risk measures: https://www.ffiec.gov/npw/FinancialReport/FRY15Reports.

evidence for European banks.[18]

As the scope of G-SIB regulation reaches beyond short-tenor currency derivatives, we expect to see the impact of regulation on longer-tenor bases, which are relatively immune to usual quarter-end dynamics away from the end of the year, as Du, Tepper and Verdelhan (2018) showed. Using an event-study approach, we demonstrate that the dollar basis at three-month tenor widens significantly during periods associated with year-end financial reporting. Given the $T+2$ settlement convention in forward exchange markets, three-month currency derivatives traded from late September to late December typically mature (i.e., have value or delivery dates) in the following year, creating a three-month time window in which these instruments stay on financial intermediaries' year-end balance sheet.[19] Thus, we should expect the G-SIB surchage to make the three-month basis even more negative when trades enter year-end balance sheets during late September. By the same token, trades done very late in December do not settle until the following year, and thus do not appear on the year-end balance sheet in the same year that the trade is executed. Thus, banks should be more willing to lend for covered interest arbitrage in the last two days of December, making dollar bases less negative then. We test these predictions for the panel of G10 currencies by projecting the daily three-month Libor basis on a set of dummy variables indicating days before and after the first day and the last day of this time window (and including currency fixed effects). Figure 5 illustrates the evidence, which supports our hypothesis. For the sample after 2016, we observe a signficant downward jump of the basis in late September (Figure 5a), and this effect becomes even stronger during the recent two years (Figure 5c), during at least part of which the G-SIB surcharge has been fully phased in. We also observe a smaller upward jump on the last two days of December (Figure 5b and 5d), with the effect statistically significant at 5 percent level for the 2018-2019 sample. In contrast, the corresponding effects for the sample restricted to 2013 to 2015 are small and insignificant for both the start and the end of the time window (Figure 5e and 5f). These findings lend support to the role of the year-end G-SIB score calculation in driving the window-dressing behavior of G-SIBs via higher charges for funding interest arbitrage.

4.2 Swap-line use at quarter ends

Recent studies demonstrate that central bank liquidity swaps are capable of easing dollar funding conditions and reducing deviations from CIP during the money market turmoil in the Great Financial Crisis (Baba and Packer, 2009). Bahaj and Reis (2020*b*), using a no-arbitrage argument, show that swap lines should act as a ceiling on the dollar basis to stabilize synthetic dollar

[18]Krohn and Sushko (2020) use detailed swap quotes and show that G-SIB banks' dealer arms pull back from liquidity provision for FX swaps of 1-month tenor. The issue of G-SIB window-dressing has also been discussed in Borio, Iqbal, McCauley, McGuire and Sushko (2018).

[19]More specifically, similar to Du, Tepper and Verdelhan (2018) for the case of one-week and one-month forwards, this time window is defined as trade dates on which the settlement date of a three-month forward contract is within the current year, and the maturity date is in the following year.

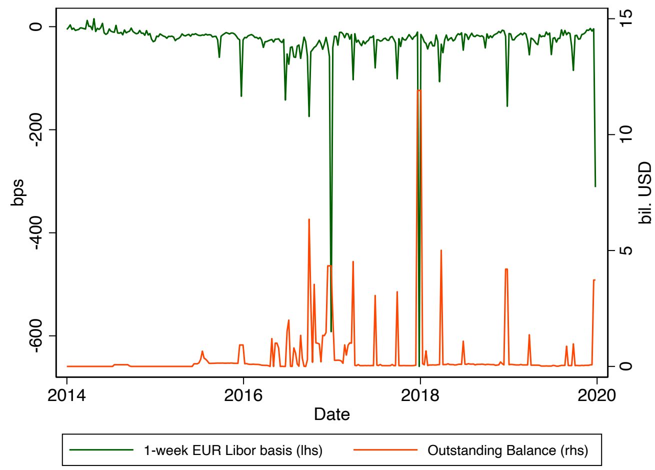


Figure 4: Swap-line usage and 1-week EUR Libor basis against USD

Note: Figure 4 plots the time-series of one-week EUR Libor basis against USD, along with total amount outstanding (in billions USD) of short-term swap line draws from ECB-Fed swap line. Short-term swap line usage is defined as swap line draws with a maturity fewer than or equal to 21 days.

funding costs and provide empirical support to this theory. From the swap operations disclosure from the Federal Reserve Bank of New York in recent years, two observations emerge:

- The scale of dollar swap usage is small in general. Among foreign central banks, only European authorities sporadically tap into dollar swap lines for short-term dollar funding.
- Large dollar swap line draws by European central banks generally coincide with quarter-ends, when dollar liquidity worsens and CIP deviations, measured by the one-week Libor basis, spike. Figure 4 plots the balance outstanding of the ECB-Fed short-term dollar swap line (defined as swap draws of tenor smaller than or equal to three weeks)[20] against the one-week euro-dollar basis. Not only is there a qualitative pattern of comovement, but quantitatively, Figure 4 provides suggestive evidence that higher swap line draws tend to be associated with a wider basis, especially at year ends after 2017.

As the Fed-ECB swap line is largely inactive during periods away from quarter-ends after 2017 (possibly due to stigma concerns), period-end swap operations after 2017 can be used as an imperfect proxy for dollar funding strain at quarter ends. Intuitively, at quarter ends, the retreat of usual sources of short-term dollar funding may prompt dollar borrowing through swap lines, with the size of borrowing measuring the dollar funding shortfall that cannot be covered by switching to other funding sources. By comparing the period-end jump in swap line usage and the jump in the one-week EUR dollar basis, one obtains a back-of-the-envelope lower-bound

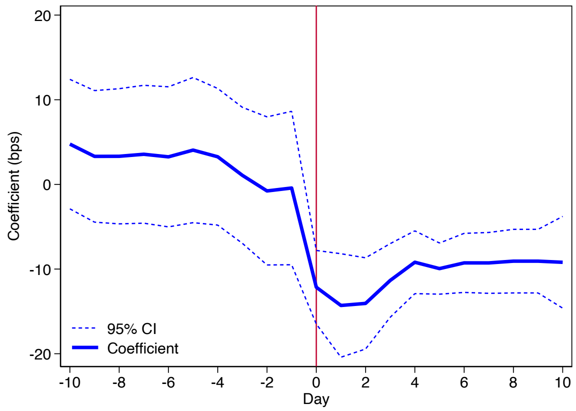
[20]We add up all swap draws with tenors no greater than three weeks into a pooled measure of "short-term" funding, as dollar swaps with a two-week or three-week tenor, rather than the conventional one-week tenor, tend to be drawn at year-ends.

estimate of the impact of dollar supply-demand imbalance on the basis. Furthermore, informed by the analysis in Section 4.1 and Correa, Du and Liao (2020), comparing the estimates for quarter ends and year ends enables us to quantify the contribution of G-SIBs' retreat from synthetic dollar lending on the supply-demand imbalance.

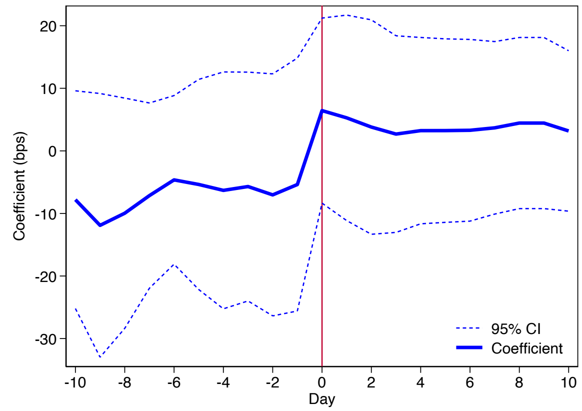
We apply a similar event-study approach as in Section 4.1 to weekly averages of the EUR dollar basis between 2017 and 2019. We project each dependent variables on a set of dummy variables indicating weeks around both quarter ends and year ends. The period 2017-2019 offers a clean sample window to conduct the estimate, as there is very little borrowing via swap lines away from quarter ends, and the prime money market mutual fund reform completed at October 2016 further reduced dollar funding sources for foreign banks.[21] Figure 6 reports the response of dollar swaps outstanding and 1-week EUR Libor basis around quarter and year ends. Reading from the peak of the estimated coefficients, a 40 basis point widening of deviations from CIP occurs at quarter ends that are not also year ends, along with a USD 2 billion drawing. For year ends, the basis spikes by 260 basis points while dollar swaps from the Fed rise by USD 6.5 billion. These estimates indicate that for each USD 1 billion shortfall in supply during quarter ends that are not also year ends, 20 basis points are added to the dollar basis (i.e., $260/6.5 - 40/2$). Our ballpark estimates based on swap line usage are broadly consistent with Correa, Du and Liao (2020), who use daily supervisory data on U.S. G-SIBs.[22]

[21]Anderson, Du and Schlusche (2019) provide evidence that following the prime MMMF reform, global banks further cut back on arbitrage positions funded by unsecured borrowing.

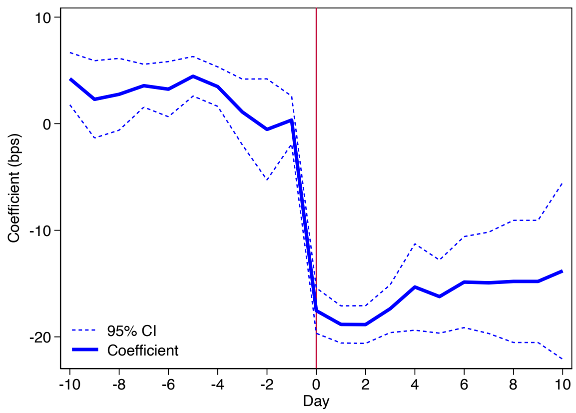
[22]U.S. G-SIBs supply USD 10 billion less arbitrage capital during year ends compared with quarter ends (Figure 8 and C.3 in Correa, Du and Liao (2020)) through "reserve fracking" (tapping excess reserves at the Fed), and the associated additional widening of the intermediation cost of 150 basis points (Figure 7 in Correa, Du and Liao (2020)) leads to a ballpark estimate of around 15 bps per billion dollar additional pressure on the one-week EUR dollar basis at year-ends.



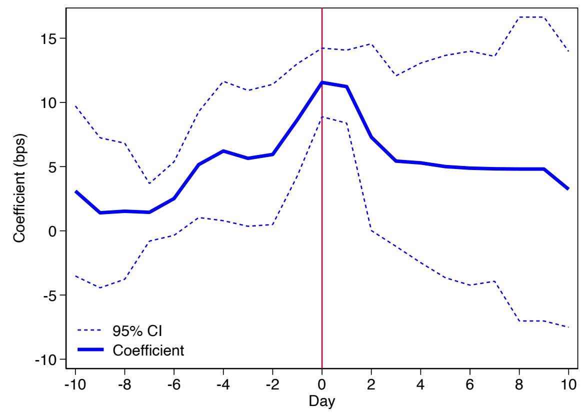
(a) Entering year-end balance sheet (2016-2019)



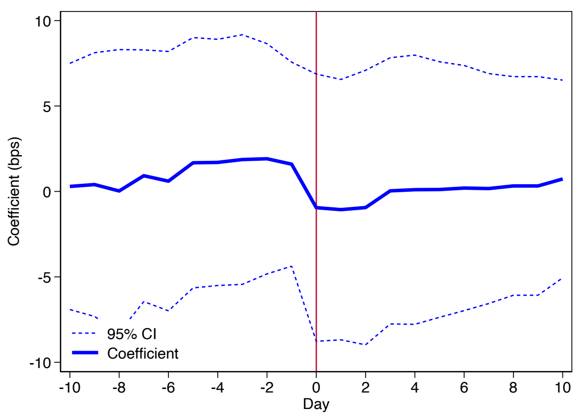
(b) Exiting year-end balance sheet (2016-2019)



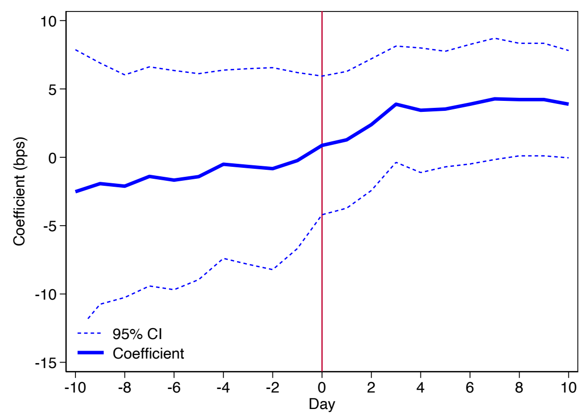
(c) Entering year-end balance sheet (2018-2019)



(d) Exiting year-end balance sheet (2018-2019)



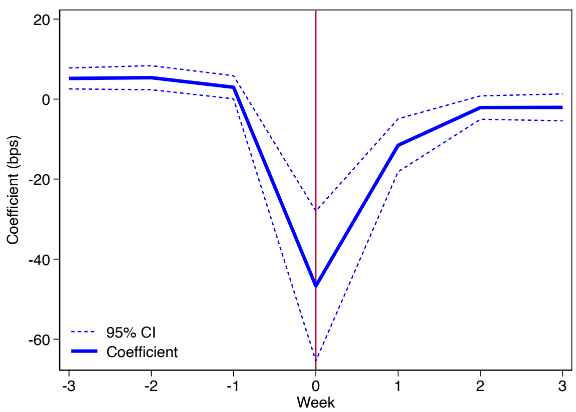
(e) Entering year-end balance sheet (2013-2015)



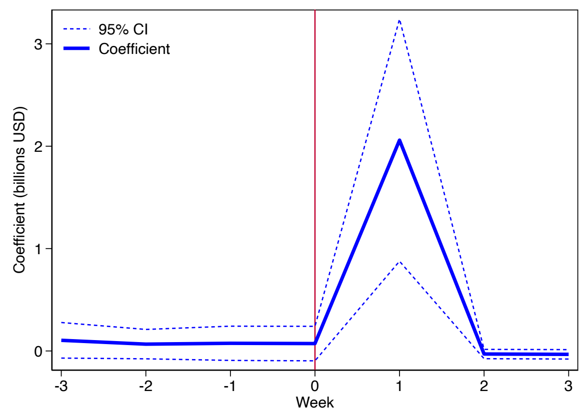
(f) Exiting year-end balance sheet (2013-2015)

Figure 5: 3-month Libor basis and year-end balance sheet: An event study

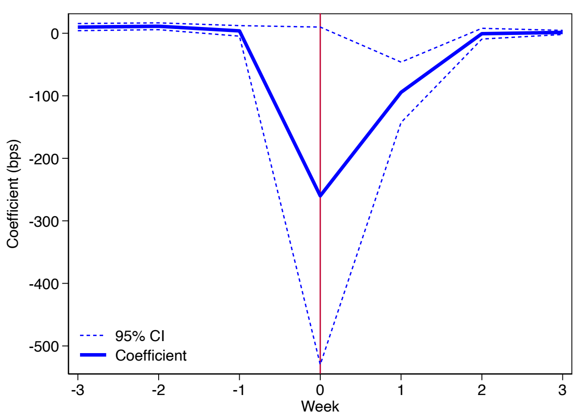
Note: Figure 5 reports event-study coefficients on a panel of G10 three-month Libor basis against dollar. The bases are projected on a set of dummy variables indicating days around the start and end of the time window in which a three-month forward's settlement date is of a different year than its maturity date, with $T + 2$ settlement convention. Day 0 in Figure 5a, 5c and 5e typically refers to two days before the end of September, while Day 0 in Figure 5b, 5d and 5f typically refers to two days before the end of December. Driscoll and Kraay (1998) standard errors are computed and 95% confidence intervals are reported.



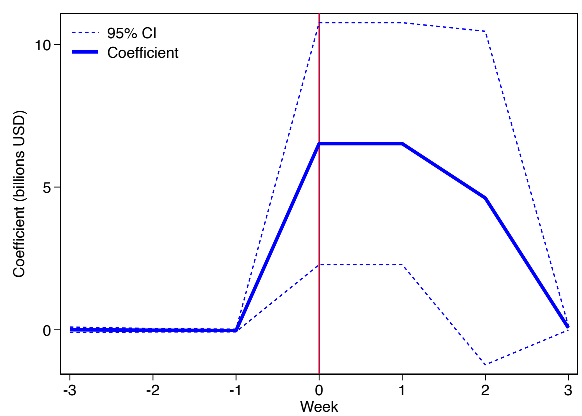
(a) 1-week EUR Libor basis: Around quarter-ends (17-19)



(b) Outstanding amount of short-term swap operation: Around quarter-ends (17-19)



(c) 1-week EUR Libor basis: Around year-ends (17-19)



(d) Outstanding amount of short-term swap operation: Around year-ends (17-19)

Figure 6: 1-week basis and swap holdings: An event study on EUR dollar basis

Note: Figure 6 reports the result of an event-study analysis on 1-week Libor-based CIP deviation of Euro against dollar and outstanding amount of ECB-Fed short-term swap line draws around period ends. Quarter-ends are defined as the second-to-last Wednesday of each quarter, excluding year-ends, which refer to the second-to-last Wednesday of each year. Weekly averages of dollar basis (Wednesday to next Tuesday) are used. 95% confidence interval is obtained using Newey-West standard errors and lag selection according to Newey and West (1994).

5 Conclusions

This paper sheds empirical light on the relationships between key macrofinancial variables and deviations from covered interest parity, with a focus on the decade after the global financial crisis. We highlight the role played by risk-taking capacity, FX market liquidty, unconventional monetary policy, and financial regulation, but we also provide evidence that some of these variables' explanatory power is typically heterogeneous across individual currencies and sometimes varies over time. An in-depth analysis of the contribution of country-specific characteristics, such as financial structure and exchange rate policy, could be an interesting extension. Equally worth exploring are the reasons behind the time-series evolution of basis correlations with macrofinancial variables, which could help us better to identify the persistent underlying forces allowing CIP deviations.

This paper seeks to describe the correlates of CIP deviations without answering the important question of the macroeconomic significance of the post-crisis breakdown of CIP. Do deviations from CIP have a quantitatively important impact on the pattern of cross-border capital flows and the cross-border transmission of U.S. monetary policy or other countries' monetary policies? What role does the cross-currency basis play in exchange rate determination? How much does a persistently negative dollar basis add to the "exorbitant privilege" enjoyed by the U.S. as an international reserve currency issuer? What are the specific implications for emerging market economies and their corporate borowers? These topics are of central importance for policy and thus should be high on the agenda for future research.

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Appendix: Data

Construction of dollar basis Our construction of various components used to compute CIP deviations is similar to Du, Tepper and Verdelhan (2018). We compute forward premia and the forward bid-ask spreads using daily London close forward points and spot rates from Bloomberg. Our daily IBOR rates come from Thomson Reuters/Datastream. Bloomberg series are used as supplements wherever needed. We convert the discrete-term interest rates to continuously compounded rates, using contract settlement and maturity dates obtained from Bloomberg. We obtain yields of treasury securities from Thomson Reuters/Datastream. In a few cases (such as Australia), we follow Du, Lim and Schreger (2018) and use Bloomberg Fair Value (BFV) series. Table A1 lists the tickers used for our baseline three-month tenor regressions.

Currency	Forward	Spot	IBOR	Treasury
AUD	AUD3M CMPL Curncy	AUDUSD CMPL Curncy	TAU3MBA	C1273M Index
CAD	CAD3M CMPL Curncy	USDCAD CMPL Curncy	CIDOR3M	TRCN3MT
CHF	CHF3M CMPL Curncy	USDCHF CMPL Curncy	BBCHF3M	TRSW3MT
DKK	DKK3M CMPL Curncy	USDDKK CMPL Curncy	CIBOR3M	TRDK3MT
EUR	EUR3M CMPL Curncy	EURUSD CMPL Curncy	EIBOR3M	C9103M Index
GBP	GBP3M CMPL Curncy	GBPUSD CMPL Curncy	BBGBP3M	TRUK3MT
JPY	JPY3M CMPL Curncy	USDJPY CMPL Curncy	BBJPY3M	TRJP3MT
NOK	NOK3M CMPL Curncy	USDNOK CMPL Curncy	NWIBK3M	C2663M Index
NZD	NZD3M CMPL Curncy	NZDUSD CMPL Curncy	NZBB90D	TRNZ3MT
SEK	SEK3M CMPL Curncy	USDSEK CMPL Curncy	SIBOR3M	TRSD3MT
USD			BBUSD3M	TRUS3MT

Table A1: Tickers for 3-month LIBOR basis computation

Factors contributing to CIP deviations We collect time series from various sources:

Effective exchange rates, VIX and liquidity For the U.S. dollar, use daily data on the nominal broad dollar index (goods only) published in the Federal Reserve H.10 release. Our last observation of the goods-only index is for December 31, 2019. We use changes in the absolute level of the index in our regressions. For the JPY and CHF indices, we use daily releases from BIS. We download daily CBOE VIX index from Datastream and log transform the index. We use the daily closing forward point bid-ask spread to proxy for FX market liquidity conditions.

Risk measures The global risky asset price factor comes from the January 2020 update of the Miranda-Agrippino-Rey dataset (Miranda-Agrippino, Nenova and Rey, 2020), covering the sample until April 2019.[23] First differences of log prices are used to extract the global factor, and

[23] Available at http://silviamirandaagrippino.com/code-data.

the final global factor is obtained by cumulation and standardization. For intermediary leverage, we use daily measures provided by He, Kelly and Manela (2017) (henthforth HKM), covering the sample until November 2018. The HKM capital ratios are calculated by aggregating the market value of equity (share price times shares outstanding) and book value of debt of primary dealers. We standardize the squared leverage ratio measure by normalizing it by its mean and standard deviation.[24] We use the square of the inverse of HKM's capital ratio measure.

Central bank balance sheets and swap line operations Data on central bank balance sheets come from various sources. For the Unted States, we use total assets less eliminations from consolidations from the Federal Reserve's weekly H.4.1 releases. Total assets of the European Central Bank and Bank of Japan are obtained from FRED. Total assets of the Bank of England and the Swiss National Bank come from central bank websites. We normalize the balance sheets measured in local currency by the domestic M2 stock, obtained from CEIC. We log transform the ratio of normalized balance sheet sizes, multiply by 100, and use the first difference in our regressions. We obtain weekly swap line operation results from the Federal Reserve Bank of New York.[25] We consider all swap line draws with a tenor equal to or smaller than three weeks.

Term premia Following Greenwood, Hanson, Stein and Sunderam (2019), we use distant-horizon forward rates (one-year rates nine years forward) computed from zero-coupon yield curves as proxies for term premia on ten-year government bonds. Zero-coupon yield curves are obtained from national sources. Our sample covers Australia, Canada, the United States, the United Kingdom, Switzerland, Japan, and the euro area. For the euro area, we use the yield curve of triple-A government securities. For the United States, we directly take the one-year forward rate (SVEN1F09) from the Gürkaynak, Sack and Wright (2007) dataset, which is highly correlated with canonical estimates of the term premium such as Adrian, Crump and Moench (2013). For Japan, there are no available data on the zero-coupon yield curve. As the coupon yield on Japanese government bonds is low in recent periods, we use the constant-maturity yield curve published by the Ministry of Finance.

[24] Available at `http://apps.olin.wustl.edu/faculty/manela/data.html`.

[25] `https://apps.newyorkfed.org/markets/autorates/fxswaps-search-result-page?SHOWMORE=TRUE`.