NBER WORKING PAPER SERIES

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MACROFINANCIAL DETERMINANTS

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Working Paper 26129
http://www.nber.org/papers/w26129

NATIONAL BUREAU OF ECONOMIC RESEARCH
1050 Massachusetts Avenue
Cambridge, MA 02138
August 2019

Cerutti is at the Asia and Pacific Department of the International Monetary Fund (IMF). Obstfeld and Zhou are now at the University of California, Berkeley, and Princeton University, respectively. Much of this work was done while all at the IMF. We thank Paul Cashin, Oyakhilome Ibhagui, Gee Hee Hong, Anne-Charlotte Paret-Onorato, Piotr Kopyrski, Roman Lafarguette, and Chris Walker for their comments. We are grateful to Gordon Liao for sharing his residualized credit spread data. The opinions expressed herein are solely the responsibility of the authors and should not be interpreted as reflecting those of the IMF, its Executive Board, IMF management, or the National Bureau of Economic Research. This Paper was also published as IMF Working Paper 19/14.

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NBER Working Paper No. 26129
August 2019
JEL No. F31,G15

ABSTRACT

For several decades until the Global Financial Crisis (GFC), Covered Interest Parity (CIP) appeared to hold quite closely—even as a broad macroeconomic relationship applying to daily or weekly data. Not only have CIP deviations significantly increased since the GFC, but potential macrofinancial drivers of the variation in CIP deviations have also become significant. The variation in CIP deviations seems to be associated with multiple factors, not only regulatory changes. Most of these do not display a uniform importance across currency pairs and time, and some are associated with possibly temporary drivers (such as asynchronous monetary policy cycles).

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I. INTRODUCTION

The principle of covered interest parity (CIP), first set out by Keynes (1923) during the floating exchange rate period after World War I, is a fundamental building block of international finance. Absent counterparty risk, CIP is a pure arbitrage relationship that equates the premium of a currency's forward over its spot exchange rate (expressed as 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 daily or even weekly 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, 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. 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, Hébert, and Wang Huber 2019).

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, 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. 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 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 when necessary.

A growing recent literature tries to rationalize recent CIP deviations.[2] 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), to changes in banks' balance-sheet capacity connected with U.S. dollar appreciation (Avdjiev et al. 2017), to interest-rate differences across currencies and their impact on the swap market (Brauning, and Ivashina 2017; Sushko et al. 2017; Liao 2019). 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 "macro-financial" 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-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. CIP deviations relative to the U.S. dollar for ten other major currencies are our focus, and we exploit both time series and cross-currency evolutions. We account for the likelihood that major drivers fluctuate over time through a range of econometric techniques: rolling estimation windows, Markov regime-switching models, and split-sample analysis. Our analysis includes both time-series and panel estimation to accommodate the idiosyncrasies of individual currency pairs as well as average generic relationships. The Libor interest rate often used for CIP calculations before the GFC worked well enough at the macro level then, but its use has been criticized recently as not reflecting the true funding cost of market arbitrageurs (Duffie and Stein 2015; Cecchetti and Schoenholtz 2017; Rime, Schrimpf, and Syrstad 2019). We therefore explore alternative interest rates and an instrumental-variable design.

Three main points summarize our findings. First, it is clear that CIP broke down during the GFC and has not held reliably since. Not only have CIP deviations—measured using different benchmarks and country pairs—increased significantly since the GFC, but also, potential drivers of the variation in CIP deviations have become statistically and economically significant. Second, even though CIP's breakdown is likely related to regulatory changes, the variation in CIP deviations seems also to be associated with multiple drivers across time, some of them associated with temporary factors (such as asynchronous monetary policy in the United States, the euro area, and Japan; or the 2016 reforms in the operation of U.S. prime money market funds). Last, time series approaches suggest that even those proposed factors that display the more statistically significant associations with CIP deviations across most of our sample (such as U.S. dollar strength), do not have a uniform

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[2] Before the post-GFC period, the literature associated possibly persistent deviations from CIP with periods of uncertainty and turmoil. For example, Taylor (1989) highlights CIP deviations on occasions such as the floatation of sterling in 1972 and the inception of the European Monetary System in 1979. Baba and Packer (2009) attribute the large CIP deviations during the GFC to differences in counterparty risks.

importance across currency pairs and time, hinting at the interaction of several time- and country-specific factors.

In most cases, our macro findings support and complement the insights from the rapidly increasing recent literature on CIP. In line with Akram, Rime, and Sarno (2008), we find that the forward premium (or swap rate) closely tracked the interest rate differential before the crisis, with no other factors significant in the CIP relationship. However, as CIP broke down during the GFC and its aftermath, U.S. dollar strength (Avdjiev et al. 2017), global risk sentiment (proxied by the VIX index), and to a very limited extent, forward exchange market liquidity conditions (measured using the bid-ask spreads of FX forwards) have significantly contributed to the variation in the cross-currency basis. These significant relationships remain robust across different maturity horizons.

Regarding the evolution of CIP deviations, although structural factors, such as post-crisis financial regulations, may have increased the cost of currency arbitrage and opened up the conditions for CIP deviations (Du, Tepper, and Verdelhan 2018), these factors are not the whole story. While empirically testing the impact of regulatory constraints is difficult owing to their slow-moving nature, we provide some evidence suggesting that structural factors alone are less able to explain the *variation* of the cross-currency basis over time. Moreover, several temporary factors play a major role in moving cross-currency bases. Major central banks' divergent monetary policy stances have widened cross-currency bases through several channels that raised the demand for swaps into U.S. dollars (Brauning and Ivashina 2017; Liao 2019). Our regressions also identify the October 2016 reform of U.S. prime money market funds as one temporary factor widening CIP deviations through a dramatic reduction in non-U.S. banks' funding for currency arbitrage (Iida, Kimura, and Sudo 2016; Nakaso 2017; Anderson, Du, and Schlusche 2019).

A much more difficult question, one that the literature has mostly not posed, concerns the policy significance of CIP deviations. Even though CIP deviations are *ipso facto* evidence of financial-market frictions, it is much less evident if these frictions significantly undermine monetary policy transmission or exchange-market stability, or in general have large welfare costs. In this context, the current empirical and theoretical evidence is still insufficient to make a case for policy intervention by national or international regulators. Our paper is a contribution to necessary further analysis.

We structure the rest of the paper follows: After Section II reviews the concept and measurement of CIP deviations, it tests for their presence at the macro level using a simple regression framework. Section III lists proposed explanations for post-GFC deviations and explores several leading ones empirically. Section IV focuses on the changing power of U.S. dollar strength in explaining the time-series variation in CIP deviations. The Appendix contains additional regression evidence and other considerations.

II. CIP DEVIATIONS BEFORE, DURING, AND AFTER THE GFC

2.1 Measuring Covered Interest Parity Deviations

For a given foreign currency and the U.S. dollar, a deviation from covered interest rate parity refers to the wedge between two rate 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 rates expressed in units of foreign currency per dollar; and (ii) the difference in the 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 (with an asterisk) and U.S. interest rates. In the absence of financial frictions, an arbitrageur could take advantage of the deviation from 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. Hence, 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:

$$x_{t,t+n} = \left(f_{t,t+n} - s_t\right) - \left(r^*_{t,t+n} - r_{t,t+n}\right) \quad (1)$$

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 crisis for both the short-term (Figure 1) and long-term horizons (Figure 2). Before the GFC, CIP deviations were very small and fluctuated around zero. This feature is in line with findings of Akram, Rime, and Sarno (2008), as described above.[4] Starting with the GFC, however, CIP started to break down, leaving a sizable unexploited cross-currency wedge. During the GFC, short-term CIP deviations reached levels of about -200 basis points (Figure 1), and more negative than -50 basis points at the five-year horizon (Figure 2). While both three-month and five-year 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 deviations from CIP against the U.S. dollar (that is, $x_{t,t+n} > 0$). This sign indicates that direct U.S. dollar funding is costlier than synthetic funding based on swapping AUD or

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[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 early empirical evidence supporting CIP.

NZD borrowings into U.S. currency. Nonetheless, Australian and New Zealand (notably, their financial institutions) 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 limited sizes of their local funding bases in domestic currency (Arsov et al. 2013; Callaghan 2017).

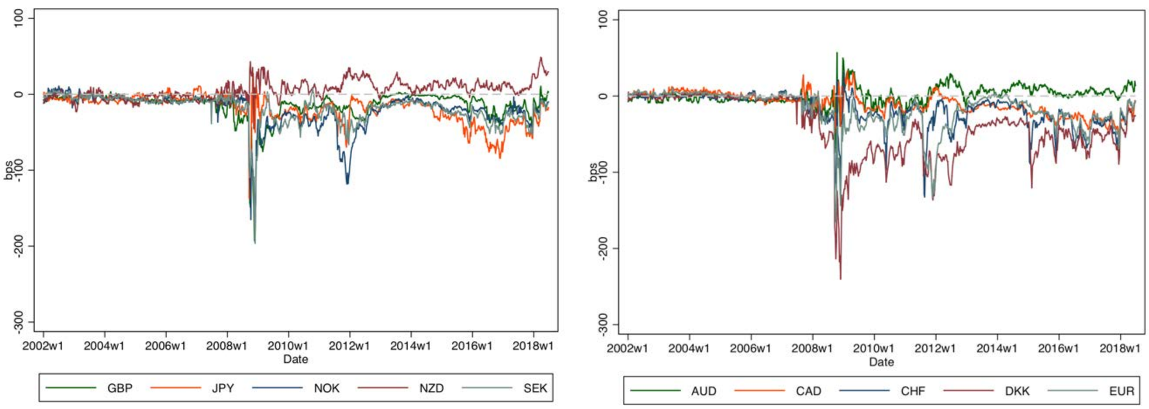

Figure 1: 3-month Libor cross-currency dollar basis

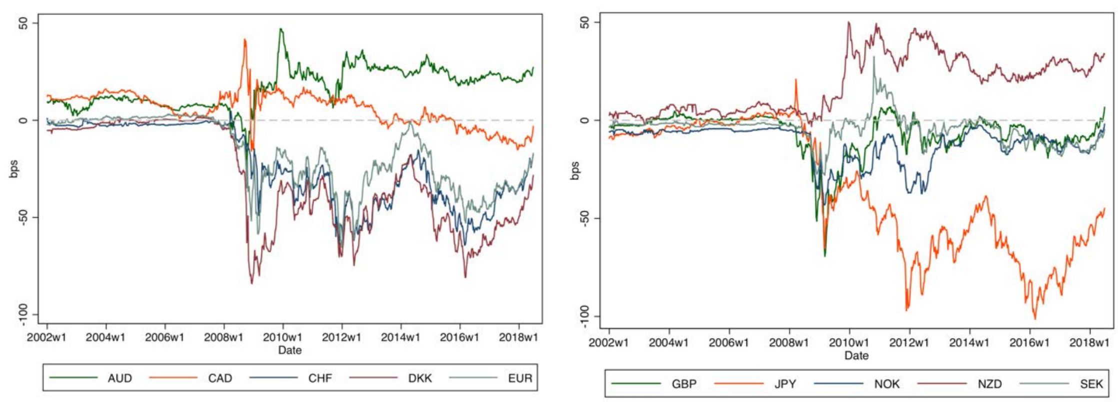

Figure 2: 5-year cross-currency dollar basis

The presence of persistent CIP deviations during, and especially after the GFC has triggered considerable attention. Some researchers suggest that the Libor rates used in the cross-currency dollar basis calculations used in Figure 1 and 2 may not accurately represent the funding cost of actual parties engaging in cross-currency trades. For example, Rime, Schrimpf, and Syrstad (2019) argue against using the Libor as the marginal funding cost faced by arbitrageurs in actual trading, as euro area banks could issue non-bank money market instruments, such as commercial paper and certificates of deposit and obtain a lower quote. Use of Libor also entails potentially serious measurement issues.[5]

[5] The fact that the Libor rate is a relatively inactive funding option is also evident from the structure of its submission, as a large proportion of submissions are no longer based on actual transactions. For instance, less than 25 percent of 3-month Libor submissions from contributor banks is transaction-based (ICE Benchmark Administration, 2016).

In this context, following the spirit of Rime, Schrimpf, and Syrstad (2019), Figure 3 shows an alternative measure of the scope for CIP arbitrage between U.S. dollars and foreign currency. For the U.S. dollar interest borrowing rate, we use the 3-month U.S. AA-rated financial commercial paper (CP) rate, published by the Federal Reserve. For the foreign interest rate, we use the 3-month government bill rate, to account for arbitrageurs' completion of the arbitrage process by investing in safe assets. For the entire sample period, we could calculate this alternative cross-currency basis measure for 6 pairs out of the 10 countries included in our baseline sample. Although the evolution of these new series is not identical to the Libor-calculated bases, especially during the GFC, the main takeaways are similar. Volatile but highly persistent CIP deviation appeared during the GFC, and although they have generally decreased, these CIP deviations have persisted after the GFC.[6] In general, when comparing with the Libor bases and the alternative definition using U.S. commercial paper and foreign government bills, we see that the two measures of CIP deviations could greatly differ during the GFC (e.g., one is positive and the other negative in the cases of the U.S. dollar/euro cross-currency basis as plotted in Figure 4). In general, Libor-based dollar bases are less negative than their counterparts calculated using commercial paper-treasury bill rate differentials, as shown in Figure 4 for the case of EUR. This finding, further documented in Table A5, is similar to Rime, Schrimpf, and Syrstad (2019). As we show in subsequent regressions, however, drivers of Libor-based CIP deviations, such as aggregate USD strength and VIX, seem to also affect CP/treasury-bill-based CIP deviations in a similar fashion. As a visual illustration, Figure 4 suggests that both measures of CIP deviations for EUR are highly correlated after 2010.

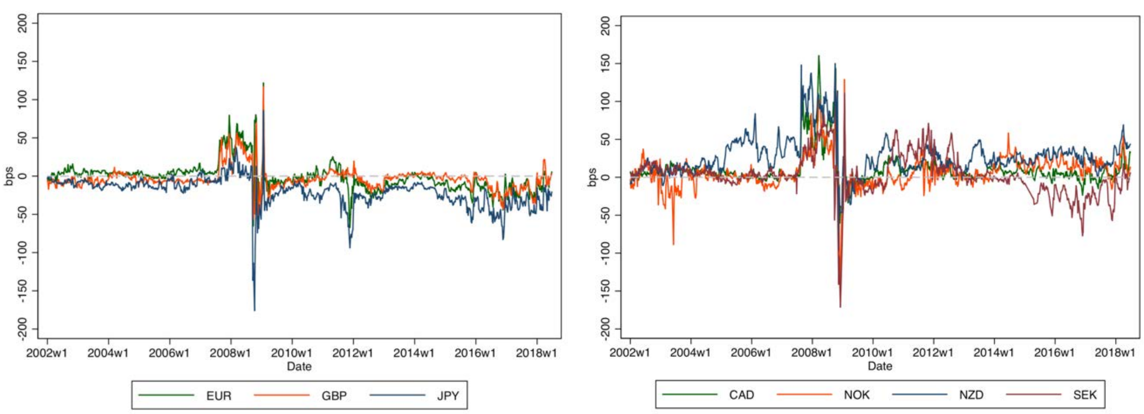

Figure 3: 3-month cross-currency dollar basis using (Foreign government bill rate – U.S. commercial paper rate)

[6] The cross-currency dollar basis depicted for New Zealand in Figure 3 for 2005-06 are larger than the Libor based ones depicted in Figures 1 and 2. They reflect high New Zealand government bill interest rates as well as a strong exchange rate due to an appreciation of commodity prices (IMF 2007). The regression analysis in the next section shows that, despite some differences in the levels of cross-currency dollar basis, results are similar across ways to measure the cross-currency bases.

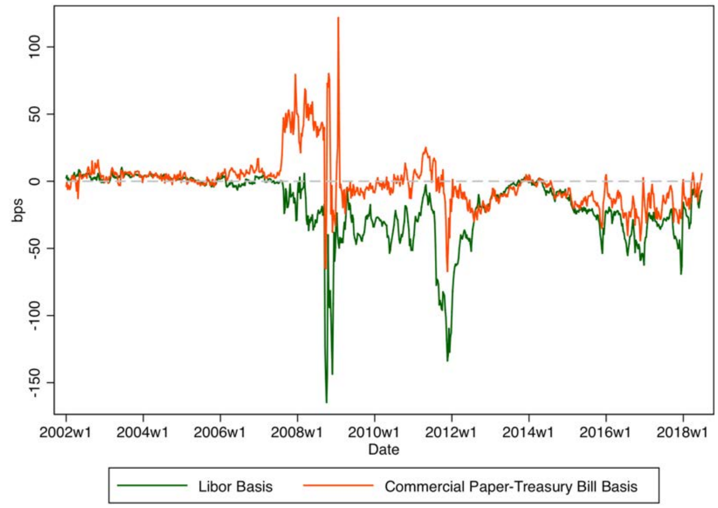

Figure 4: EURUSD 3-Month CIP Deviation: Libor and Alternative Basis

Liquidity conditions in the foreign exchange market might also help explain the persistence of CIP deviations after the GFC, although bid-ask spreads at short-term and long-term maturities have tended to be small with spikes that increase in frequency during and after the GFC (Figure 5). Meanwhile, there is consensus in the literature that structural factors, such as regulatory burdens, created limits to arbitrage allowing failures to profit from CIP deviations (see Du, Tepper, and Verdelhan 2018 for a review). However, regulation changes alone, due to their slow-moving nature, are not necessarily effective in explaining variations in CIP deviations over time. While tighter regulation may have induced potential arbitrageurs to stay away from arbitraging cross-currency dollar basis, little evidence could be directly found in aggregate data.[7] Figure 6 plots the annual capital charge measure from Du, Tepper, and Verdelhan (2018), calculated from the Value-at-Risk (VaR) in a five-year Libor CIP trade. Substantial volatility in cross-currency dollar bases after the crisis, coupled with tighter capital requirements (mostly in recent years), seem to have significantly pushed up the cost of arbitraging since the GFC. Nonetheless the time-series evolution of capital charges does not explain the seeming temporary restoration of CIP from 2013 to 2014, or the widening after that.

[7] Cenedese, Della Corte, and Wang (2017) utilize a unique transaction-level dataset on over-the-counter foreign exchange derivatives to investigate the relationship between the cross-currency basis and leverage ratio. They find that hedging demand causes a widening of the basis especially when dealer banks face deleveraging pressure associate with a higher leverage ratio.

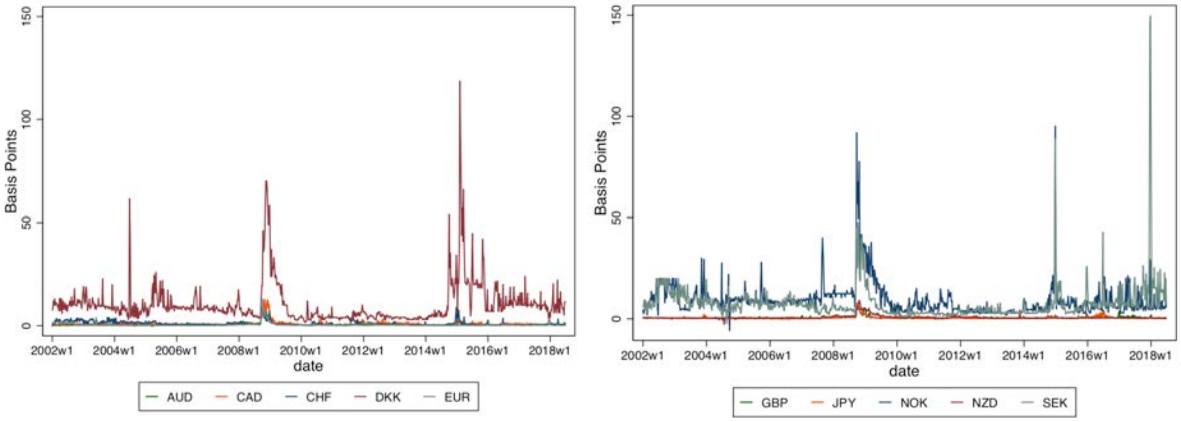

Figure 5: 3-month forward point bid-ask spread (forward point difference)

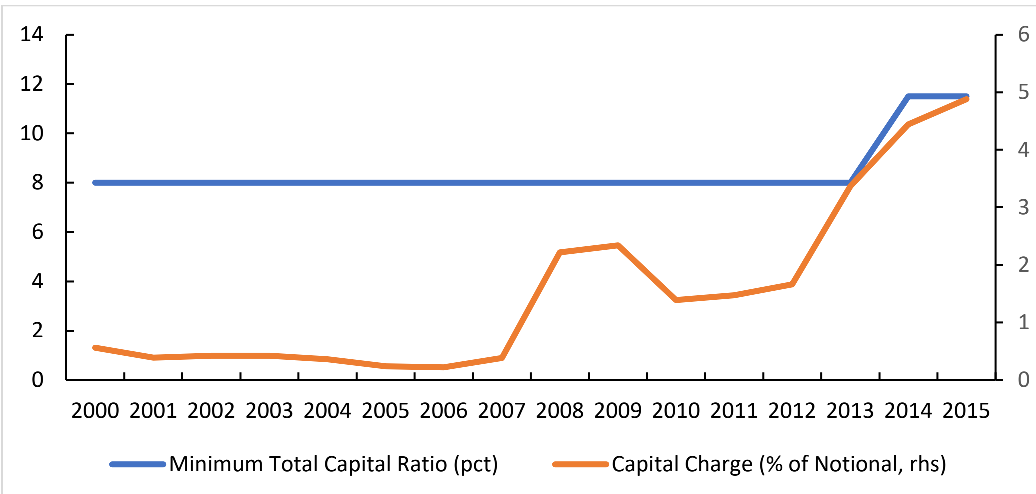

Figure 6: Du, Tepper, and Verdelhan (2018) capital charge measure against 5-year Libor CIP trade

2.2 Basic regression Analysis using Libor-based cross-currency calculations

We now adopt a regression-based approach to analyze the possible drivers of CIP deviations over time.

In analogy to the uncovered interest rate parity (UIP) literature (e.g., Fama 1984), we regress the forward rate premium over the spot rate (the *forward premium*) on the interest differential and other potential determinants. Our empirical specification, based on the first difference of equation (1), can be written as

$$\Delta\left(f_{t,t+n} - s_t\right) = \alpha + \beta \cdot \Delta\left(r^*_{t,t+n} - r_{t,t+n}\right) + \delta X_t + \varepsilon_t ,$$

with X_t representing a vector of potential drivers of $\Delta x_{t,t+n}$, the change in the cross-currency dollar basis. In the event that CIP is satisfied, $\alpha = \delta = 0$ and $\beta = 1$, as the change in the interest rate differential perfectly explains any change in the forward premium.[8] Subtracting $\Delta\left(r^*_{t,t+n} - r_{t,t+n}\right)$ from both sides, the estimating equation is equivalent to $\Delta\, x_{t+n} = \alpha + (\beta - 1) \cdot \Delta\left(r^*_{t,t+n} - r_{t,t+n}\right) + \delta X_t + \varepsilon_t$, in which the interest rate differential serves as a potential additional driver of the change in cross-currency dollar basis.

In our baseline specification, we will consider three potential drivers of the changes in the cross-currency basis. First, following Avdjiev et al. (2017), we examine the aggregate strength of the U.S. dollar. They observe a strong inverse relationship between the cross-currency dollar basis and dollar strength: the basis *x* becomes more negative as the trade-weighted dollar strengthens, an increase in the cost of synthetic dollar borrowing (via the swap market) compared with direct dollar borrowing. According to them, the underlying explanation hangs on the interplay among dollar strength, bank leverage, and dollar credit. As the dollar strengthens non-U.S. residents' balance sheets weaken, and this change impairs their ability to access dollar credit on favorable terms, allowing the absolute CIP deviation to rise. Second, also following Avdjiev et al. (2017), we use the log change in the U.S. VIX index to control for global risk sentiment. In principle, heightened risk sentiment could deter covered interest arbitrage through a generalized retrenchment in balance sheets. Third, we look at forward bid-ask spreads to capture liquidity in the FX market. We will introduce and explore other factors, most of which arise after the GFC, in Section III.

Our baseline regressions focus on the weekly average of 3-month forward premiums, the Libor/interbank rate differential, the Federal Reserve Board (FRB) U.S. trade-weighted broad dollar index, and the log VIX index from 2002 to 2018. We start with the period 2002-2006 before the GFC, in which the 3-month Libor-based cross-currency dollar basis is generally close to zero (see Figures 1 and 4 for the case of the EUR/USD pairing). As the parity held closely before the crisis, we expect that only the change in interest rate differential will track the (small) variation in the forward premium. Table 1a confirms this expectation. Changes in dollar strength and risk sentiment have barely any power to affect the forward premium beyond the interest rate differential. This finding holds true in our time-series regressions for individual currencies, as well as in a panel regression that includes currency fixed effects.[9]

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[8] In reporting regressions results below, we do not include estimates of the constant term α, which is statistically insignificant from zero in most specifications. We also run similar regressions using levels instead of first differences. Results are very similar, but tests showed that we cannot reject the presence of unit roots in the evolution of most series. Hence, we prefer to present regressions estimated on first differences.

[9] We do not include Australia and New Zealand in the panel baseline regressions since they consistently experience positive cross-currency dollar basis. Fukuda and Tanaka (2017) focuses on the positive level of the cross-currency dollar basis and concludes that unique monetary policy features in Australia and New Zealand made deviations from the CIP condition distinct on the forward contract. In our context, the individual regression series results are in line with the other countries with respect to interest rate differential, with dollar strength and VIX does not seem to statistically significantly drive the evolution of the basis. The panel regressions results are almost identical if we include Australia and New Zealand.

Δ(f-s)	Australia AUD	Canada CAD	Switzerland CHF	Denmark DKK	Euro Area EUR	UK GBP	Japan JPY	Norway NOK	New Zealand NZD	Sweden SEK	**Panel**
Δ (r*-r)	0.890***	0.858***	1.010***	0.983***	0.978***	0.914***	0.983***	1.021***	0.932***	1.005***	0.976***
	(0.0484)	(0.0347)	(0.0509)	(0.0442)	(0.0288)	(0.0380)	(0.0627)	(0.0415)	(0.0474)	(0.0290)	(0.0240)
Δ USDINDEX	-0.0682	-0.360	0.0431	0.0423	-0.0728	0.419*	-0.225	0.225	0.727*	0.0608	0.0354
	(0.362)	(0.268)	(0.244)	(0.192)	(0.157)	(0.245)	(0.270)	(0.306)	(0.407)	(0.215)	(0.0907)
Δ lnVIX	-0.0427	0.220	0.375	0.321	-1.622	-1.751	3.248	0.303	1.484	-0.478	0.234
	(2.428)	(1.673)	(1.747)	(1.290)	(1.359)	(1.692)	(2.133)	(2.413)	(3.298)	(1.679)	(0.554)
Δ Forward	-0.473	0.574	0.0418	-0.0413**	-0.629**	0.0162	0.795	0.0526	1.042*	-0.0555	-0.0128
Bid-Ask	(1.871)	(0.822)	(0.153)	(0.0185)	(0.316)	(0.973)	(0.630)	(0.0403)	(0.602)	(0.0427)	(0.0292)
N	259	259	259	259	259	259	259	259	259	259	2072
R-sq	0.706	0.779	0.771	0.808	0.857	0.805	0.642	0.852	0.629	0.815	0.798

Table 1a: Pre-crisis weekly regression (3-month Libor rate, 2002-2006)

Starting in 2007 the cross-currency dollar basis started to widen and displayed erratic movement during the crisis. Table 1b presents the regression results, restricting the sample to the peak crisis period, 2007-2009. Compared with Table 1a, the fit is significantly worse: R-squared statistics in almost all regressions are much lower than those in Table 1a, suggesting that movements in forward premiums were less fully tracked by the interest rate differential than in the pre-crisis period, and that additional factors, especially dollar movements, mattered. In the panel regression, the coefficient on the change in the interest rate differential is generally farther from 1.0 than in in estimates of Table 1a. Changes in dollar strength are highly significant and negative in the panel estimation—that is, they raise the cost of synthetic dollar borrowing compared with direct dollar funding—although this additional factor usually is not significant in any of the individual-currency time-series regressions.

Δ(f-s)	Australia AUD	Canada CAD	Switzerland CHF	Denmark DKK	Euro Area EUR	UK GBP	Japan JPY	Norway NOK	New Zealand NZD	Sweden SEK	**Panel**
Δ (r*-r)	0.666***	0.920***	0.922***	0.939***	0.820***	0.758***	0.861***	0.843***	0.911***	0.823***	0.887***
	(0.141)	(0.108)	(0.220)	(0.114)	(0.150)	(0.181)	(0.166)	(0.132)	(0.0757)	(0.135)	(0.0262)
Δ USDINDEX	-5.110**	-0.956	-0.339	1.249	1.246	-2.499	-2.103	-1.454	-1.668	-0.608	-0.864**
	(2.457)	(1.504)	(2.714)	(2.576)	(2.629)	(2.616)	(1.991)	(2.310)	(1.411)	(2.002)	(0.274)
Δ lnVIX	-4.376	8.125	-8.294	-10.63	5.873	-7.122	-5.962	-21.73	8.657	-5.021	-10.39**
	(11.27)	(13.04)	(20.15)	(21.25)	(13.22)	(13.20)	(10.28)	(14.98)	(8.029)	(13.51)	(3.474)
Δ Forward	-11.78**	-2.426	0.667	-1.311*	-10.38***	-3.082	-14.38	-0.110	2.908	-0.462	-0.456
Bid-Ask	(5.571)	(2.069)	(4.597)	(0.669)	(3.821)	(3.381)	(8.804)	(0.186)	(3.396)	(0.484)	(0.265)
N	156	156	156	156	156	156	156	156	156	156	1248
R-sq	0.661	0.617	0.402	0.532	0.563	0.375	0.530	0.614	0.712	0.640	0.483

Table 1b: Crisis period weekly regression (3-month Libor rate, 2007-2009)

Next, we turn to the post-GFC period, 2010-2018. The significance of dollar strength and the VIX rises during this period, as Table 1c shows. Dollar strength and the VIX are not only significant in the panel regression, but also in most of the time-series regressions.[10] The coefficient of change in the log VIX index is most significant and largest in magnitude in the case of traditional safe haven currencies (CHF and JPY), possibly reflecting the higher hedging demand for dollar swaps of those currencies following rising volatilities and uncertainties. The FX liquidity measure is only significant in the case of Swiss Franc, euro area, and overall panel. This finding is consistent with that of Pinnington and Shamloo (2016), who find that FX liquidity effects on deviations from CIP were especially strong for currency pairs involving the Swiss franc after the Swiss National Bank's 2015 decision to lift its exchange rate ceiling.

Δ(f-s)	Australia AUD	Canada CAD	Switzerland CHF	Denmark DKK	Euro Area EUR	UK GBP	Japan JPY	Norway NOK	New Zealand NZD	Sweden SEK	**Panel**
Δ (r*-r)	0.740***	0.852***	1.572***	1.407***	0.858***	0.735***	0.898***	0.573***	0.598***	1.120***	1.087***
	(0.0557)	(0.0862)	(0.207)	(0.160)	(0.161)	(0.160)	(0.240)	(0.0542)	(0.0428)	(0.0688)	(0.189)
Δ USDINDEX	-0.295	-0.727***	-0.967*	-2.453***	-2.676***	-1.157***	-1.735***	-1.917***	-0.207	-1.961***	-1.679***
	(0.336)	(0.249)	(0.573)	(0.520)	(0.401)	(0.279)	(0.427)	(0.370)	(0.244)	(0.434)	(0.285)
Δ lnVIX	-1.598	-0.764	-6.424**	-2.830	-1.499	0.207	-5.846**	-3.802*	0.377	-1.464	-2.892**
	(1.349)	(1.169)	(3.127)	(2.924)	(2.318)	(1.312)	(2.415)	(1.971)	(0.976)	(1.819)	(0.855)
Δ Forward	-0.0841	-0.390	-3.342***	-0.0532	-4.897**	-0.176	-1.394	-0.0260	0.186	-0.0134	-0.0548*
Bid-Ask	(0.838)	(0.308)	(0.709)	(0.0573)	(2.362)	(0.761)	(0.858)	(0.0392)	(0.315)	(0.0471)	(0.0254)
N	442	442	442	442	442	442	442	442	442	442	3536
R-sq	0.404	0.440	0.448	0.436	0.312	0.208	0.198	0.367	0.346	0.486	0.332

Table 1c: Post-crisis weekly regression (3-month Libor rate, 2010-2018M6)

The results across the different three periods are very similar, especially with regard to the dollar movements, if we use a 5-year horizon together with Libor-based measurement of the cross-currency basis (See the Appendix).

2.2 Regression analysis using alternative marginal funding costs

As we noted at the beginning of the section, although they are widely used, Libor-based measures do not necessarily track well changes in various market participants' actual marginal funding costs. We use two sets of regressions to address this issue. First, we replace the Libor-based differential in our OLS regression model with 3-month foreign government bill rate-US commercial paper differential and repeat the same exercise. In other words, we test a type of covered interest arbitrage, where a generic type of company is comparing the returns of issuing 3-month U.S. AA-rated financial commercial paper (assuming that this is representative of its marginal funding costs), then investing the amount borrowed in 3-month

[10] While Avdjiev et al (2017) propose the use of the VIX, they do not detect the VIX having a significant impact on CIP deviations.

foreign treasuries while also hedging the exchange rate risks.[11] Second, we use that alternative differential as an instrumental variable for the Libor-based rate differential, in both time-series and panel IV regressions. In the case that both interest rate differentials are noisy proxies of the true differential with classical measurement error, the estimated coefficients would be consistent.[12]

Tables 2a through 2c report the results of IV regressions using a subset of currencies for which we have complete data coverage on 3-month treasury bill yields. (We relegate the OLS results to the Appendix.) We obtain somewhat similar conclusions compared to those in Tables 1a-1c, in that dollar strength, the VIX index, and liquidity conditions are significant in most time-series regressions and panel regressions on the post-crisis sample, but rarely significant before and during the crisis. Contrary to Table 1b, however, the panel estimate of USD strength flips sign and is significantly positive. This difference possibly reflects the wild price movements in interbank and money market during the crisis period – indeed, Figure 4 shows that the Euro/USD Libor basis and the commercial paper-treasury bill basis diverged significantly in late 2008.

Δ(f-s)	Canada CAD	Euro Area EUR	UK GBP	Japan JPY	Norway NOK	New Zealand NZD	Sweden SEK	**Panel**
Δ (r*-r)	0.912***	1.023***	0.935***	0.980***	0.963***	0.986***	1.040***	0.972***
	(0.0390)	(0.0362)	(0.0403)	(0.0636)	(0.0938)	(0.0604)	(0.0326)	(0.0187)
Δ USDINDEX	-0.297	-0.0580	0.442*	-0.226	0.241	0.723*	0.0856	0.0291
	(0.269)	(0.157)	(0.244)	(0.266)	(0.297)	(0.406)	(0.215)	(0.116)
Δ lnVIX	0.404	-1.569	-1.704	3.256	1.036	1.466	-0.616	0.228
	(1.688)	(1.359)	(1.676)	(2.116)	(2.491)	(3.233)	(1.664)	(0.773)
Δ Forward Bid-Ask	0.619	-0.619*	-0.0505	0.795	0.0558	1.033*	-0.0541	0.0151
	(0.819)	(0.334)	(0.979)	(0.624)	(0.0414)	(0.590)	(0.0423)	(0.0398)
N	259	259	259	259	259	259	259	1554
R-sq	0.776	0.855	0.804	0.642	0.849	0.627	0.814	

Table 2a: Pre-crisis IV regressions (Commercial Paper-Treasury Bill rate as instrument, 3-month deviations, 2002-2006)

[11] This is different than focusing on the Law-of-One-Price (LOOP)—which stipulates that identical claims issued by the same firm but traded in different markets are priced similarly due to arbitrage. In our example, it would mean comparing the cheapest way to borrow. It would not involve investing in safe foreign government T-bills but comparing the cost of two perfectly alike bonds in terms of maturity, rating, liquidity, and firm-specific characteristics. This not easy in practice even when using firm level data as shown in Liao (2019). In the next section, we will use Liao's (2019) estimates, but they are available only after the GFC.

[12] For robustness, we use change in CIP deviation as dependent variable, which would control for other common shocks that affect both forward premium and interest rate differential. We also find that that dollar strength and the VIX index are significant in most time-series regressions and panel regressions on the post-crisis sample, but rarely significant before and during the crisis.

Δ(f-s)	Canada CAD	Euro Area EUR	UK GBP	Japan JPY	Norway NOK	New Zealand NZD	Sweden SEK	**Panel**
Δ (r*-r)	1.367***	1.141***	2.143***	1.526**	1.660***	0.998***	1.084***	1.584***
	(0.451)	(0.217)	(0.629)	(0.621)	(0.609)	(0.158)	(0.171)	(0.135)
Δ USDINDEX	2.478	2.199	1.594	-1.440	3.011	-0.111	1.973	1.705***
	(2.503)	(2.883)	(5.302)	(3.715)	(5.104)	(1.543)	(2.079)	(0.516)
Δ lnVIX	12.13	9.263	-13.97	-2.005	-19.47	9.999	-2.338	-5.774
	(11.19)	(12.99)	(17.36)	(13.15)	(14.73)	(7.701)	(11.22)	(4.842)
Δ Forward Bid-Ask	-4.836**	-10.42**	0.264	-11.22	-0.184	1.029	-0.518	-0.369**
	(2.410)	(4.051)	(4.602)	(10.52)	(0.315)	(3.927)	(0.470)	(0.182)
N	151	151	151	151	151	151	151	906
R-sq	0.505	0.559	0.341	0.421	0.312	0.749	0.651	

Table 2b: Crisis period IV regressions (Commercial Paper-Treasury Bill rate as instrument, 3-month deviations, 2007-2009)

Δ(f-s)	Canada CAD	Euro Area EUR	UK GBP	Japan JPY	Norway NOK	New Zealand NZD	Sweden SEK	**Panel**
Δ (r*-r)	0.917***	2.017***	1.097***	0.558	1.197***	0.662***	0.656***	1.108***
	(0.125)	(0.417)	(0.331)	(0.470)	(0.314)	(0.0651)	(0.234)	(0.237)
Δ USDINDEX	-0.654**	-2.027***	-1.033***	-1.860***	-1.512***	-0.176	-2.328***	-1.555***
	(0.265)	(0.445)	(0.280)	(0.470)	(0.417)	(0.246)	(0.543)	(0.277)
Δ lnVIX	-0.900	-2.320	-0.125	-5.743**	-3.380	0.363	-0.376	-2.415***
	(1.187)	(2.452)	(1.380)	(2.403)	(2.213)	(0.968)	(2.112)	(0.867)
Δ Forward Bid-Ask	-0.383	-4.191	-0.0910	-1.480*	-0.0543	0.198	-0.0264	-0.0286**
	(0.308)	(2.810)	(0.739)	(0.886)	(0.0526)	(0.324)	(0.0500)	(0.0122)
N	442	442	442	442	442	442	424	2634
R-sq	0.438	0.082	0.174	0.187	0.097	0.342	0.408	

Table 2c: Post-crisis IV regressions (Commercial Paper-Treasury Bill rate as instrument, 3-month deviations, 2010-2018M6)

III. Other Proposed Factors Affecting CIP Deviations

The previous section complements the literature documenting CIP deviations and confirms the existence of significant deviations during and after the GFC. Not only simple plots of the cross-currency basis, but also more formal regression analysis, confirm that the events around the GFC may have introduced structural changes to the FX arbitrage that resulted in a wider and more variable cross-currency basis. It seems that changes in the regulatory environment after the GFC most likely helped limit arbitrage operations, making the strength of the U.S. dollar and risk sentiment explanators of the changes in CIP deviations (see Rime, Schrimpf, and Syrstad 2019). In this section, we review complementary proposed drivers of CIP deviations post-GFC, and test their implications within our regression framework.[13]

3.1 Review of literature and summary of additional hypotheses

Monetary policy divergence: Figure 7, which we reproduce and extend based on Du, Tepper and Verdelhan (2018), plots the highly positive cross-sectional relationship between G10 countries' period-average interest rates (measured by Libor) and their period-average cross-currency bases against the USD, for 2010-18 and 2015-18, respectively. Countries with lower interest rates tend to exhibit more negative cross-currency dollar bases. This relationship seems to be even stronger during the recent period (the right panel in Figure 7). Brauning and Ivashina (2017) suggest that domestic monetary easing widens the difference between foreign and domestic interest rates, so that global banks respond by increasingly placing funds in central-bank deposit facilities offering higher yields.[14] This demand leads to a rise in currency hedging costs, contributing to the widening of cross-currency dollar bases.

Recent policy divergence, such as the European Central Bank's quantitative easing operation amid the U.S. monetary tightening cycle, may also have led to favorable borrowing condition for multinational corporates in currencies other than U.S. dollar. Lower borrowing cost in euros relative to the U.S. dollar, for example, could encourage the issuance of corporate bonds in euros. Liao (2019) documents such issuance flows by large global corporates. A higher demand to convert the proceeds into U.S. dollars, consequently, could raise the price of dollar swaps and widen the basis.

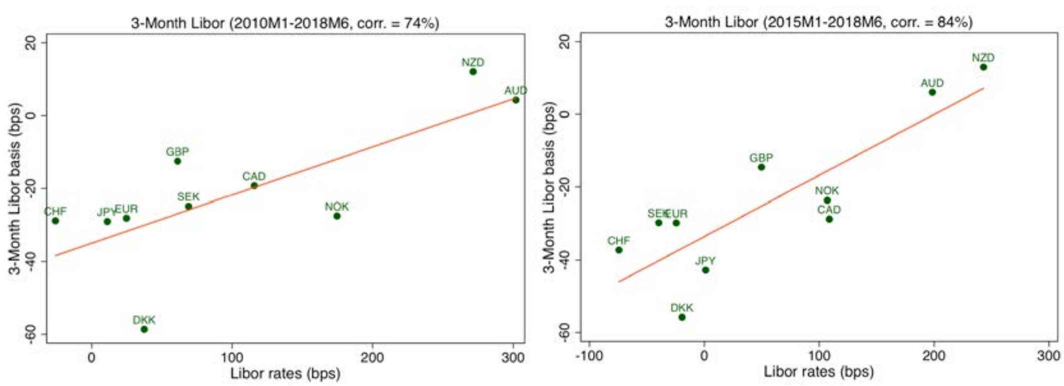

Figure 7: Cross-sectional variation in 3-month currency basis (2010-2018 and 2015-2018)

[13] While the list of factors reviewed here is large, we do not attempt to test all factors identified in the literature. While FX hedging demand can be noisily proxied by the dollar funding gap using BIS International Banking Statistics data, as in Sushko et al. (2017), that variable's low-frequency availability (quarterly) restricts its use in higher-frequency regressions. Amador et al. (2017) investigate central banks' exchange rate policy at the zero lower bound as driving deviations from interest parity with limited international arbitrage.

[14] Brauning and Ivashina (2017) incorporate the fact that global banks fund themselves primarily in their domestic currencies and rely on synthetic funding to lend in foreign currencies. This has an effect on their use of internal capital markets, which leads to contrary effects of monetary policy for the domestic and foreign lending of global banks.

Liao (2019) measures the borrowing costs of multinational corporates by creating a measure of currency-specific credit risk pricing relative to the USD, controlling for maturity, credit rating, liquidity, and firm-specific characteristics (variable *Residualized_Spread* in our subsequent regressions). Brauning and Ivashina (2017) use central banks' interest paid on excess reserves (IOER) as their proxy for local monetary policy stance.[15] In this context, we use both the Liao's (2019) series on residualized credit spread and the IOER differential to extend their analyses. Different from literature, following our baseline framework in the previous section, we also control for dollar strength (represented by the change in the USD index), risk sentiment (captured by change in log VIX), and the changes in the bid-ask spreads. As a result, we have the following hypotheses:

Hypothesis 1 (IOER differential). Controlling for other factors, a larger difference between the deposit facility rate in the central bank where a foreign global bank is headquartered and U.S. IOER ($IOER^{*}$-$IOER^{US}$) leads to a decrease in the FX hedge demand (which would reduce a cross-country dollar negative basis, implying a negative regression coefficient in our framework).

Hypothesis 2 (Corporate Issuance). Controlling for other factors, the more favorable borrowing conditions are in domestic currencies compared with those in USD (the lower the variable *Residualized_Spread*), the higher would be the demand of currency hedges, implying a widening of cross-country dollar negative basis, and a positive regression coefficient in our framework).

Regulatory constraints: CIP's status as a no-arbitrage condition has led to past literature discussing the relationship between CIP deviation and limits to arbitrage due to new regulation established after the GFC. Du, Tepper, and Verdelhan (2018) and Rime, Schrimpf, and Syrstad (2019) discuss the effect of various banking regulatory instruments that increase the cost of engaging in currency arbitrage. Brauning and Puria (2017) finds that higher bank balance sheet costs, along with an increasing demand for U.S. dollars due to monetary policy divergence, push up the price of dollar swaps and thus lead to the amplification of CIP deviations. Intuitively, however, low-frequency changes in prudential regulatory instruments, such as capital requirements, are unable to explain the high-frequency movement in the cross-currency basis.[16]

Nonetheless, there are other regulatory changes that we can examine within our framework. Foreign bank branches in the United States also rely on non-bank sources for short-term dollar funding, mainly via commercial paper and certificates of deposits held by U.S. prime

[15] Global banks may actively manage their balance sheets and take advantage of central banks' reserves or deposit facilities in responding to local monetary policy changes. Here IOER follows the classification of Brauning and Ivashina (2017) and includes the interest rate on central banks' deposit facilities.

[16] Using Du, Tepper, and Verdelhan (2018)'s measure of capital charges, we tested in Table A4 of the Appendix if the interaction of our previous section high-frequency variables with the low-frequency capital charges. We find little evidence suggesting that non-structural factors contribute more to the variation of the five-year basis during periods of higher capital charges.

money market funds (MMF). Iida, Kimura, and Sudo (2016), Nakaso (2017), and Du, Tepper, and Verdelhan (2018) discuss the impact of prime money market fund reform in late 2015 on the movement of CIP deviations. As the reform triggered large outflows from prime MMFs to government MMFs, foreign banks lost considerable dollar funding, potentially resulting in a more deeply negative cross-currency basis.

We obtain monthly gross holdings data for U.S. prime money market funds from the Office of Financial Research Money Market Fund Monitor. The holdings data map each bank borrower to an ultimate parent and country. For each month *t* and each currency *i* in our sample, the variable $Holdings_{i,t}$ is constructed by assigning the aggregate value of holdings of U.S. MMFs on bank branches headquartered in the country for which currency *i* is official. For instance, $Holdings_{JPY,t}$ includes prime MMFs' claims on all branches of Japanese bank in the United States.[17] $Holdings_{i,t}$ is included in the baseline time-series and panel regressions along with dollar strength and the VIX to test the following hypotheses:

Hypothesis 3 (Dollar funding strain). Controlling for other factors, a negative shock to prime money market fund holdings (a lower value of $Holdings_{i,t}$) leads to a higher CIP deviation in favor of USD (a widening of negative dollar bases and a positive regression coefficient).

Domestic risk sentiment: Table 1c suggests that although U.S. VIX may drive CIP deviations for a number of individual currencies, it does not work well for the euro and the pound sterling. Using the U.S. VIX's counterparts in Europe (VDAX-New Index for Germany) and UK (VFTSE Index), we test the hypothesis that the domestic VIX may be better at explaining the corresponding currencies' CIP deviations against the dollar.

Hypothesis 4 (Domestic risk prospect). Controlling for other factors, a rise in the VDAX index widens CIP deviations of EUR/USD in favor of USD. Similarly, a rise in the VFTSE index widens CIP deviations of GBP/USD in favor of USD (implying negative coefficients for both indices).

3.2 Empirical tests: Results

We use our regression framework to examine the four hypotheses just summarized.

Table 3 presents the results for testing Hypothesis 1, including the weekly IOER differential as an additional control variable. The 2010-2018 sample is used for individual-currency, time-series regressions, while the sample is further split for panel regressions, separated by the start of ECB's quantitative easing program (March 2015). The coefficient of the IOER differential in time-series regressions is statistically significant and negative only in the case of Japan. This coefficient is also significantly negative in our post-crisis (2010-2018M6)

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[17] For $Holdings_{EUR,t}$, we sum up the holdings on branches of banks headquartered in France, Germany, Netherlands, Belgium, Austria, Spain, Italy, and Luxembourg.

panel and recent-period (2015W11-2018M6) panel. In the data, IOER differentials grew substantially after 2015, indicating clear monetary policy divergence given the tightening cycle in the U.S. and the sustained easing policy by other major central banks. Quantitatively, a ten-basis-point increase of the U.S. IOER in our 2015W11-2018M6 panel regression, holding foreign IOER unchanged, would widen 3-month CIP deviations in favor of the U.S. dollar by 2.5 basis points. The results for our baseline controls (dollar strength, the VIX, and FX liquidity) are in line with the previously reported regressions.

Δ(f-s)	Canada AUD	Switzerland CAD	Euro Area CHF	UK EUR	Japan GBP	Panel (10M1-18M6)	Panel (10M1-15W10)	Panel (15W11-18M6)
Δ (r*-r)	0.919***	1.614***	0.946***	0.820***	1.101***	1.254***	1.251***	1.053***
	(0.0883)	(0.243)	(0.157)	(0.149)	(0.199)	(0.205)	(0.235)	(0.0968)
Δ USDINDEX	-0.762***	-0.975*	-2.681***	-1.139***	-1.705***	-1.378**	-1.147	-1.435***
	(0.245)	(0.574)	(0.407)	(0.279)	(0.400)	(0.379)	(0.574)	(0.235)
Δ lnVIX	-0.642	-6.322**	-1.395	0.176	-5.697**	-3.079*	-7.502**	0.218
	(1.159)	(3.160)	(2.284)	(1.290)	(2.295)	(1.304)	(2.584)	(0.986)
Δ Forward Bid-Ask	-0.434	-3.412***	-4.981**	-0.277	-1.343	-2.515*	-2.754*	-1.796*
	(0.318)	(0.721)	(2.349)	(0.769)	(0.846)	(0.937)	(1.059)	(0.674)
Δ (IOER* - IOER)	-0.0999	-0.118	-0.135	-0.111	-0.394**	-0.211***	0.155*	-0.253***
	(0.0638)	(0.178)	(0.126)	(0.0905)	(0.174)	(0.0415)	(0.0682)	(0.0475)
N	442	442	442	442	442	2210	1350	860
R-sq	0.446	0.449	0.316	0.215	0.234	0.333	0.422	0.217

Table 3: Hypothesis 1 - IOER Differences and CIP Deviations (3-month, weekly regression)

The monthly data used to test Hypothesis 2 span the years 2010 to 2016. As corporate bonds tend to have a longer investment horizon, we use 5-year FX forwards and 5-year interest rates to calculate long-term forward premiums and interest rate differentials. Table 4 reports the results. Again, the time-series regression coefficient for the change in the credit spread is significant and positive only in the case of Japan (and marginally significant for UK), while the coefficient is also significantly positive in the panel regression, consistent with Hypothesis 2. A ten-basis-point reduction in local-currency borrowing costs widens 5-year CIP deviations by 1.1 basis point in favor of U.S. dollar. The results for dollar strength are also visible in Table 4, but not as much for the VIX and FX liquidity.

Δ(f-s)	Australia AUD	Canada CAD	Switzerland CHF	Euro Area EUR	UK GBP	Japan JPY	Panel
Δ (r*-r)	0.876***	0.971***	0.954***	1.141***	1.122***	0.920***	0.995***
	(0.0214)	(0.0268)	(0.0427)	(0.0501)	(0.0476)	(0.0415)	(0.0440)
Δ USDINDEX	0.0559	-0.420	-1.690***	-2.240***	-0.692**	-0.825	-1.228**
	(0.314)	(0.284)	(0.509)	(0.613)	(0.278)	(0.585)	(0.314)
Δ lnVIX	-2.366	2.633**	-5.183	2.164	-4.269	1.141	-0.434
	(1.546)	(1.263)	(3.114)	(3.015)	(3.442)	(4.191)	(1.763)
Δ Forward Bid-Ask	-0.0188	0.0405	-0.0199	-0.172**	0.0260	-0.140	0.0123
	(0.0288)	(0.0326)	(0.0775)	(0.0727)	(0.0205)	(0.222)	(0.0179)
Δ Residualized Spread	0.0627	0.00447	0.0164	0.0655	0.0883	0.203**	0.110**
	(0.0613)	(0.0432)	(0.0748)	(0.0813)	(0.0553)	(0.0929)	(0.0332)
N	81	81	81	81	81	81	405
R-sq	0.955	0.961	0.909	0.909	0.916	0.890	0.898

Table 4: Hypothesis 2 - Corporate Borrowing Conditions and CIP Deviations (5-year, monthly regression, 2010- 2016)

Time-series regressions for Japan seem to suggest that monetary policy divergence is a powerful explanation for JPY's persistent and large deviations from CIP. This finding is consistent with Japan's non-bank financial institutions' search-for-yield motives during the recent easing cycle. Figure 8, reproduced and extended from Nakaso (2017), plots the quarterly exchange-rate adjusted stock of outward investment in securities for Japanese financial institutions. The growth in overseas assets for insurance companies and pension funds largely coincides with the period of larger-scale monetary easing by the central bank. Nakaso (2017) further notes that life insurers and investment trusts in Japan tend to hedge a large portion of their currency exposure – which would tend to raise the cost of synthetic borrowing of dollars through the swap market.

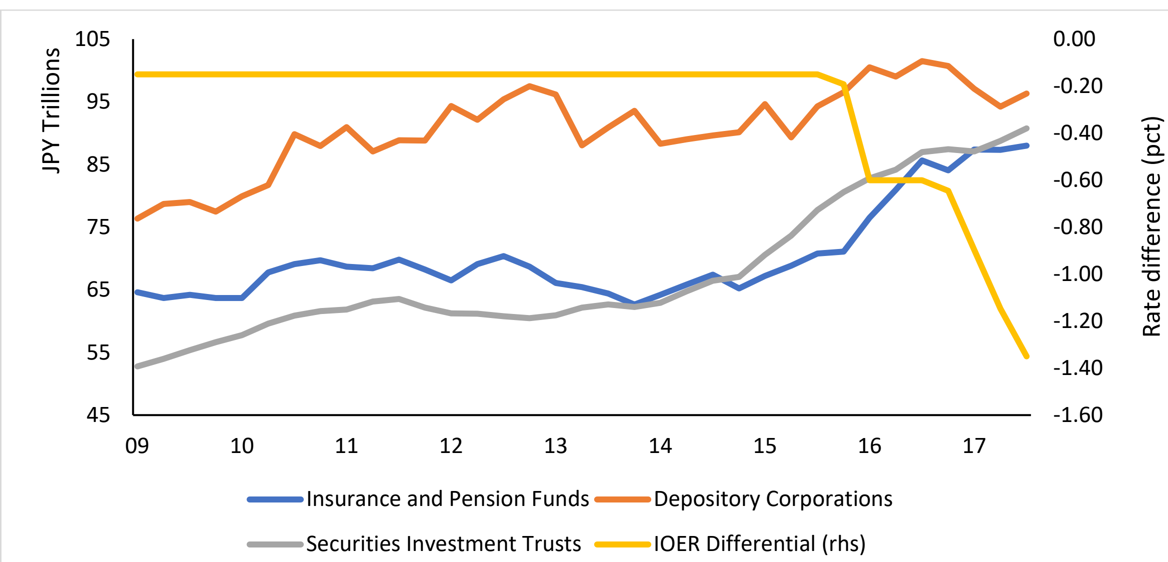

Figure 8: Outward investment in securities by Japanese financial institutions and IOER differential against US

Table 5 reports regression results testing Hypothesis 3. The change in log gross prime MMF holdings is added as additional control for each currency, so that the coefficient can be interpreted as a semi-elasticity. At monthly frequency, the time-series regressions yield less precise estimates of this elasticity. Panel regressions, however, largely confirm Hypothesis 3. The coefficient of changes in MMF holdings is positive across the 2011-2017M12 sample.[18] This positive relationship is statistically significant after 2015, when the proposal to reform the money market funds by requiring floating net asset value was announced and started to trigger substantial outflows from prime MMFs. In our full panel regression, a ten-percent negative shock in prime fund holdings leads to the widening of short-term CIP deviations by sixteen basis points in favor of the dollar. With respect to our baseline control variables, we find that both increases in dollar strength and a worsening in FX liquidity raise the cost of synthetic dollar borrowing compared with direct dollar funding. The results for the US VIX are less robust, and they even flip the sign in the most recent period (2015M1-2017M12).

Δ(f-s)	Australia AUD	Canada CAD	Switzerland CHF	Euro Area EUR	UK GBP	Japan JPY	Norway NOK	Sweden SEK	Panel (11M1-17M12)	Panel (11M1-14M12)	Panel (15M1-17M12)
Δ (r*-r)	0.942***	1.032***	1.493***	0.744***	0.771***	0.897***	0.603***	1.069***	0.980***	0.840***	1.103***
	(0.0568)	(0.125)	(0.165)	(0.223)	(0.181)	(0.263)	(0.139)	(0.0776)	(0.139)	(0.148)	(0.108)
Δ USDINDEX	0.493	-0.312	0.756	-2.489***	-0.753	-1.129*	-1.861***	-1.048**	-1.082**	-1.424	-1.329***
	(0.394)	(0.470)	(1.415)	(0.833)	(0.457)	(0.666)	(0.704)	(0.502)	(0.366)	(0.735)	(0.251)
Δ lnVIX	-7.055**	-2.018	-17.70	-6.677	2.079	-5.615	-6.440	-0.0371	-7.976	-19.67**	9.978***
	(3.391)	(2.880)	(14.62)	(12.32)	(3.390)	(7.208)	(8.366)	(4.880)	(4.331)	(7.307)	(2.567)
Δ Forward	-0.670	0.864	-8.365**	-13.08*	-0.747	-1.843	-0.0966	0.0794**	-0.0352	-0.102	0.0205
Bid-Ask	(2.320)	(1.815)	(3.298)	(6.798)	(2.455)	(3.800)	(0.114)	(0.0306)	(0.0722)	(0.198)	(0.0340)
Δ MMF	-8.020	-7.721	-5.923	7.192	2.128	2.435	0.896	7.574*	1.668	4.240	1.153**
Holdings	(6.121)	(5.657)	(12.98)	(6.874)	(2.538)	(10.69)	(1.006)	(4.010)	(0.982)	(2.529)	(0.421)
N	83	83	83	83	83	83	83	83	581	329	252
R-sq	0.821	0.716	0.583	0.438	0.408	0.243	0.411	0.698	0.434	0.383	0.566

Table 5: Hypothesis 3 - Money Market Fund Holdings and 3-month CIP Deviations (monthly regression)

[18] The OFR MMF monitor data are compiled from the mandatory SEC filings (Form N-MFP) of U.S. money market funds since 2011. We choose the endpoint of our sample at end-2017 as the reform shock is likely to dissipate as banks recoup the loss of funding from other sources (Nakaso 2017). Once we extend the sample to 2018M6, the coefficient of MMF holdings are less significant, possibly reflecting the very temporary nature of funding strains due to one-time MMF reform.

Δ(f-s)	Euro Area EUR		UK GBP	
Δ (r*-r)	0.871***	0.866***	0.734***	0.735***
	(0.161)	(0.154)	(0.160)	(0.158)
Δ USDINDEX	-2.527***	-2.825***	-1.163***	-1.144***
	(0.389)	(0.389)	(0.290)	(0.267)
Δ Forward Bid-Ask	-4.649*	-4.833**	-0.178	-0.178
	(2.380)	(2.383)	(0.759)	(0.762)
Δ lnVDAX	-5.503*			
	(3.177)			
Δ lnVDAX residual		-8.659**		
		(4.019)		
Δ lnVFTSE			0.328	
			(1.296)	
Δ lnVFTSE residual				0.237
				(1.981)
N	442	442	442	442
R-sq	0.320	0.321	0.208	0.208

Table 6: Hypothesis 4 - Domestic VIX and CIP Deviations (3-month, 2010-2018M6)

Finally, Table 6 reports the results of tests of Hypothesis 4. We estimate the time-series regressions for the euro and the pound, replacing changes in the log U.S. VIX with its domestic counterparts. Since implied volatility indices co-move closely, we also residualize domestic volatility by regressing log levels of the VDAX-New and VFTSE indexes on the log U.S. VIX. For the euro, domestic variation in implied volatility does much better than the U.S. VIX in explaining short-term CIP deviations, as changes in both log level of VDAX-New and residualized VDAX-New have a highly significant and negative coefficient. A surge in euro area-wide risk sentiment increases the attractiveness of dollar-denominated investment options, thus boosting the demand for dollar swaps from euros and widening CIP deviations in favor of the U.S. dollar. On the other hand, we find no evidence that local-specific risk sentiment contributes materially to wider CIP deviations in the case of United Kingdom.

IV. Time-varying explanatory power of aggregate U.S. dollar strength: Evidence from time-series regressions

So far we have identified and tested the importance of various proposed factors associated with CIP deviations. Many of these factors, however, could have episodic or one-off effects. For example, while the outflow from prime MMFs following the U.S. reform may have temporarily increased foreign banks' effective dollar funding cost by making FX swaps more expensive, this effect could have been reduced as global banks found alternative sources of dollar funding over time. Nakaso (2017) observes that Japanese banks, in response to the prime MMF reform, compensated for the loss of prime MMF funding by building up stable funding sources via client-related deposits and repo. As more central banks begin to implement reduced asset purchases and exits from monetary easing, future convergence in monetary policy stances may compress multinational companies' international issuance, further removing a contributing factor to the deviations.

It is also possible that aggregate U.S. dollar strength goes farther in explaining CIP deviations in some specific episodes than in others. To analyze this point, we focus on the euro and estimate the dynamic Markov-switching time-series regression

$$\Delta\,(f_{t,t+n} - s_t) = \alpha_s + \beta_s \cdot \Delta\left(r^*_{t,t+n} - r_{t,t+n}\right) + \delta_s \Delta USDINDEX_t + \gamma_s \Delta\ln(VIX_t) + \eta_s \Delta\ln(BIDASK_t) + \varepsilon_{st},$$

where $\alpha_s, \beta_s, \delta_s, \gamma_s, \eta_s$ are state-dependent coefficients. The disturbance ε_{st} follows a normal distribution with zero mean and a state-dependent variance σ_s^2 . We assume that $s \in \{1,2\}$. Table 7 reports the two-state regression output, with the predicted state-1 probability plotted in Figure 8.

Δ(*f*-*s*)	s = 1	s = 2
Δ (*r**-*r*)	1.909***	0.147
	(0.230)	(0.247)
Δ USDINDEX	-3.352*	-1.770***
	(2.018)	(0.540)
Δ lnVIX	-7.528	0.174
	(6.144)	(1.919)
Δ Forward Bid-Ask	-12.41***	-0.199
	(1.190)	(1.472)
σ_s	3.782	3.384
	(1.118)	(0.520)
P (1 | *s*)	0.737	0.117
	(0.151)	(0.155)
N	441	441

Table 7: Dynamic Markov-switching regression (3-month, Euro, 2010-2018M6)

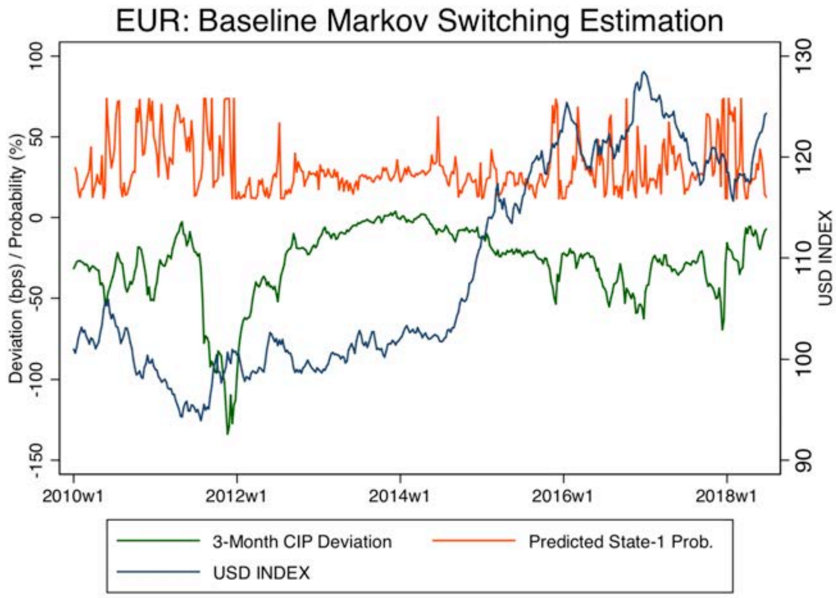

Figure 9: Dynamic Markov-switching regression: Predicted State-one probability (3-month, Euro, 2010-2018M6)

The transition probability in Table 7 indicates that both states are persistent. As shown in Figure 9, state one is associated with the episodes where Euro/USD cross-currency basis exhibits stronger up-and-down movements and co-moves negatively with dollar strength. These episodes largely coincide with the euro area crisis and the recent period after the ECB initiated its QE program. However, from late 2012 to 2015, CIP deviations are quantitatively small and less volatile. The estimated coefficient of the USD index in state 2 is substantially smaller in magnitude than that in state 1. In particular, the abrupt surge in aggregate dollar strength from mid-2014 to early 2015 does not, by itself, seem to put heavy pressure on the cross-currency basis.

As an alternative to the Markov-switching approach, we also employ a 100-week window rolling regression to evaluate the time-varying importance of dollar strength in explaining Euro/USD CIP deviations. Figure 10 plots the evolution of the estimated USDINDEX coefficient. As in Figure 9, the episode in which variations in dollar strength has the most significant impact (the most negative coefficient values) is the euro crisis period. While the dollar's impact on CIP deviations has been gradually rising again in the recent period, the magnitude has remained relatively small. We repeat the exercise on other currencies and plots the moving-window estimates in Figure A6 in the Appendix. Table 8 reports the time-series correlations of this time-varying coefficient across our G10 currency sample. The response of the cross-currency basis to move in the effective U.S. dollar seems to be highly positively correlated across EUR, NOK, and SEK. (This is intuitive as NOK and SEK movements tend to be linked to those in EUR.) As with EUR, dollar appreciation substantially widens these currencies' CIP deviations in favor of USD during the euro crisis, and that effect is gradually rising again in recent data. On the other hand, we see only a moderate positive correlation between CHF, GBP, JPY and the euro. For these currencies, idiosyncratic factors play a bigger role than USD strength in accounting for CIP deviations.

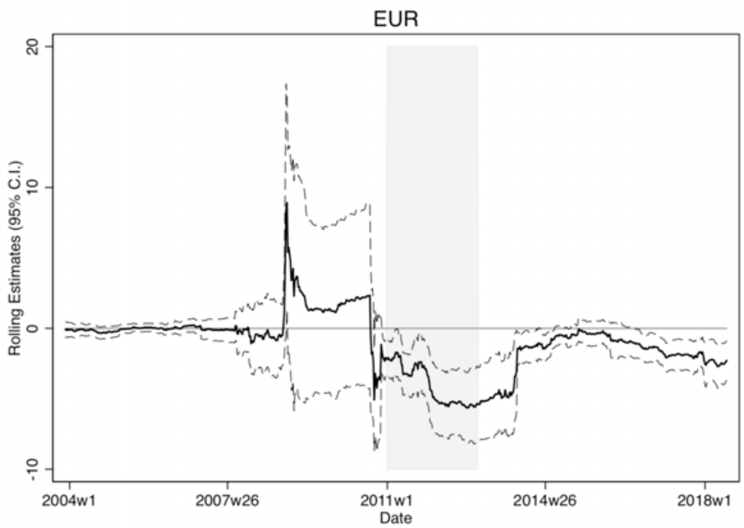

Figure 10: Estimated USDINDEX coefficient from 100-week rolling regression (3-month Euro/USD CIP deviations; 95 percent confidence bands are shown; shaded area corresponds to Eurozone crisis).

	AUD	CAD	CHF	DKK	EUR	GBP	JPY	NOK	NZD	SEK
AUD	1.000									
CAD	-0.109	1.000								
CHF	0.116	-0.013	1.000							
DKK	-0.067	0.628	0.141	1.000						
EUR	-0.225	0.759	0.073	0.920	1.000					
GBP	0.491	0.080	0.344	-0.002	-0.093	1.000				
JPY	0.475	0.558	0.214	0.660	0.586	0.574	1.000			
NOK	0.147	0.677	-0.044	0.870	0.846	-0.134	0.624	1.000		
NZD	0.571	-0.413	0.133	-0.525	-0.578	0.652	0.078	-0.496	1.000	
SEK	0.059	0.690	0.031	0.906	0.913	-0.090	0.647	0.962	-0.501	1.000

Table 8: Correlation matrix of rolling USDINDEX coefficients (3-month basis, 2010-2017)

V. CONCLUSIONS

This paper analyses the role of different macrofinancial variables as drivers of the evolution of CIP deviations. Plots of the cross-currency dollar basis – for alternative currencies and interest benchmarks – show the dramatic persistence of CIP violations since the GFC. We document how different macrofinancial variables appear to drive the evolution of CIP deviations. We find that those drivers can statistically help to explain the variation in CIP deviations since the GFC, and that factors beyond regulatory changes play a role. This explanatory power is especially strong for U.S. dollar strength and FX liquidity conditions, and to a lesser extent the VIX, especially in recent periods.

In addition, some of these drivers are associated with temporary factors (such as asynchronous monetary policies in the United States, the euro area, and Japan). More generally, our time series approaches suggest that even those proposed factors that display the more statistically significant associations with CIP deviations across most of our sample (such as U.S. dollar strength) do not have a uniform importance across currency pairs and time, hinting at the interaction of several time- and country-specific factors. These findings help explain why different authors have stressed a wide range of often complementary potential drivers as part of the fast-growing literature that tries to rationalize CIP deviations.

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APPENDIX: ADDITIONAL TABLES

Variable	Notation	Source	Notes
Forward Premium	f-s	Bloomberg	For five-year frequency, use 5-year forward rate.
Libor Rate Differential	r*-r	Haver Analytics, Bloomberg	Asterisk denotes foreign (as opposed to U.S.). For five-year frequency, use 5-year interest rate swap.
Commericial Paper - Treasury Bill Rate Differential	r^{*TB}-r^{CP}	Bloomberg, Datastream	Asterisk denotes foreign (as opposed to U.S.).
Trade Weighted U.S. Dollar Index: Broad	USDINDEX	Haver Analytics	
Forward Point Bid-Ask Spread	Forward Bid-Ask	Bloomberg	In unit of forward point difference.
U.S. VIX Index	VIX	Haver Analytics	
FTSE 100 VIX Index	VFTSE	Bloomberg	
Dax-New Volatility Index	VDAX	Bloomberg	
Interest Differential on Excess Reserves	IOER*-IOER	Haver Analytics, Brauning and Ivashina (2017)	Asterisk denotes foreign (as opposed to U.S.). Definition of IOER comes from Brauning and Ivashina (2017), including deposit facility rates.
Currency-specific corporate credit spread against USD	Residualized Spread	Liao (2019)	
Prime Money Market Holdings	MMF Holdings	Office of Financial Research	In log billions USD. Each currency is mapped to its country/region, which in turn is mapped to the ultimate parent country identified by OFR.

Table A1: Data Sources

Δ(f-s)	Canada CAD	Euro Area EUR	Japan JPY	Norway NOK	New Zealand NZD	Sweden SEK	**Panel (No NZD)**
Δ (r*-r)	0.725***	0.704***	0.836***	0.350***	0.587***	0.751***	0.565***
	(0.0474)	(0.0490)	(0.0569)	(0.0837)	(0.0677)	(0.0498)	(0.121)
Δ USDINDEX	-0.638*	0.213	-0.119	0.308	0.929*	0.191	-0.153
	(0.352)	(0.278)	(0.313)	(0.611)	(0.498)	(0.335)	(0.149)
Δ lnVIX	0.435	-0.925	4.174	9.345*	1.195	-0.665	1.374
	(2.030)	(2.057)	(2.545)	(5.618)	(4.054)	(2.759)	(1.738)
Δ Forward Bid-Ask	1.298	-1.550***	0.731	0.0903	1.058	-0.0204	0.0320
	(0.990)	(0.413)	(0.794)	(0.0977)	(0.915)	(0.0562)	(0.0432)
N	259	259	259	259	259	259	1554
R-sq	0.627	0.611	0.543	0.219	0.392	0.569	0.404

(a) Pre-crisis (2002-2006)

Δ(f-s)	Canada CAD	Euro Area EUR	Japan JPY	Norway NOK	New Zealand NZD	Sweden SEK	**Panel (No NZD)**
Δ (r*-r)	0.248***	0.417***	0.520*	0.445***	0.367***	0.472***	0.454***
	(0.0886)	(0.118)	(0.264)	(0.125)	(0.0961)	(0.158)	(0.0566)
Δ USDINDEX	-2.127	2.787	-1.032	-2.056	-2.231	-0.0461	-0.163
	(2.612)	(2.505)	(2.816)	(4.273)	(4.052)	(2.186)	(0.828)
Δ lnVIX	0.257	-2.821	-17.99	-14.61	-9.817	-7.648	-12.92*
	(17.22)	(16.43)	(15.46)	(16.03)	(17.09)	(19.57)	(5.311)
Δ Forward Bid-Ask	-1.963	-6.656	-17.51*	0.181	-1.781	-0.214	-0.0188
	(4.085)	(4.692)	(10.24)	(0.258)	(5.261)	(0.824)	(0.180)
N	151	151	151	151	151	151	906
R-sq	0.221	0.488	0.382	0.404	0.252	0.292	0.304

(b) Crisis (2007-2009)

Δ(f-s)	Canada CAD	Euro Area EUR	Japan JPY	Norway NOK	New Zealand NZD	Sweden SEK	**Panel (No NZD)**
Δ (r*-r)	0.302***	0.378***	0.0804	0.177***	0.319***	0.159**	0.224***
	(0.0660)	(0.0662)	(0.0665)	(0.0410)	(0.0442)	(0.0715)	(0.0458)
Δ USDINDEX	-1.245***	-2.475***	-2.038***	-1.965***	-0.156	-2.599***	-1.973***
	(0.282)	(0.399)	(0.449)	(0.454)	(0.267)	(0.570)	(0.249)
Δ lnVIX	0.977	-1.583	-5.654**	-3.719**	0.823	1.106	-1.399
	(1.377)	(2.264)	(2.450)	(1.862)	(1.143)	(2.315)	(1.173)
Δ Forward Bid-Ask	-0.282	-3.309*	-1.584*	-0.00314	0.344	-0.0385	-0.0317**
	(0.369)	(1.859)	(0.923)	(0.0346)	(0.321)	(0.0544)	(0.00925)
N	442	442	442	442	442	424	2634
R-sq	0.224	0.299	0.123	0.211	0.198	0.108	0.155

(c) Post-crisis (2010-2018M6)

Table A2: Baseline Regressions, Commercial Paper-Treasury Bill Rate Differences (3-month horizon)

Δ(f-s)	Australia AUD	Canada CAD	Switzerland CHF	Denmark DKK	Euro Area EUR	UK GBP	Japan JPY	Norway NOK	New Zealand NZD	Sweden SEK	**Panel**
Δ (r*-r)	0.656***	0.894***	0.628***	0.880***	0.854***	0.819***	0.789***	0.979***	0.626***	0.740***	0.850***
	(0.0424)	(0.0367)	(0.0635)	(0.0474)	(0.0556)	(0.0268)	(0.0238)	(0.0701)	(0.0986)	(0.0903)	(0.0359)
Δ USDINDEX	-0.316	-0.352	-1.211	-0.551	-0.369	-0.474	-0.129	0.340	-1.143	-0.829	-0.116
	(0.502)	(0.511)	(1.010)	(0.470)	(0.508)	(0.357)	(0.439)	(0.913)	(1.291)	(1.068)	(0.244)
Δ lnVIX	0.475	-5.413	-0.278	6.347	-4.784	-1.879	-6.672**	7.817	9.154	-3.693	-2.825
	(3.809)	(3.406)	(5.014)	(3.898)	(3.545)	(2.800)	(3.080)	(7.180)	(7.973)	(8.978)	(2.499)
Δ Forward	-0.055***	-0.0175	0.055***	0.017***	-0.0134	-0.0069**	-0.0037	-0.00454	-0.056**	0.014***	0.0108
Bid-Ask	(0.0125)	(0.0170)	(0.00440)	(0.00347)	(0.0132)	(0.00271)	(0.00336)	(0.00413)	(0.0249)	(0.00304)	(0.00806)
N	222	228	230	181	259	259	228	232	259	182	1799
R-sq	0.687	0.773	0.750	0.764	0.658	0.817	0.865	0.571	0.252	0.507	0.545

(a) Pre-crisis (2002-2006)

Δ(f-s)	Australia AUD	Canada CAD	Switzerland CHF	Denmark DKK	Euro Area EUR	UK GBP	Japan JPY	Norway NOK	New Zealand NZD	Sweden SEK	**Panel**
Δ (r*-r)	0.848***	1.014***	0.890***	1.032***	0.940***	0.952***	0.883***	0.951***	0.816***	0.949***	0.948***
	(0.0410)	(0.0345)	(0.0395)	(0.0750)	(0.0613)	(0.0496)	(0.0362)	(0.0387)	(0.0261)	(0.0399)	(0.0184)
Δ USDINDEX	-0.215	0.434	-0.167	0.150	-1.291*	0.393	-0.333	0.256	0.255	0.257	-0.150
	(0.587)	(0.509)	(0.688)	(1.381)	(0.723)	(0.918)	(0.691)	(0.596)	(0.495)	(0.704)	(0.223)
Δ lnVIX	1.028	7.927	0.484	-1.962	2.602	1.072	4.164	-4.385	1.005	-5.206	0.857
	(5.061)	(5.087)	(3.793)	(4.912)	(4.710)	(4.251)	(3.706)	(4.313)	(3.649)	(7.256)	(1.630)
Δ Forward	-0.0349*	-0.0325**	-0.0077	0.0035	-0.072***	-0.0807**	0.0552*	0.007***	0.0358	0.00392	0.0041**
Bid-Ask	(0.0210)	(0.0162)	(0.0186)	(0.00519)	(0.0249)	(0.0327)	(0.0320)	(0.00247)	(0.0335)	(0.00483)	(0.00142)
N	156	156	156	156	156	156	156	154	156	156	1246
R-sq	0.761	0.828	0.824	0.690	0.784	0.753	0.846	0.834	0.908	0.819	0.783

(b) Crisis (2007-2009)

Δ(f-s)	Australia AUD	Canada CAD	Switzerland CHF	Denmark DKK	Euro Area EUR	UK GBP	Japan JPY	Norway NOK	New Zealand NZD	Sweden SEK	**Panel**
Δ (r*-r)	0.733***	0.943***	0.899***	0.914***	1.053***	0.952***	0.849***	0.948***	0.892***	0.965***	0.932***
	(0.0261)	(0.0223)	(0.0264)	(0.0464)	(0.0255)	(0.0264)	(0.0242)	(0.0237)	(0.0424)	(0.0305)	(0.0221)
Δ USDINDEX	-0.937***	-0.305	-0.583*	-0.885***	-1.449***	-0.735***	-1.336***	-1.077***	0.444	-0.454	-0.898***
	(0.260)	(0.192)	(0.298)	(0.334)	(0.241)	(0.178)	(0.296)	(0.244)	(0.524)	(0.290)	(0.160)
Δ lnVIX	1.081	0.652	-0.313	-0.843	-0.153	0.134	-0.0505	-0.504	1.167	-0.657	-0.135
	(1.115)	(0.889)	(1.043)	(1.470)	(1.090)	(0.931)	(1.221)	(1.110)	(1.345)	(1.033)	(0.226)
Δ Forward	-0.0144*	0.0118	0.0110	-0.000094	0.0174	0.033***	-0.00539	-0.00143	-0.072***	-0.00095**	-0.00053
Bid-Ask	(0.00830)	(0.00895)	(0.0180)	(0.00028)	(0.0251)	(0.00964)	(0.0484)	(0.00095)	(0.0237)	(0.00045)	(0.00037)
N	442	442	442	442	442	442	442	442	442	442	3536
R-sq	0.758	0.848	0.795	0.673	0.861	0.829	0.791	0.833	0.678	0.797	0.793

(c) Post-crisis (2010-2018M6)

Table A3: Baseline Regressions (5-year horizon)

Δ(f-s)	Australia AUD	Canada CAD	Switzerland CHF	Denmark DKK	Euro Area EUR	UK GBP	Japan JPY	Norway NOK	New Zealand NZD	Sweden SEK	**Panel**
Δ (r*-r)	0.867***	0.982***	0.927***	0.952***	0.997***	0.966***	0.835***	0.994***	0.847***	0.971***	0.947***
	(0.0270)	(0.0301)	(0.0309)	(0.0455)	(0.0319)	(0.0307)	(0.0396)	(0.0374)	(0.0191)	(0.0314)	(0.0188)
Δ USDINDEX	0.937	-0.715*	-0.582	-2.756**	-1.067*	-0.865	-0.508	-0.908	0.0483	-0.133	-1.144***
	(0.647)	(0.409)	(0.723)	(1.261)	(0.613)	(0.520)	(0.856)	(0.770)	(0.511)	(0.633)	(0.235)
Δ USDINDEX * Capital Charge	-0.283	0.135	-0.122	0.334	-0.166	-0.115	-0.188	0.112	0.0351	-0.177	0.0115
	(0.203)	(0.144)	(0.221)	(0.356)	(0.183)	(0.169)	(0.320)	(0.214)	(0.153)	(0.179)	(0.0605)
Δ lnVIX	-12.77**	2.822	-10.75*	-21.94**	-12.87**	-17.90***	-4.886	-11.93	-5.438	-14.52	-13.00***
	(6.208)	(4.194)	(5.670)	(8.525)	(5.668)	(5.406)	(7.603)	(9.144)	(6.733)	(9.044)	(3.659)
Δ lnVIX * Capital Charge	1.423	1.113	0.330	3.241	3.924	3.188	2.901	3.010	-1.234	4.096	2.871**
	(2.585)	(1.732)	(2.669)	(5.075)	(3.130)	(2.791)	(3.643)	(4.312)	(3.257)	(2.864)	(0.905)
Δ Forward Bid-Ask	0.00253	0.178***	0.0546**	-0.00584	-0.0215	0.0220	-0.0306	-0.00887	-0.0360	0.0152	0.00833
	(0.0309)	(0.0497)	(0.0231)	(0.0120)	(0.0599)	(0.0154)	(0.0681)	(0.00643)	(0.0379)	(0.0138)	(0.0137)
Δ Bid-Ask * Capital Charge	0.0153	-0.115***	-0.0211	-0.00161	-0.159	-0.0543*	-0.000135	0.00271	0.0548	-0.00777	-0.00411
	(0.0223)	(0.0282)	(0.0492)	(0.00292)	(0.103)	(0.0276)	(0.102)	(0.00271)	(0.0329)	(0.00885)	(0.00484)
N	53	55	55	50	55	55	53	53	55	51	427
R-sq	0.979	0.973	0.958	0.915	0.953	0.963	0.927	0.953	0.980	0.973	0.938

Table A4: Interaction with Du, Tepper and Verdelhan (2018) capital charges (2002-2015, 5-year horizon, quarterly regression)

Currency	Libor-based	CP/Tbill-based	Differences
CAD	-19.91	6.43	-26.34
EUR	-27.23	-11.09	-16.14
GBP	-11.98	-5.94	-6.04
JPY	-29.32	-29.95	0.63
NOK	-26.51	12.25	-38.76
NZD	12.64	24.58	-11.94
SEK	-24.92	-2.59	-22.52

Table A5: Average 3-month CIP deviations (2011-2018M6)

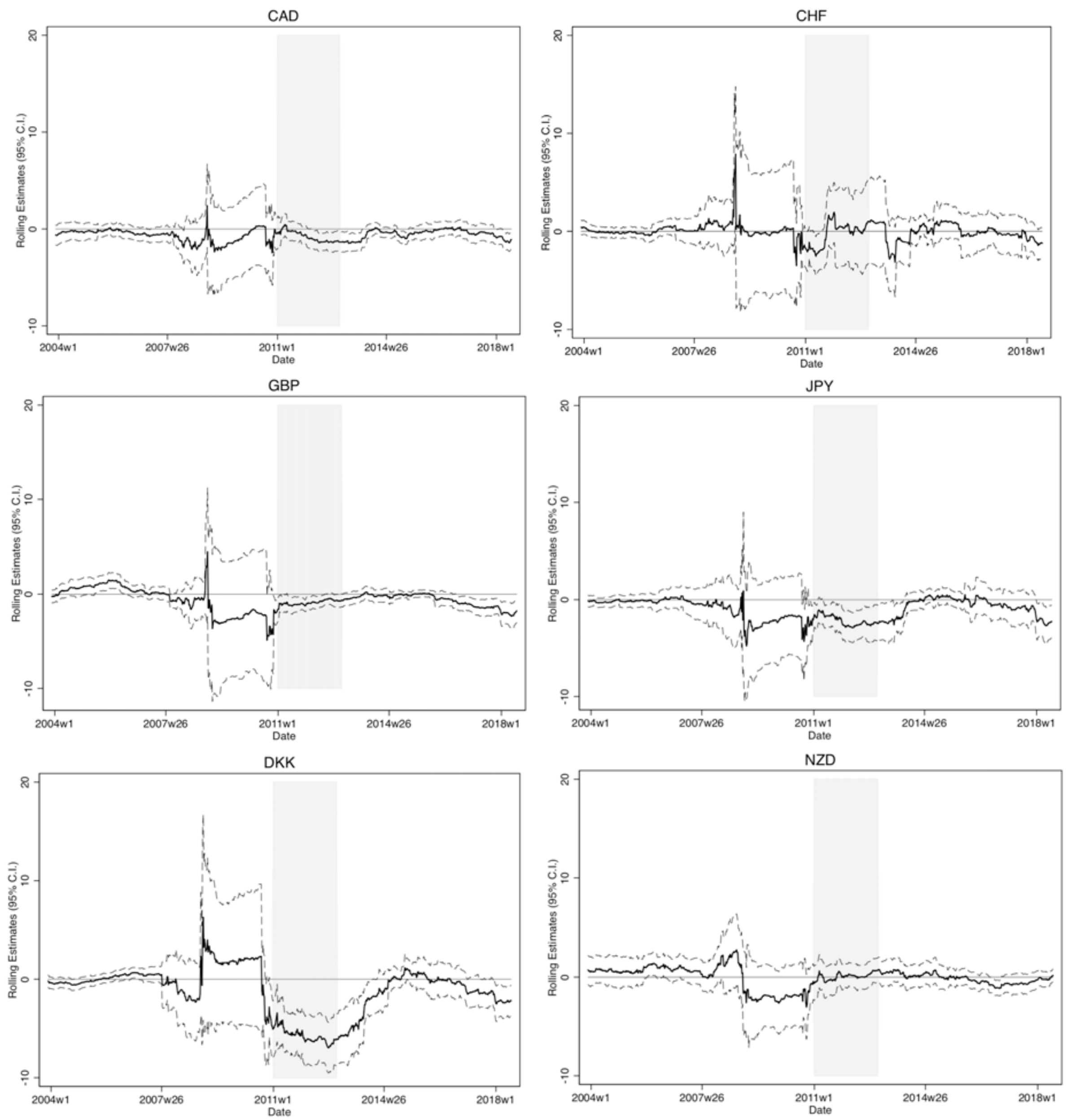

Figure A6: Estimated USDINDEX coefficient from 100-week rolling regression (3-month Libor-based CIP deviations; shaded area corresponds to Eurozone crisis)