BANK OF ENGLAND

Staff Working Paper No. 779

Currency mispricing and dealer balance sheets

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February 2019

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Abstract

We relate currency mispricing originating from the breakdown of covered interest rate parity to the dealer balance-sheet constraints resulting from the post-crisis financial regulation. Using a unique data set on contract-level foreign exchange derivatives with disclosed counterparty identities, we find that dealers with a higher leverage ratio demand an additional premium from their clients for synthetic dollar funding. We handle endogeneity using two exogenous variations associated with the public disclosure of the leverage ratio, and the introduction of the UK leverage ratio framework while controlling for changes in demand conditions at the client level.

Key words: Exchange rates, dollar basis covered interest parity condition, arbitrage opportunities.

JEL classification: F31, G12, G15.

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The views expressed in this paper are those of the authors, and not necessarily those of the Bank of England or its committees. The authors would like to thank Torben Andersen, Andrea Appeddu, Ekkehart Boehmer, Falk Bräuning, Carole Comerton-Forde, Magnus Dahlquist, Wenxin Du, Darrell Duffie, Riccardo Colacito, Pierre Collin-Dufresne, Rodrigo Guimarães, Tarek Hassan, Mike Joyce, Roman Kozhan, Ulf Lewrick, Yue Liu, Matteo Maggiori, Jose Manuel Marques, Bob McCauley, Michael Moore, Brent Neiman, Matteo Regesta, Ricardo Reis, Jean-Paul Renne, Lucio Sarno, Stephen Schafer, Antoinette Schoar, Vania Stavrakeva, Suresh Sundaresan, Előd Takáts, Itay Tuchman, Adrien Verdelhan, Vikrant Vig, Gertjan Vlieghe, Josef Zechner, conference participants at the 2016 Workshop on the Financial Determinants of Exchange Rates in London, 2017 BIS Symposium on CIP--RIP?, 2017 Bank of England Research Awayday, 2017 EFA Annual Meeting, 2017 Asset Pricing Workshop at the University of York, 2017 Bank of Canada/Bank of Spain Workshop on International Financial Markets, 2017 Annual Conference on the Microstructure of Financial Markets, 2017 Chicago Booth International Macro-Finance Conference, 2018 Finance Down Under Conference, 2018 London Empirical Asset Pricing Workshop, 2018 Inquire Spring Seminar, 2018 WFA Annual Meeting, 2018 Vienna Symposium on Foreign Exchange Markets, 2018 CQAsia Conference in Hong Kong as well as seminar participants at the Bank for International Settlements, the Bank of England, City University of Hong Kong, European Stability Mechanism, Fulcrum Asset Management, HEC Montréal, INSEAD, King's College London, Norges Bank Investment Management, Queen Mary University of London, Swiss National Bank, and University College Dublin for their helpful and constructive comments. We gratefully acknowledge financial support from INQUIRE Europe and the Canadian Derivatives Institute. Gino Cenedese and Tianyu Wang started this project while being employed by the Bank of England. All remaining errors are our own. This paper was previously circulated under the title 'Limits to arbitrage in the foreign exchange market: evidence from FX trade repository data'.

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ISSN 1749-9135 (on-line)

"We need to better understand what underpins the supply and demand that determines the basis and what causes those two curves to shift. Who are the relevant participants and what, if any, constraints might they have on their behaviour?"

— Guy Debelle (2017), Deputy Governor of the Reserve Bank of Australia

1 Introduction

In the wake of the global financial crisis, policy-makers and regulators embarked in a bundle of financial reforms to enhance the ability of the banking sector to absorb capital losses. As part of this package, the Basel Committee on Banking Supervision (BCBS) introduced a minimum requirement on the leverage ratio, defined as capital over consolidated exposures, to act as a backstop to the risk-weighted capital requirement (BCBS, 2014). The leverage ratio can strengthen the resilience of the banking system by reducing the chances of harmful deleveraging in a downturn. However, some market participants have argued that the leverage ratio may have increased the costs of financial intermediation, especially for balance-sheet-intensive activities (e.g., ESRB, 2016a,b). This happens as the leverage ratio affects the size rather than the composition of a bank's balance sheet relative to its capital. A Reuters article on 5 August 2013, for example, voiced that: *"[A]t the end of the day the Basel Committee has put aside some three decades of oversight based on risk-weighted assets in favour of a blunt measure of total leverage—with all kinds of unintended consequences the likely result."*

This paper studies the link between the leverage ratio of dealer banks and the recent violations of the covered interest parity (CIP), a no-arbitrage condition affecting the foreign exchange (FX) market (e.g., Akram, Rime, and Sarno, 2008). These deviations have made the cost of borrowing dollars through the world's largest financial market significantly more expensive than in the US money market, thus commanding a premium for international investors with dollar funding needs. While this mispricing has been associated with banks' balance sheet costs that coincide with tighter leverage constraints at quarter ends (e.g., Du, Tepper, and Verdelhan, 2018), the evidence is far from being conclusive as the current literature relies on aggregate data that prevent a neat empirical identification of the underlying determinants.[1] Also, as noted by He and Krishnamurthy (2018), aggregate data only allow us to learn how a shock to capital affects the aggregate supply curve for forward contracts. Quantifying how a percentage change in capital impacts supply is, moreover,

[1]For example, Rime, Schrimpf, and Syrstad (2017) suggest that CIP deviations can be explained by differences in liquidity premia resulting from the underlying money market rates whereas Borio, Iqbal, McCauley, McGuire, and Sushko (2018) refer to balance sheet constraints arising from counterparty risk in the derivatives market. Moreover, Arai, Makabe, Okawara, and Naganono (2016) provide evidence on the role of both monetary policy divergence and regulatory reforms as possible drivers while Bahaj and Reis (2018) show that central bank swap line have created a ceiling on CIP deviations.

critically important for academics to construct economically sound models and regulators to understand the actual implications of the leverage ratio rule. We fill these gaps in the literature using supervisory data on dealer banks matched with contract-level data on forward exchange rates enriched with counterparty information, a critical ingredient in isolating factors that affect the supply side from those that affect the demand side. We also differentiate the impact of the leverage ratio rule from the one of the risk-weighted capital ratio requirement.

As an illustrative example, Figure 1 displays the average leverage ratio of major dealer banks operating in London (the global hub for FX trading) and the one-month dollar basis (the difference between dollar lending rates in the US money market and FX market) on the euro and yen against the dollar. While this chart provides evidence of a strong correlation – the basis widened substantially between 2014 and 2016, reaching more than 100 basis points per annum, while dealers faced tighter leverage constraints – testing any causal relationship between the leverage ratio and the dollar basis remains difficult as both components may be driven by common yet unobserved factors. The most important challenge for the empirical identification is to find an exogenous variation in the leverage ratio requirement of dealer banks. Also, the leverage ratio requirement varies little over time and whenever it is revised, it may change for all major banks at the same time and be correlated with unobserved bank characteristics. Finally, to quantify the effects of the leverage ratio requirements on the dollar basis, we should disentangle the changes in supply from those affecting demand.

Figure 1 about here

We address these challenges by first using counterparty-currency-time fixed effects that sweep out all counterparty- and currency-specific characteristics in the spirit of Khwaja and Mian (2008). We then improve our identification by exploiting plausibly exogenous variations in banks' capital resulting from either the introduction of the UK leverage ratio framework in January 2016 or the public disclosure of the leverage ratio in January 2015, thus accounting for potential omitted variables that could correlate with banks' balance sheet shocks. To preview our results, we find that dealer banks charge an extra premium to their clients for synthetic dollar funding (or equivalently dollar hedging) when the leverage ratio increases. Intuitively, the leverage ratio makes it costly for banks to engage in low-margin activities that require high turnover to be profitable, and the intermediation of FX swaps and forwards effectively expands a bank's balance sheet. This expansion happens as dealer banks are unable to net positions across different counterparties for the calculation of their regulatory leverage exposure. We then estimate that a one standard deviation increase in the leverage ratio of dealer banks can raise the dollar funding cost for clients up to 28 basis points per annum. This translates, using a simple back-of-the-envelope calculation, into (up to) $92 billion of extra borrowing costs per year given an outstanding amount of dollar-denominated FX swaps and forwards of $33 trillions at the end of December 2016 (Borio, McCauley, and McGuire, 2017).

Our analysis employs contract-level data on forward exchange rates (outright forwards and forward legs of FX swaps) for six major currency pairs relative to the US dollar, i.e., Australian dollar, British pound, Canadian dollar, euro, Japanese yen, and Swiss franc. We use all over-the-counter transactions (where at least one counterparty is a UK legal entity) reported to the Depository Trust & Clearing Corporation Derivatives Repository (DTCC) between December 2014 and December 2016, corresponding to 42% of the global daily trading activity (e.g., BIS, 2016). Our forward rates, for which we observe counterparty information and contract characteristics, are then synchronized with Thomson Reuters Tick History's second-level quotes on spot exchange rates and overnight index swap (OIS) rates for the construction of contract-level dollar basis.[2] The contract-level dollar basis are then matched with the leverage ratio of major dealer banks reporting to the Bank of England. This measure is quantified as Tier 1 capital in the form of common shares and disclosed reserves over total consolidated assets measured as on- and off-balance sheet items including derivatives exposures (BCBS, 2014).

A bank can raise its leverage ratio in two different ways. It can either act on the numerator by increasing its amount of regulatory capital or adjust the denominator by shrinking its asset exposure (e.g., Admati, DeMarzo, Hellwig, and Pfleiderer, 2018). While boosting capital is regarded as good deleveraging by regulators, reducing exposure on the asset side can have negative effects if multiple banks simultaneously engage in cutting their activity (e.g., Hanson, Kashyap, and Stein, 2011). In a recent study, Gropp, Mosk, Ongena, and Wix (2018) examine the impact of higher capital requirements on banks' balance sheets and find that banks are reluctant to issue new equity to increase their regulatory adequacy ratios. *Prima facie*, we document that the widening of the dollar basis is related to the leverage ratio of dealer banks by regressing contract-level dollar basis on the lagged leverage ratio of dealer banks. Since different segments of the market (e.g., hedge funds as opposed to corporate firms) may respond to different types of demand shocks (e.g., funding costs or regulatory standards), we categorize all counterparties into real money investors, hedge funds, corporate firms, non-dealer banks and central banks, and then control for currency-sector-time fixed effects to capture time-variant and time-invariant unobserved currency and sector-related factors.

[2] This exercise allows us to construct contract-level dollar basis whereby only the forward price differs across parties, consistent with the view that a non-zero basis is primarily caused by shifts in the supply and/or demand of forwards (Du, Tepper, and Verdelhan, 2018; Borio, Iqbal, McCauley, McGuire, and Sushko, 2018).

We find that a one standard deviation increase in the leverage ratio is associated with a wider dollar basis of up to 28 basis points per annum. In addition to adjusting prices, banks also restrict their supply of forwards in response to an increase in their balance-sheet related costs as we uncover a substantial fall in trading volume (up to 17%) when the leverage ratio increases by a one standard deviation. In contrast, the capital ratio of dealer banks, a risk-weighted capital adequacy measure introduced by the Basel Committee since the late 1980s, displays no significant relationship with the dynamics of the dollar basis and the trading activity of the forward contracts.

The demand for dollar funding via FX swaps may also vary within a given client sector. We deal with this challenge akin to Khwaja and Mian (2008), i.e., we introduce client-time fixed effects to absorb client-specific changes in demand. We collapse our contract-level dollar basis into volume-weighted weekly data in order to have clients with multiple trading relationships. This approach removes all confounding demand factors and is equivalent to asking whether the same counterparty in the same time period dealing with multiple dealer banks faces a larger basis from the dealer bank with a relatively higher leverage ratio.[3] We find that a one standard deviation increase in the leverage ratio is associated with a larger dollar basis of up to 17 basis points per annum.

We also account for possible omitted bank-related variables as, for example, a higher leverage ratio could result from an active balance sheet management instead of a binding regulatory constraint. We improve our identification by using a difference-in-differences approach based on plausibly exogenous variation arising from the introduction of the UK leverage ratio framework in January 2016 for major UK banks.[4] We exploit a change in how regulated banks had to report their leverage ratio since there was no incentive for them to adjust the reporting requirement prior to its actual change. Following a transitional period of twelve months, covered by our sample, affected banks were required to quantify their capital measure and asset exposure on the last day of each month and then average over the reference quarter. Other banks, in contrast, continued to measure their non-binding leverage ratio on the last day of each quarter as prescribed by the EU legislation. This shift from end-of-quarter to a monthly average reduced the ability of affected banks to window-dress their balance sheet at period ends and effectively made the leverage ratio more binding. In our experiment, UK dealer banks constitute the treatment group whereas the subsidiaries of international banks represent the control group. Using a pre- and post-regulatory sample, we document an increase of 24 basis points in the dollar basis for affected dealer banks which confirms the role of the regulatory leverage ratio

[3] This method also controls for changes in counterparty risk that may give rise to credit value adjustments (CVA). See, for instance, the work of Andersen, Duffie, and Song (2018).

[4] The UK framework was announced in December 2015 and became mandatory for major UK banks in January 2016, two years ahead of the Basel Committee proposal (Bank of England, 2015b). We are indebted to our discussant José Manuel Marqués Sevillano from the Banco de España for suggesting this exercise.

requirement as a key determinant of the dollar basis. To put it differently, as the leverage ratio becomes more binding, regulated dealer banks face higher intermediation costs which translate into a wider dollar basis. A placebo test around a post-regulatory date, moreover, shows that the parallel trends assumption behind our methodology is at work (e.g., Roberts and Whited, 2013).

As an alternative difference-in-differences exercise, we test whether dealer banks with a low leverage ratio prior to the policy debate on excessive leverage (e.g., Draghi, 2008; G20 Summits, 2008) have faced a large dollar basis after the introduction of the leverage ratio rule. We first measure the leverage ratio in December 2007 as shareholders' claims to total assets using published accounts (see, for instance, Bank of England, 2015a), and then group banks with a low (high) leverage ratio into the treatment (control) group. Hence, we perform a difference-in-differences exercise around January 2015, a date that marked the beginning of public disclosure for leverage ratio (BCBS, 2014). Despite there being no minimum requirement at the time, banks had an incentive to adjust their leverage ratio around the expected minimum requirement to avoid, for instance, any reputation costs as soon as public disclosure became effective.[5] We uncover an increase in dollar basis evolving around 36 basis points for treated dealer banks compared to untreated dealer banks, after absorbing for changes in demand conditions. Our results remain unchanged if we rank banks on the basis of the average leverage ratio between 2000 and 2007.

We then consider the effect of demand factors and the interaction with the leverage ratio of dealer banks (e.g., Borio, Iqbal, McCauley, McGuire, and Sushko, 2018). First, we study the changes in the dollar basis around monetary policy announcements which proxy for exogenous shocks to the hedging demand of international investors. We find that a larger monetary policy shock is associated with a larger dollar basis at the dealer level, especially when the leverage ratio is higher. Second, we examine the dollar basis around the implementation of the US money market fund reform in October 2016. This event represents a shock to the supply of dollars to market participants in the cash instrument market (e.g., commercial paper). In turn, these participants tapped the FX swap market to get dollar funding. The data suggest that the larger the leverage ratio of dealer banks, the wider the basis after this reform.

We also examine the behavior of client demand in the forward market by constructing a measure of order flow using buy and sell orders that dealers receive from their clients. We find that aggregate order flow is on average negative, i.e., clients tend to sell US dollars in the forward market or

[5] The Basel Committee (BCBS, 2009a) defines reputation risk as "the risk arising from negative perception on the part of customers, counterparties, shareholders, investors, debt-holders, market analysts, other relevant parties or regulators that can adversely affect a bank's ability to maintain existing, or establish new, business relationships and continued access to sources of funding (e.g., through the interbank or securitisation markets)."

equivalently borrow US dollars in the FX swap market. This finding is in line with the story that international investors and corporations increased their dollar hedging demand as a result of monetary policy divergence between the US and Japan (e.g., Borio, McCauley, McGuire, and Sushko, 2016). The richness of our dataset, however, allows us to split order flow by client sector. We report evidence that real money investors (i.e., asset managers, pension funds, and insurance companies) and non-financial corporates sell dollar forwards, consistent with the increased dollar hedging demand from this group of clients. At the same time, non-dealer banks and central banks take the other side of the trade, which is consistent with the behavior of a CIP arbitrageur. We then investigate the interaction effect between the leverage ratio of dealer banks and aggregate order flow as a proxy of hedging demand. We uncover that an increase in the aggregate net demand of dollars is associated with a larger dollar basis, the higher the leverage ratio. Intuitively, the leverage ratio steepens the supply curve of dealer banks, with more constrained banks requiring a higher compensation to take the other side of a trade due to increased hedging demand.

Finally, while most of the analysis revolves around short-term (i.e., less than a year maturity) dollar basis, we also show that the cross-currency basis swap spread, analogous to long-term CIP deviations, is directly associated with balance-sheet constraints, especially in the form of risk-weighted capital requirements. Using transaction-level regressions, we find that an increase in the capital ratio is associated with a widening of the basis during the following quarter. This result is consistent with the fact that long-term contracts tend to have higher risk weight in the calculation of the regulatory capital ratio (e.g., Du, Tepper, and Verdelhan, 2018; Borio, Iqbal, McCauley, McGuire, and Sushko, 2018).

Literature Review. There exists a voluminous literature on the validity of the CIP condition and our paper speaks to this literature. This condition has worked fairly well for the last few decades (e.g., Frenkel and Levich, 1975, 1977; Clinton, 1988; Akram, Rime, and Sarno, 2008). Its validity, however, was severely compromised during the 2007–2008 financial crisis when an unprecedented US dollar funding shortage primarily due to funding liquidity and counterparty risk materialized (e.g., Baba and Packer, 2009; Coffey, Hrung, and Sarkar, 2009; Fong, Valente, and Fung, 2010; Buraschi, Menguturk, and Sener, 2015; Ivashina, Scharfstein, and Stein, 2015; Eguren-Martin, Ossandon Busch, and Reinhardt, 2018).[6] Despite a significant improvement in market conditions, recent years have been characterized again by large and systematic arbitrage deviations. Du, Tepper, and Verdelhan (2018) find that credit risk and transaction costs fail to explain the existence of persistent

[6]This literature also includes, among many others, Baba, Packer, and Nagano (2008); Mancini-Griffoli and Ranaldo (2012); Avdjiev, Koch, Shin, and Du (2016); Iida, Kimura, and Sudo (2016); and Liao (2016).

CIP deviations. The authors instead document that one-week and one-month CIP deviations are more pronounced at quarter-ends starting from January 2015 when the public disclosure of the leverage ratio for European banks started. They interpret this finding as evidence that constrained banks window-dress their leverage ratios that must be reported at quarterly frequency. In this regard, they find evidence of an effect of the leverage ratio on the aggregate supply of FX hedging. We go beyond their analysis in two key aspects: we identify the supply at the *dealer level*, exploiting much more variation in the data; and we *quantify* this leverage effect. Also, our analysis controls for changes in client demand and, to the best of our knowledge, this is the first paper to apply this methodology to the exchange rate economics literature. Borio, Iqbal, McCauley, McGuire, and Sushko (2018) identify the increase in FX hedging demand on one side and limits to arbitrage due to higher balance sheet costs on the other side as potential explanations. Rime, Schrimpf, and Syrstad (2017) instead argue that market segmentation and funding liquidity premia play an important role as only global international banks can enjoy risk-free arbitrage opportunities.

Our findings are also consistent with the growing literature on intermediary asset pricing (Brunnermeier and Pedersen, 2009; He and Krishnamurthy, 2013; Gabaix and Maggiori, 2015; Adrian, Etula, and Muir, 2014; He, Kelly, and Manela, 2017). Our results indeed suggest that financial intermediaries play an important role in the pricing of financial assets. For example, Adrian, Etula, and Muir (2014) show empirically that the *leverage* (which is the inverse of the *leverage ratio* according to the regulatory definition) of broker-dealers is a good proxy for the marginal utility of financial intermediaries. They explain their findings based on the model by Brunnermeier and Pedersen (2009): when funding constraints are tight, intermediaries are forced to deleverage, so that when intermediaries' leverage is low (that is when the leverage ratio is high), their marginal value of wealth is high and therefore the required return for holding a risky asset is higher. Gabaix and Maggiori (2015) present a new theory of exchange rate determination that builds on the limited risk-bearing capacity of financial intermediaries. Their model links a number of stylized facts about exchange rates, including CIP deviations, to the balance sheet of intermediaries. Our results are also related to the literature on limits to arbitrage (for a survey, see Gromb and Vayanos, 2010). In particular, Gromb and Vayanos (2018) propose a model in which arbitrageurs have limited capital, which constrains their activity and in turn gives rise to multiple pricing anomalies, including CIP deviations.

We also contribute to the literature on the impact of financial regulation on asset markets. Adrian, Boyarchenko, and Shachar (2017) argue that post-crisis regulation had an adverse impact on the liquidity of US corporate bonds. Bicu, Chen, and Elliott (2017) find that liquidity in the UK government bond and repo markets deteriorated after the introduction of the leverage ratio rule.

Cenedese, Ranaldo, and Vasios (2018) show that recent regulation introduced heterogeneity in the pricing of interest rate swaps. Kotidis and van Horen (2018) report that the leverage ratio negatively affects dealer-client repo intermediation.

The remainder of this paper is organized as follows. Section 2 reviews the CIP condition and the recent regulatory changes. Section 3 provides a detailed description of the data and explains the construction of the transaction-level CIP deviations. Section 4 links CIP and balance sheet costs while Section 5 examines the interaction between demand and supply factors. Section 6 examines the long-term dollar basis based on cross-currency swaps before concluding in Section 7.

2 Background

This section reviews the covered interest rate parity (CIP) condition and then summarizes the key aspects of post-crisis financial regulation, with a particular emphasis on the UK regulatory framework.

2.1 A Review of the Covered Interest Rate Parity

The CIP condition states that the funding cost in the domestic cash market should be equal to the funding cost implied by the FX market. From the perspective of a US investor, this is equivalent to saying that lending dollars in the domestic cash market should yield the same payoff as converting dollars into foreign currency at the prevailing spot exchange rate, investing the resulting amount in the foreign cash market, and then hedging currency risk by selling foreign currency for dollars in the forward market. This strategy is often implemented via an FX swap contract, which combines together spot and forward transactions.

When the *dollar basis* – the gap between on-shore and swap-implied dollar interest rates – deviates from zero, CIP is no longer valid and arbitrage opportunities arise. As an example, suppose that the dollar basis is negative. Then an arbitrageur could earn a profit by simultaneously borrowing in the dollar cash market, selling dollars for euros in the spot market, lending the resulting amount in the euro cash market, and entering a forward contract to convert the final proceeds in dollars at maturity, thus offsetting the initial short domestic position.

This simple no-arbitrage relationship is routinely summarized as follows

$$1 + r_{\ell,t} = \frac{F_{i\ell,t}}{S_{i,t}}(1 + r_{i\ell,t}), \tag{1}$$

where $S_{i,t}$ denotes the spot exchange rate expressed in units of dollars per foreign currency i, $F_{i\ell,t}$ is the forward exchange rate with delivery date $t+\ell$ for the corresponding currency pair, $r_{\ell,t}$ is the dollar interest rate with maturity ℓ, $r_{i\ell,t}$ is the equivalent foreign currency interest rate, and all quantities are set on day t. While the left-hand side of this equation indicates the gross return from lending in the dollar cash market, the right-hand side is the swap-implied dollar rate obtained from lending in the foreign cash market while *covering* foreign currency risk. When the underlying cash market instruments are equivalent in all respects, except for the currency of denomination, both strategies are equivalent and must deliver an identical payoff. This is the usual textbook-style exposition which abstracts from bid and ask prices, assumes absence of default, liquidity, counterparty and settlement risk, and relies on periodic interest rates (e.g., Bekaert and Hodrick, 2012).

Starting from mid-2014, markets have experienced large and persistent negative dollar basis. In this paper, we will empirically show that such negative basis can be attributed to a steeper supply curve of forwards resulting from tighter leverage ratio constraints. As an illustrative example in the spirit of Prachowny (1970), suppose that a Japanese investor borrows an amount x_i in the local money market, exchanges yen for dollars in the spot market, invests in the US money market, and finally hedges her currency exposure by selling dollars for yen in the forward market. Assume that the supply of yen in the forward market is such that the forward price rises with the quantity of funds transacted x_i, i.e., $dF_i/dx_i > 0$. The dealer's profit π, who takes the other side of the transaction, can be then written as (we remove both ℓ and t as subscripts for simplicity)

$$\pi = x(1+r_i)\frac{F_i}{S_i} - x(1+r),$$

with profit maximization implying that

$$\frac{\partial \pi}{\partial x_i} = (1+r_i)\frac{F_i}{S_i} + (1+r_i)x_i\frac{dF_i}{dx_i} - (1+r) = 0. \tag{2}$$

If one defines the elasticity of supply of forwards as $E_s \equiv (dx_i/dF_i)(F_i/x_i)$, Equation (2) can be rewritten as follows

$$(1+r_i)\left(\frac{F_i}{S_i} + \frac{F_i}{E_s}\right) = 1 + r. \tag{3}$$

With perfectly elastic supply (i.e., $E_s = \infty$), Equation (3) reduces to the textbook CIP condition; when the supply of forwards is inelastic, however, the dollar basis turns out to be negative. We now move to outline the key components of the financial regulation designed in the aftermath of the global financial crisis.

2.2 Post-Crisis Financial Regulation

Since the 2007-2008 global financial crisis, policy-makers and regulators have embarked in a significant program of financial reforms to strengthen the resilience of the banking sector, ultimately to reduce negative spillovers from the financial sector to the real economy. Among these reforms, a key role is played by the new regulatory framework on bank capitalization, stress testing, and market liquidity risk announced by the Basel Committee on Banking Supervision in July 2010. This package is generally referred to as the "Basel III" accord (e.g., BCBS, 2009b, 2010).

As part of this comprehensive bundle of rules, the Basel Committee proposed a non-risk-weighted capital requirement – the leverage ratio – according to which a bank has to hold a minimum level of high-quality loss-absorbing (Tier 1) capital in proportion to its total consolidated assets. The latter include on-balance sheet exposures, derivatives exposures, securities financing transactions exposures, and other off-balance sheet items (e.g., BCBS, 2014).[7] By weighting all exposures equally, the leverage ratio can potentially increase the intermediation costs of those assets that are characterized by low margin and high volume. This is especially true for FX derivatives which can substantially expand a dealer's balance sheet thus attracting a capital charge under the leverage ratio framework. For the calculation of the leverage ratio, moreover, banks have a limited capability to net out derivatives exposure that offset each other across different counterparties. This happens as derivatives generate an underlying asset exposure and counterparty credit risk exposure (e.g., BCBS, 2014).

Figure 2 about here

The Basel Committee finalized the definition of the leverage ratio in May 2014 (BCBS, 2014) and have required banks to disclose publicly their leverage ratio on a quarter-end basis since January 2015. A mandatory minimum requirement, however, was postponed to January 2018. In the UK, the leverage ratio was announced in early December 2015 and became mandatory for major UK banks (those with deposits over £50 billion) since January 2016.[8] It consists of a *minimum leverage ratio requirement* of 3% (three quarters of which must be met with common equity Tier 1 capital instruments), a *countercyclical buffer*, and an *additional buffer for global systemically*

[7] The leverage ratio differs from the capital ratio, which is defined as capital over risk-weighted assets. The weights depend on both credit and market risk with the latter being measured using a value-at-risk (VaR) based on 10-day holding period returns.

[8] In October 2014, as part of a review process initiated by the government for a more resilient banking system, the Financial Policy Committee recommended introducing as soon as practicable a binding minimum leverage ratio requirement plus two macroprudential buffers for large UK banks (Bank of England, 2014). Based on these premises, the Prudential Regulation Authority first started a consultation process in July 2015, and then announced the UK leverage ratio framework in early December 2015.

important institutions (Bank of England, 2015c,b). Regarding the reporting requirements, the regulator introduced a transition period of 12 months during which the numerator and denominator of the leverage ratio were calculated using end-of-month figures during the reference quarter. Other regulated banks, i.e., small domestic banks as well as the subsidiaries of foreign banks, remained subject to the path set by the Basel Committee.[9] We summarize the key dates in Figure 2.

In our empirical analysis, we will make use of two regulatory events, namely the public disclosure of the leverage ratio in 2015 and the introduction of the UK leverage ratio framework in 2016, to design difference-in-differences regressions. Ultimately, this exercise will help improve our identification, thus offering a supply-side explanation for the existence of a non-zero dollar basis. We now move to the description of the data before turning to our empirical analysis.

3 Data Description

This section first describes the trade repository data on forward contracts and then shows the construction of the contract-level dollar basis that we use in our empirical analysis.

3.1 Trade Repository Data

Over-the-counter (OTC) derivatives markets are regarded as the most opaque financial markets. Understanding the complexity and functioning of these "dark markets" is notoriously difficult as buyers and sellers negotiate the terms of the trade privately (e.g., Duffie, 2012). Not surprisingly, financial regulators have struggled for a long time to gather key information such as price, volume, maturity, outstanding transactions, and counterparty identities. The recent global financial crisis, however, marked an important turning point as G20 leaders put forward in September 2009 a broad reform agenda to improve profoundly the level of transparency in these markets. As part of this initiative, it was agreed that all OTC derivatives contracts would be reported to trade repositories in order to grant policy-makers and regulators access to high-quality and high-frequency data.

In the European Union, this commitment was introduced with the European Market Infrastructure Regulation (EMIR). Since February 2014, it has been mandatory for counterparties resident in the European Union to report by the following business day the details of any derivative transactions

[9] In the European Union, Basel III was introduced through a legislative package covering prudential rules for banks, building societies and investment firms, i.e., the Capital Requirements Directive (2013/36/EU) implemented through national law, and the Capital Requirements Regulation (575/2013) directly applicable to firms across the Union.

to a trade repository authorized by the European Securities and Markets Authority (ESMA).[10] This reporting obligation covers both over-the-counter and exchange-traded derivatives, comprises all asset classes – credit, commodity, equity, interest rates and foreign exchange (FX) – and applies to clearing houses, financial counterparties, and non-financial counterparties that are legal entities under the jurisdiction of the European Union.[11]

While the reporting obligation was introduced in February 2014, a large number of observations was initially missing or incorrectly reported. In response to this issue, ESMA introduced a formal process of data validation in December 2014 that substantially improved the quality of the data. For instance, Abad, Aldasoro, Aymanns, D'Errico, Rousova, Hoffmann, Langfield, Neychev, and Roukny (2016) use month-end data from DTCC and find that the percentage share of missing variables was about 30% before the introduction of the validation process. After this date, the percentage share of missing variables dropped sharply below 10% and since then there has been a clear downward trend. Guided by this information about data quality, our sample starts in December 2014 and ends in December 2016.

Within the OTC derivatives market, FX derivatives represent the largest segment in terms of daily transaction volume and the second-largest segment in terms of notional value after interest rate derivatives (see BIS, 2016). Our dataset consists of contract-level outright forwards and forward legs of FX swaps, which we refer to as forward contracts. While the outright forward is an agreement to exchange two currencies on a future date at a rate agreed on the inception date, the FX swap comprises an initial transaction of two currencies, typically at the spot rate, coupled with the commitment to reverse the transaction on a future date at the forward rate. Although these contracts may be driven by different motives, no information is available in the EMIR data to discriminate one from the other as only the forward leg is reported for FX swaps.

We have been given access to this dataset by the Bank of England. In particular, we observe all derivatives transactions where at least one of the counterparties is a UK legal entity and rely on the reports submitted to the DTCC – the largest trade depository in terms of market share – as there exists a lack of data harmonization across trade repositories. Finally, we focus on the most liquid developed currencies – Australian dollar (AUD), Canadian dollar (CAD), Swiss franc (CHF), euro (EUR), British pound (GBP), Japanese yen (JPY) – relative to the US dollar (USD).

[10] The list of registered trade repositories includes (i) CME Trade Repository Ltd., (ii) Depository Trust & Clearing Corporation (DTCC) Derivatives Repository Ltd., (iii) ICE Trade Vault Europe Ltd., (iv) Krajowy Depozyt Papierów Wartościowych S.A., (v) Regis-TR S.A., (vi) UnaVista Limited (UnaVista), and (vii) Bloomberg Trade Repository Limited.

[11] A similar reform in the US, for instance, has been implemented trough the Dodd-Frank Wall Street Reform and Consumer Protection Act, or simply the Dodd-Frank Act. As of June 2016, according to the Financial Stability Board (FSB), 19 out of 24 FSB jurisdictions have enforced trade reporting requirements.

3.2 Data Structure and Classification

We collect data from the "trade activity report" which contains, for each transaction, information about the counterparties (i.e., the Legal Entity Identifier (LEI) and the corporate sector) and the contract's characteristics (e.g., forward price, notional amount, type of delivery, maturity date, execution date, execution venue, execution time, currency cross) for a total of more than 100 fields. We then discard duplicates of the same transaction using the unique trade identifier as the EMIR imposes a double-sided reporting regime. In a number of cases, we have removed multiple copies of the same trade due to modifications, corrections, and valuation updates. Finally, we drop any transactions with missing key information and remove observations with extreme notional values by winsorizing the data at the 99.9% level.

We then proceed to the classification of individual counterparties. The FX market consists of two tiers: an interbank market where dealers (typically large international banks) trade among themselves and a retail segment where financial and non-financial clients trade with either dealers or other clients. In line with this characterization, we categorize individual counterparties into dealers and clients and then group their transactions accordingly. This process, however, was done largely manually as the LEI reference system does not provide any standardized source of classification of firms. Moreover, transactions are generally reported at the legal entity level thus implying that each subsidiary of large international banks, for instance, will separately report its transactions. As a result, we have consolidated a large number of single LEI reports to obtain transactions at the parent group level as in Cielinska, Joseph, Shreyas, Tanner, and Vasios (2017).

We classify the largest banks by overall market share according to the 2015 and 2016 Euromoney FX survey as dealers. Using this criterion, we end up with a list of 17 dealers which comprises (in alphabetic order) Bank of America Merrill Lynch, Barclays, BNP Paribas, Citi, Crédit Agricole, Credit Suisse, Deutsche Bank, Goldman Sachs, HSBC, JP Morgan, Morgan Stanley, Nomura, Royal Bank of Scotland, Société Générale, Standard Chartered, State Street, and UBS. This set of dealers is obtained by consolidating up to 106 different legal entities. Dealers' counterparties are manually split into several sectors, i.e., real money investors (asset managers, pension funds, insurance firms, state institutions and unclassified funds), hedge funds, non-financial corporates, non-dealer banks (commercial banks, prime brokerage firms, and non-bank firms offering trading services), central banks (including monetary authorities), and unclassified clients (individual counterparties for which the LEI was either missing/incorrect or associated with an entity difficult to categorize). In our sample, we classify more than 30,000 clients, which correspond to more than 98% of the total trading volume. The unclassified clients therefore only account for less than 2% of the total volume.

3.3 Volume Breakdown by Currency, Maturity and Sector

Since we employ a subset of the EMIR data, one might be concerned that our data are not representative of the market trading activity. To shed light on the representativeness of our data, we compare the aggregates of our data with the summary statistics reported in the 2016 BIS Triennial Survey (BIS, 2016).

Figure 3 about here

Specifically, we measure daily forward volume using all transactions recorded in our dataset, and report the comparison in Figure 3. As displayed in this figure, the daily average turnover as of April 2016 for the six currency pairs examined in our analysis is about 366 USD billion for outright forwards and 1.622 USD trillion for FX swaps, for a total amount of $1,988$ USD trillion, according to the Triennial Survey. In our dataset, we uncover an average daily volume of 844 (867) USD billions for both types of instruments as of April 2016 (full-sample period). Although the comparison may not be perfect due to different aggregation criteria, our calculations suggest that we observe more than 42% of the daily trading activity. This is consistent with the fact that London is the largest trading center for FX instruments (e.g., BIS, 2016).

Figure 4 about here

We also break down the volume by currency, maturity, and sector. Figure 4 presents this decomposition for the FX forward market and reveals that a large fraction of the trading activity is dominated by the euro against the dollar, spans contracts up to a week maturity, and is concentrated in the inter-dealer market. In particular, the breakdown by currency pairs shows that approximately 39% of the total daily volume – or up to 340 USD billions per day – is for EUR against USD, an additional 41% is equally split between GBP and JPY, whereas AUD, CAD and CHF (all relative to USD) cover a residual 20%. When we consider the breakdown by maturity, we find that more than 70% of the daily volume is for contracts with less than a week maturity, and up to 93% covers contracts with less than three-month maturity. Contracts with longer maturities are less popular and make up about 7% of the market. The third pie chart in Figure 4 slices the trading volume by sector: 55% of the trading activity takes place in the inter-dealer market, 44% between dealers and clients, and only a tiny amount is inter-clients. In the dealer-to-client segment, moreover, we document that more than 27.6% of the daily volume is with respect to non-dealer banks (typically acting on behalf of corporate firms and small financial players), 7.6% is with respect to real money investors, 4.1%

with respect to hedge funds, 2% with respect to corporates, and less than 1% relative to central banks.

3.4 Bank-Level Data

We use data on the quarterly leverage ratio (Tier 1 capital over total exposures) and the capital ratio (Tier 1 capital over risk-weighted assets) of eleven major dealer banks reporting to the Bank of England (i.e., UK COREP dataset). This list includes Barclays, Citi, Credit Suisse, Goldman Sachs, HSBC, JP Morgan, Morgan Stanley, Nomura, Royal Bank of Scotland, Standard Chartered, and UBS. A number of European dealer banks are not part of this directory as they are not part of the UK COREP dataset. As a result, we only use a subset of eleven major dealer banks in our empirical analysis.

We also use bank size measured as the log of a bank's total assets in levels, liquid asset share quantified as the holdings of liquid assets (i.e., cash and market loans) scaled by non-equity liabilities, and deposit share proxied by the fraction of the bank's balance sheet financed with core deposits. These data are measured quarterly and are from the Bank of England (BT forms). Finally, we also employ data on five-year CDS spreads and one-month option implied volatility of dealer banks from Bloomberg.[12]

3.5 Contract-Level Dollar Basis

We measure the dollar basis at contract-level by synchronizing transaction prices on forward contracts with second-level data on spot exchange rates and overnight index swap (OIS) interest rates from Thomson Reuters Tick History. Depending on the availability of OIS rates, we use all forwards between one-week and three-month maturity. For non-standard maturity contracts (e.g., a 45-day forward), we rely on linearly interpolated OIS rates using the closest available tenors (e.g., one-month and two-month OIS rates).

We construct our contract-level dollar basis using a sample of nearly 3.5 million observations as follows:

$$B_{ij\kappa\ell,t} = \varsigma\left[(1 + r_{\ell,t}) - (1 + r_{i\ell,t})\frac{F_{ij\kappa\ell,t}}{S_{i,t}}\right], \tag{4}$$

where $B_{ij\kappa\ell,t}$ denotes the dollar basis recorded on day t between dealer j and counterparty κ for

[12]We report summary statistics for these variables in Table A.1 in the Internet Appendix. The mean leverage ratio is 3.92% with a standard deviation of 1.41% whereas the mean capital ratio is slightly higher than 11% with a standard deviation of 1.80%. The mean of liquid asset share is close to 20% with a standard deviation of 15.77% while the mean deposit share is slightly above 55% with a standard deviation of roughly 15%.

currency i and maturity ℓ, $r_{\ell,t}$ is the dollar interest rate with maturity ℓ, $r_{i\ell,t}$ is the equivalent foreign interest rate, $S_{i,t}$ is the spot exchange rate defined in units of dollars per currency i, $F_{ij\kappa\ell,t}$ is the forward exchange rate with delivery date $t+\ell$ between dealer j and counterparty κ for the same currency pair, and ς is a constant that translates $B_{ij\kappa\ell,t}$ in basis points (bps) per annum. To keep our notation in Equation (4) simple, we omit any contract-level subscript and use periodic interest rates by appropriately scaling the OIS rates (quoted in percentage per annum). We abstract from any bid-ask spread but simply use mid quotes on interest rates and spot exchange rates for two reasons. First, Du, Tepper, and Verdelhan (2018) already show that transaction costs cannot fully explain CIP deviations in the recent period, while our interest is more on what causes the basis to move rather than measuring whether the basis represents a "free lunch." Second, the indicative bid-ask quotes typically used in the literature come from electronic platforms (e.g., Reuters or EBS) that cover a small fraction of the transaction volume of our sample, and the spreads calculated from these quotes may not be representative of the other market segments that are covered by our dataset (e.g., Moore, Schrimpf, and Sushko, 2016). On a more positive side though, it should be stressed that our forward prices reflect *actual transactions* as opposed to indicative quotes, so may help us understand better what causes actual transaction prices to move. The forward prices can be either a bid or an ask price depending on the recorded transaction.[13]

Table 1 about here

Table 1 presents means (with standard deviations in parentheses) of one-week, one-month and three-month dollar basis expressed in bps per annum. The left-hand side columns (labeled as LIBOR) display the textbook-style dollar basis computed using LIBOR rates coupled with the closing spot and forward exchange rates recorded by Bloomberg in London (e.g., Bekaert and Hodrick, 2012; Du, Tepper, and Verdelhan, 2018). In the middle columns (labeled as OIS), we replace the LIBOR rates with the overnight index swap (OIS) rates sampled at 11 am London time using second-level data from Thomson Reuters Tick History. The right-hand side columns (labeled as Contract-level) refer to the dollar basis constructed as in Equation (4). To ease the comparison, we first take the intraday average and then use the resulting daily time series to compute means and standard deviations (results remain similar with volume-weighted intra-day averages). Panel A reports one-week dollar basis only for EUR, GBP, and JPY as intra-day OIS rates for this maturity are not available for other currencies. Panel B and Panel C display one-month and three-month dollar basis respectively, for all currency pairs. Despite using different data and sources, dollar basis deviations

[13] Note that we only use transactions between dealers and clients as otherwise we would be unable to control for unobserved characteristics at the counterparty dealer level, thus failing to fully isolate demand and supply factors.

remain largely comparable. For instance, the mean deviation at one-week maturity (see Panel A) for the British pound vis-à-vis the US dollar is about -21.77 *bps* per annum with LIBOR rates, -21.82 *bps* per annum with OIS rates, and -18.27 *bps* per annum when turning to transaction-level data. Similarly when we consider the cross-currency average, i.e., -34.79 *bps* per annum with LIBOR rates, -38.62 *bps* per annum with OIS rates, and -34.37 *bps* per annum with transaction-level data. The average 1-month deviation (see Panel B) for the euro relative to the US dollar is about -40.49 *bps* per annum with LIBOR rates, -46.92 *bps* per annum with OIS rates, and -33.06 *bps* per annum with transaction-level data. The cross-currency average, moreover, equals -34.17 *bps* per annum with LIBOR rates, -37.44 *bps* per annum with OIS rates, and -29.15 *bps* per annum with transaction-level data. Panel C produces the same statistics for 3-month deviations and confirms the findings reported in previous panels as the cross-currency average goes from -25.33 *bps* pr annum with LIBOR rates to -32.36 *bps* per annum with transaction-level data.

4 The Dollar Basis and the Leverage Ratio

This section examines empirically how the dollar basis responds to an increase in the Basel III leverage ratio of major dealer banks and attempts to offer a supply interpretation. In our first exercise, we regress contract-level dollar basis on the lagged leverage ratio of dealer banks while controlling for observed dealer characteristics as well as unobserved currency and sector (e.g., real money) characteristics. In our second exercise, we enhance our identification strategy by absorbing changes in demand conditions at the client level following the path-breaking work of Khwaja and Mian (2008). We then move to difference-in-differences regressions to further control for bank-related omitted variables. As a companion exercise, we also study the impact of balance sheet costs on the trading activity in the forward market.

4.1 Controlling for Sector and Currency Characteristics

Our analysis begins with contract-level dollar basis constructed using dealer-to-client transactions, and employs fixed-effect panel regressions based on the following specification:

$$A_{ij\kappa\ell,t} = \beta_1 L_{j,t-1} + \beta_2 C_{j,t-1} + \gamma' X_{j,t-1} + FE + \varepsilon_{ij\kappa\ell,t}, \tag{5}$$

where $A_{ij\kappa\ell,t}$ denotes all dollar basis in absolute terms recorded on day t for currency i, dealer j, counterparty κ and maturity ℓ (we omit any contract-level subscript for simplicity), $L_{j,t}$ ($C_{j,t}$) is the leverage (capital) ratio of dealer j, and $X_{j,t}$ refers to bank-specific control variables. All right-hand side variables are lagged (up to a quarter) and we retrieve higher-frequency observations by forward filling, i.e., we keep the latest available observation fixed until a new one is made available.[14] We complement our specifications with both time-invariant and time-variant fixed effects (FE). The former include currency (α_i), dealer (α_j), maturity (α_ℓ) and hour (α_h) fixed-effects. The latter comprises sector-time ($\alpha_{s,t}$) or currency-sector-time ($\alpha_{i,s,t}$) fixed effects obtained by interacting currency and/or sector fixed effects with a daily (calendar date) fixed effect.

Table 2 about here

Table 2 reports the coefficient estimates with standard errors clustered by currency and time dimension (in parentheses) associated with Equation (5). We find that the estimates of β_1 are always positive and highly statistically significant, even after controlling for dealer-specific variables including the capital ratio. This suggests that an increase in the leverage ratio of dealer banks is associated with a widening of the dollar basis. In contrast, estimates of the slope coefficient β_2 turn out to be statistically insignificant leading us to conclude that the capital ratio has a negligible impact on the dollar basis.

Specification (1), for instance, uses the lagged leverage ratio as an explanatory variable together with dealer, maturity, hour, currency, and sector-time fixed effects. The estimate of the slope coefficient associated with the leverage ratio is 19.11 and is highly statistically significant (with a *t-stat* larger than 3). By interacting sector and time fixed effects, we control for all time-variant unobserved characteristics at the sector level. These would include, for example, heterogeneity in funding rates across different sectors (e.g., real money investors versus non-financial corporates) which are not directly observable. A sector–time fixed effect should account for such unobserved differences. Note that separate sector and time fixed effects are spanned by the sector–time fixed effects and are, thus, dropped here.

Specification (2) introduces dealer-specific control variables and records qualitatively a similar outcome as the estimate of β_1 is 20.457 with a standard error of 3.480. In specification (3), our result remains robust to the inclusion of currency-sector-time fixed effects which account for time-variant currency and sector characteristics. The estimate of β_1 is 20.193 with a t-statistic above 3. In economic terms, the dollar basis widens by approximately 28 *bps* per annum when the lagged leverage ratio increases by a one standard deviation (i.e., $20.193 \times 1.41 \approx 28$).

Specifications (4) to (6) replace the leverage ratio with the (risk-weighted) capital ratio of dealer

[14] We present a description of these variables in Table A.1 in the Internet Appendix.

banks. While estimates of β_2 are highly statistically significant, their economic importance is small. In specification (6), for example, the estimate of β_2 is 3.487 with standard error of 1.229. This roughly corresponds to a widening of the basis of 6 *bps* per annum when the lagged capital ratio rises by a standard deviation (i.e., $3.487 \times 1.80 \approx 6$). Finally, specifications (7) to (9) use both leverage and capital ratios as lagged explanatory variables. While these additional specifications confirm the statistical and economic significance of the leverage ratio, the capital ratio appears to be statistically insignificant and economically small. In specification (9), for example, the economic value of β_1 is close to 27 *bps* per annum whereas the economic value of β_2 does not even reach 2 *bps* per annum.

4.2 Controlling for Client and Currency Characteristics

The previous section documents a strong predictive relationship between the dollar basis and the leverage ratio of dealer banks while controlling for changes in demand conditions at the sector level. This empirical relationship, however, may face an identification challenge as changes in the individual counterparty fundamentals could drive the widening of the dollar basis irrespective of dealer-specific variables, including balance sheet constraints. If so, we would be unable to give a supply interpretation to our estimates. We solve this problem in the spirit of Khwaja and Mian (2008), i.e., we control for all time-variant client and currency characteristics through the inclusion of client-currency-time fixed effects. For its implementation, we collapse our absolute contract-level dollar basis into weekly volume-weighted absolute dollar basis as this allows us to identify clients with multiple trading relationships. This approach removes all confounding demand factors and is equivalent to asking whether the same counterparty in the same time period dealing with multiple dealer banks faces a larger basis from the dealer bank with a relatively higher leverage ratio.

Similar to Equation (5), we run panel regressions based on the following specification:

$$A_{ij\kappa,t} = \beta_1 L_{j,t-1} + \beta_2 C_{j,t-1} + \gamma' X_{j,t-1} + FE + \varepsilon_{ij\kappa,t}, \tag{6}$$

where $A_{ij\kappa,t}$ denotes the volume-weighted absolute dollar basis measured in week t. We include combinations of currency (α_i), dealer (α_j), client-time ($\alpha_{\kappa,t}$) and currency-client-time ($\alpha_{i,\kappa,t}$) fixed effects. The client–time and currency-client-time fixed effects are obtained by using a weekly (calendar date) fixed effect.

TABLE 3 ABOUT HERE

The coefficient β_1 (β_2) measures the impact of the leverage (capital) ratio on the dollar basis, controlling for any observable and unobservable characteristics between dollar basis or within dollar basis over time. These estimates, reported in Table 3, by and large confirm the evidence recorded in the previous table. In specification (3), for example, the estimate of β_1 is 16.911, has a standard error of 3.985, and an economic significance of about 23 *bps* per annum. In specification (9), both β_1 and β_2 turn out to be statistically significant. The estimate of β_1 is 12.713 with a standard error of 3.330 whereas the estimate of β_2 is 4.135 with a standard error of 1.355. The economic value of β_1 (17 *bps* per annum), however, is substantially larger than the economic value of β_2 (7 *bps* per annum).

4.3 Leverage Ratio and Trading Activity in the Forward Market

Dealer banks have an incentive to expand their balance sheet per unit of capital unless a backstop is at play. In response to a tighter constraint, banks can reduce their leverage exposure in two different ways. They can either increase their levels of regulatory capital (i.e., the numerator of the leverage ratio) or shrink their asset exposure (i.e., the denominator of the leverage ratio). While raising capital is generally regarded as good deleveraging by regulators, decreasing the asset side has potentially adverse effects if multiple banks simultaneously engage in slashing their activities. How dealer banks adjust their balance sheets in response to tighter regulatory requirements is important to understand the implications of the post-crisis financial regulation.

On the basis of these considerations, we complement our findings on the dollar basis with the following panel regressions:

$$lnV_{ij\kappa,t} \times 100 = \beta_1 L_{j,t-1} + \beta_2 C_{j,t-1} + \gamma' X_{j,t-1} + FE + \varepsilon_{ij\kappa,t}, \tag{7}$$

where $V_{ij\kappa,t}$ is the forward volume measured in week t for currency i, dealer j, and counterparty κ, and ln is the natural log operator. We include combinations of currency (α_i), dealer (α_j), client–time ($\alpha_{\kappa,t}$) and currency-client-time ($\alpha_{i,\kappa,t}$) fixed effects. The client-time and currency-client-time fixed effects are obtained by using a weekly (calendar date) fixed effect. Moreover, we scale the dependent variable such that the coefficient β_1 (β_2) will approximately measure the percentage change in volume predicted by a unit increase in the leverage (capital) ratio. We report the estimates with standard errors (in parentheses) clustered by currency and time dimension in Table 4, and find that an increase in the leverage ratio of dealer banks goes hand-in-hand with a future fall in trading activity on the forward market. The estimate of β_1 is always negative and highly statistically significant while controlling for observed dealer-specific characteristics and currency-client-time fixed effects.

Table 4 about here

For example, the estimate of β_1 in specification (3) equals -13.716 and is statistically significant at the 1% confidence level. Similarly, when we control for the capital ratio in specification (9), the estimate of β_1 is -12.942 and remains statistically significant at the 1% confidence level. The economic magnitude of these estimates is substantial as a one standard deviation increase in the leverage ratio predicts a fall in volume of 17.6% for specification (3) and 16.7% for specification (9). The coefficient estimate associated with the capital ratio turns out to be statistically insignificant and economically small when controlling for the leverage ratio. In specification (9), for example, the estimate of β_2 equals -0.762, has a standard error of 0.955 and predicts a fall in volume of 1.3% when the capital ratio increases by a one standard deviation. To sum up, we find evidence that an increase in the leverage ratio predicts both a higher intermediation premium as well as a fall in trading activity in the forward market.

4.4 Controlling for Bank-Related Omitted Variables

The identification of a supply-side effect faces an additional challenge arising from the potential correlation of supply-side characteristics. For example, a higher leverage ratio could result from an active management of the balance sheet as opposed to the impact of a regulatory constraint. If so, the leverage ratio could proxy for other bank-related factors thus leading to a biased estimate of β_1. We alleviate this concern relating to possible time-varying omitted bank-related variables using two difference-in-differences exercises based on plausibly exogenous variations. The first one is based on the introduction of the UK leverage ratio framework in January 2016 whereas the second one employs the requirement on the public disclosure of the leverage ratio in January 2015. Ultimately, we will assess how affected dealer banks adjust their balance sheets in response to these exogenous shocks compared to otherwise similar banks.

4.4.1 Difference-in-Differences Regressions

To enhance our identification in the presence of time-varying bank-related omitted variables, we study the dollar basis before and after the regulatory intervention between treated and untreated dealer banks using difference-in-differences regressions based on the following specification:

$$A_{ij\kappa,t} = \beta D_p + \delta D_a + \gamma(D_p \times D_a) + FE + \varepsilon_{ij\kappa,t}, \tag{8}$$

where $A_{ij\kappa,t}$ is the volume-weighted absolute dollar basis measured in week t for currency i, dealer j and counterparty κ, D_p is a dummy variable that selects observations after the regulatory intervention, D_a is a dummy variable that takes on the value of one for affected banks and 0 otherwise, and $D_p \times D_a$ is the interaction term between time and treatment group dummy variables. We include combinations of currency (α_i), dealer (α_j), client-time ($\alpha_{\kappa,t}$) and currency-client-time ($\alpha_{i,\kappa,t}$) fixed effects. The client-time and currency-client-time fixed effects are obtained by using a weekly (calendar date) fixed effect. The coefficient γ measures the difference in the dollar basis between dealers that were subject to the regulatory intervention (the treatment group) and dealers that were exempted (the control group) such that a positive estimate of γ implies a widening of the dollar basis following the regulatory shocks. The specification also includes dealer and currency fixed effects to absorb time-invariant dealer and currency-specific characteristics, and/or client-time and client-currency-time fixed effects to account for observed and unobserved heterogeneity in time-varying client and currency characteristics. We estimate the difference-in-differences regressions via least-squares and cluster standard errors at the currency level.

We also examine the impact of a regulatory shock on the trading activity of the forward market using the same set of difference-in-differences regressions subsumed by Equation (8) as

$$lnV_{ij\kappa,t} \times 100 = \beta D_p + \delta D_a + \gamma(D_p \times D_a) + FE + \varepsilon_{ij\kappa,t}, \tag{9}$$

except that we use the percentage log forward volume measured in week t for currency i, dealer j, and counterparty κ as the dependent variable. In this case, a negative estimate of γ would measure the percentage drop in volume for dealers subject to the regulatory intervention (the treatment group) relative to those dealers that were exempted (the control group) from the regulatory intervention.

4.4.2 The UK Leverage Ratio Framework

In our first difference-in-differences exercise, a plausibly exogenous shock arises from the introduction of the UK leverage ratio framework in January 2016, which only affected major UK banks whereas the subsidiaries of foreign banks (including all other domestic banks) continued to fall under the prescription of the EU legislation. This regulatory change constitutes an ideal quasi-natural experiment to identify the impact of the leverage ratio rule on the dollar basis. It lends itself to a difference-in-differences exercise as it allows us to identify a treatment and a control group of dealer banks. In our sample, four dealer banks (Barclays, HSBC, Royal Bank of Scotland, and Standard Chartered) form our treatment group and the subsidiaries of seven international banks (Citibank, Credit Suisse, Goldman Sachs, JP Morgan, Morgan Stanley, Nomura, and UBS) act as a control group. While the selection within each block is not random, our banks are all categorized as global systemically important banks (G-SIBs) by the Financial Stability Board and the Basel Committee and, hence, should be regarded as largely comparable. This is important as any causal inference would be compromised if our group of treated banks were systematically different, say in terms of business models or funding strategies, from our pool of control banks.

In addition to a minimum requirement, the UK framework also introduced an important change in reporting obligations. During a transitional period of 12 months from January to December 2016, major UK banks were obliged to quantify the key ingredients for the calculation of the leverage ratio (i.e., capital and exposure measures) on the last day of each month during the reference calendar quarter and then average them. In contrast, other banks continued to report the leverage ratio recorded on the last day of each quarter. The aim of this end-of-month average rule was to reduce the ability of regulated banks to window-dress their balance sheet at quarter ends, thus making the leverage ratio rule more effective. As banks had little incentive to adjust their reporting obligations ahead of the implementation date, the change in the reporting obligations can be seen as a plausibly exogenous variation that affected a group of banks while leaving other similar banks unaffected.

In our exercise, the pre-intervention period runs from November 2 to December 18, 2015 whereas the post-intervention period runs between January 11 and February 26, 2016. Both periods are intended to capture two months of observations before and after the regulatory shock while removing the weeks bracketing the year-end to avoid, for instance, end-of-year volatility or tax-driven window-dressing effects. Also, we construct volume-weighted dollar basis using forward contracts with maturities between one week and one month. This is to minimize any cross-period contamination as, for instance, a two-month forward contract traded on December 15, 2015 (pre-intervention period) would affect the balance sheet of a dealer at the end of January 2016 (post-intervention period).[15]

Tables 5 about here

We report the difference-in-differences estimates of γ for the absolute dollar basis in Panel A of

[15] This exercise will mostly use dollar basis based on the most liquid currency pairs (i.e., EUR, GBP, and JPY relative to USD) as for the least liquid currency pairs (i.e., AUD, CAD, and CHF vis-á-vis USD) we have no intra-day data for less than a month interest rates (see the previous section for more details).

Table 5. The estimates in specifications (1) and (2) are always positive and statistically significant. For example, specification (2) employs currency-client-time fixed effects and uncovers an estimate of 23.787 with a standard error of 9.084. These estimates imply that dealer banks subject to the UK leverage ratio framework faced a widening of their dollar basis by approximately 24 *bps* per annum relative to the dealer banks in the control group after January 2016. For robustness, we also run a placebo exercise by shifting the time window by a two-month period but uncover no statistically significant coefficient. This allows us to rule out the alternative that the dollar basis increase was part of an ongoing trend of deleveraging among low capitalized banks. In Panel B of Table 5, we present the difference-in-differences estimates of γ using the percentage log volume (i.e., $lnV_{ij\kappa,t} \times 100$) as dependent variables. As an example, the estimate of γ is negative (-1.055) but statistically insignificant in specification (2). This is equivalent to saying that dealer banks subject to the UK leverage ratio framework faced an approximately 1% drop in volume relative to the dealer banks in the control group.

Figure 5 about here

We also visualize the impact of the regulatory intervention on the dollar basis in Figure 5. In particular, we report the difference in absolute dollar basis in *bps* per annum between the treatment and control group dealers before and after the change in reporting requirements. We also add to each bar the 95% confidence interval. While differences in absolute dollar basis were statistically insignificant during the pre-intervention period, they turn out to be statistically significant in the post-intervention period.

4.4.3 The Public Disclosure of the Leverage Ratio

The second difference-in-differences exercise exploits, as a plausibly exogenous shock, the requirement of banks to make detailed public disclosures about their Basel III leverage ratios starting from January 2015. While the leverage ratio rule was not mandatory at the time, banks had an incentive to adjust their leverage ratio around the expected minimum requirement. Failing to disclose a leverage ratio in line with the Basel Committee's expectation could have increased, for example, media attention and reputation risk for highly leveraged banks. It could have also affected the cost of capital as a higher level of financial disclosure reduces information asymmetries.

The public disclosure requirement may have created unexpected winners and losers in the cross-section of banks. Depending on their ex-ante leverage exposure, banks with a larger shortfall in regulatory capital may have experienced a marked deleveraging process, leading to a widening of their dollar basis and a fall in their trading activity. To measure the ex-ante leverage exposure of dealer banks, we rely on published accounts data obtained from the Bank of England (see, Bank of England, 2015a) and construct a simple measure of the leverage ratio as of December 2007, prior to the policy debate on excessive leverage in the banking sector (e.g., Draghi, 2008), using shareholders' claims to total assets.[16] We then form a treatment and a control group of dealer banks using the cross-sectional median value of this measure, with the former (latter) group including banks with a leverage ratio lying below (above) the median value. We then use the variation in dollar basis around January 2015 to test the causal impact of the leverage ratio. The public disclosure requirement constitutes a shock under the assumption that it was not anticipated by banks. This assumption is, however, benign. If banks had fully anticipated the negative impact associated with the public disclosure requirement, they might have decided to adjust their leverage ratio prior to this disclosure obligation, thus leading us to underestimate the effect of this rule change.

Tables 6 about here

In our exercise, the pre-intervention period runs from December 1, 2014 (when our sample starts) to December 19, 2014 while the post-intervention period runs from January 12 to January 30, 2016. Both periods are intended to capture a month of observations before and after the regulatory shock while removing the weeks bracketing the year end. We use volume-weighted dollar basis using all available forward contracts. We report the difference-in-differences estimates of γ for the absolute dollar basis in Panel A of Table 6. These estimates – see specifications (1) and (2) – are always positive and statistically significant. For example, specification (2) employs currency-client-time fixed effects and uncovers an estimate of 54.591 with a standard error of 13.306. This estimate implies that dealer banks with a low ex-ante leverage ratio faced a widening of their dollar basis of approximately 55 *bps* per annum relative to the dealer banks with a high ex-ante leverage ratio. As a robustness, we also run a placebo exercise by shifting the time window by a month but uncover no statistically significant coefficient. In Panel B of Table 6 we present the difference-in-differences estimates of γ using the percentage log volume (i.e., $lnV_{ij\kappa,t} \times 100$) as dependent variables and find significant evidence that the regulatory intervention caused a substantial drop in the trading activity of forward contracts. As an example, the estimate of γ in specification (2) is negative (-31.009) and statistically significant at the 1% confidence level. This translates into a 31% drop in volume for affected dealer banks relative to the unaffected ones. Our results, moreover, remain unchanged

[16] The regulatory leverage ratio introduced with Basel III was not available at that time. We use a simple measure of leverage ratio using data provided by the Bank of England.

if we rank dealer banks on the basis of the average simple leverage ratio between 2000 and 2007.[17] Overall, we confirm the role of the leverage ratio requirement as a determinant of the dollar basis.

5 Interaction between Demand and Supply Factors

The previous section shows that the supply of dollar swap funding steepened at the dealer level while controlling for changes in client demand. If the supply curve were perfectly elastic, demand shocks would have no effect. Borio, McCauley, McGuire, and Sushko (2016) provide empirical evidence that aggregate demand has an impact on the basis. We now report evidence that demand shocks impact the basis at the dealer level but that the effect is larger the higher the leverage ratio of dealer banks.

5.1 Monetary Policy Shocks

The widening of the basis, for instance, could be attributed to the surge in net foreign currency hedging demand and, in particular, to the monetary policy divergence between the US and other countries (e.g., Borio, Iqbal, McCauley, McGuire, and Sushko, 2018). Higher interest rates in the US relative to Japan and the euro area, for instance, might have created an incentive for investors to swap capital from local currency-denominated assets into dollar-denominated assets. At the same time, financial institutions hedge most of their foreign currency investments, thus causing an appreciation of the dollar in the spot market coupled with its depreciation in the forward market.

In our first exercise, we examine the interaction between changes in monetary policy and dealer banks' leverage ratio using an event study centered around the interest rate announcements of the European Central Bank, which includes 17 announcement dates in our sample. Following Du, Tepper, and Verdelhan (2018), we first consider a two-hour window that starts (ends) at 13:30 (15:30) Central European Time (CET), thus including the release of the monetary decision at 13:45 CET and the one-hour press conference that takes place between 14:30 and 15:30 CET. We then measure the change in the dollar-euro basis for dealer j over this window, where the basis at 13:30 (15:30) CET is constructed as the volume-weighted average of all contract-level dollar basis between 11:30 and 13:30 (15:30 and 17:30) CET against dealer j. Finally, we proxy the monetary policy shock as the difference between the change in the 2-year German zero-yield and the change in the 2-year US zero-yield between 13:30 and 15:30 CET. We use data from Thomson Reuters Tick History

[17] In addition to the leverage ratio as of December 2007, we also rank our dealer banks using the leverage ratio as of December 2012. The results, which we report in Table A.5 in the Internet Appendix, remain qualitatively similar.

and this component is common across all dealers.

Table 7 about here

We regress the change in dollar basis ($\Delta B_{j,t}$) on the monetary policy shocks (MP), the leverage (or capital) ratio, and their interaction terms while controlling for dealer fixed effects. Results are presented in Table 7. In the first specification, MP is the only driving factor behind the dollar basis. Consistent with the evidence reported in Du, Tepper, and Verdelhan (2018), the coefficient estimate is positive and statistically different from zero, and this implies that the dollar basis widens as interest rates in the Euro Area fall (i.e., an increase in monetary policy divergence). In the second specification, we introduce the leverage ratio and the interaction term between the leverage ratio and the monetary policy shock. While the coefficient estimate on the monetary policy divergence loses its statistical significance, the coefficient estimate on the interaction term is positive and statistically significant at 10% level. The weak significance is likely due to a small number of observations. In the last specification, we replace the leverage ratio with the capital ratio but find no statistical evidence. In conclusion, we find that monetary policy divergence is associated with a widening of the basis especially when dealer banks face an increase in their leverage ratio.

5.2 US Money Market Fund Reform

In our second exercise, we consider the US money market fund reform as a shock that affected the demand for dollar funding in the FX swap market. Specifically, on October 14, 2016 the SEC completed the reform of the money market funds, an industry that was about to implode following the debacle of Lehman Brothers. The new regulation required prime money market funds to adopt a floating net asset value and introduce a redemption fee during periods of market stress. This made prime funds, among the largest providers of unsecured banking loans, less attractive for cash investors who rerouted nearly 1 trillion of US dollars from prime funds into government funds. In response, prime funds decreased their investment in commercial paper and other short-term debt, hitting demand for an important dollar funding source for foreign banks. European and Japanese banks were particularly exposed to this dollar funding squeeze and many of them were forced to use FX swaps for their dollar funding needs.

Table 8 about here

We run an event study by selecting a window of $-/+$ 3 days around the implementation date of the money market fund reform.[18] The length of the sample period is to minimize the presence of contaminating events during the estimation window. We report the estimates in Table 8. In specification (1), we regress the absolute contract-level dollar basis $A_{ij\kappa\ell,t}$ on a dummy variable that equals one from the implementation date of the reform (denoted as MMF) while controlling for hour, maturity, currency, and sector fixed effects. We find that the coefficient estimate associated with MMF is positive and statistically significant, corresponding to a widening of the dollar basis of 4.131 *bps* per annum following the implementation of the reform. In specification (2), we augment our panel regression with the leverage ratio of dealer banks while adding the interaction term with MMF, and find strong statistical significance for the coefficient estimate associated with the interaction component. This is equivalent to saying that a shock to the demand for dollar funding is associated with a larger dollar basis when dealer banks in the foreign exchange market face a higher leverage ratio. In specification (3), we replace the leverage ratio with the capital ratio but uncover no statistical evidence.

5.3 Order Flows

In our last exercise, we proxy aggregate hedging demand using the order flow between dealers and clients. Hence, we ask the following question: What does hedging demand from different investors tell us about the dollar basis? We construct order flow as the value of buyer-initiated orders minus the value of seller-initiated orders for a particular currency. We rely for our exercise on the buy/sell indicator for forwards available between November 2015 and December 2016. When the dollar basis is negative, an arbitrageur should borrow dollars, buy foreign currency in the spot market, invest in the local money market and simultaneously hedge her currency risk by buying dollars in the forward market. We then sign each transaction positively or negatively depending on whether the initiator of the transaction (the non-quoting counterparty) is buying or selling US dollars such that a positive (negative) order flow indicates net demand (supply) of US dollars in the forward market, thus indicating more arbitrageurs (hedgers) populating the FX forward market.

Figure 6 about here

We aggregate order flows within each week and display the standardized average weekly order flow that dealers face from their clients in Figure 6. The total order flow is on average negative, that

[18] While it was announced earlier, the reform did not trigger any significant outflows until it became effective as investors tried to earn the extra yield spread offered by prime funds (e.g., Rennison and Foley, 2016). Moreover, unsecured funding to foreign banks by prime funds largely dropped between the end of Q3 and the beginning of Q4 2016. See, for instance, Figure A1 in Aldasoro, Ehlers, Eren, and McCauley (2017).

is, in our sample clients tend to sell US dollars forward (or equivalently fund themselves in US dollars in the FX swap market). This statistic is consistent with the story put forward by market participants and policy-makers (e.g., Borio, McCauley, McGuire, and Sushko, 2016) that during our sample period international investors and corporations increased their dollar hedging demand, as the monetary policy divergence between the US on one side and the euro-area and Japan on the other side pushed them to hold more dollar-denominated securities while at the same time hedging their FX exposure. This story is also supported when we split the order flow by client category: real money and non-financial corporates sell dollar forwards, consistent with the increased dollar hedging demand from this group of clients; at the same time, dealers, who are the the other counterparty in the transactions, and central banks take the other side of the trade, which is a behavior consistent in principle with CIP arbitrage.[19] Average order flows from non-dealer banks are also slightly positive, while those from hedge fund are close to zero.

We then regress the change in the weekly dollar basis on the order flow, the leverage (or capital ratio), and their interaction terms, while controlling for currency and dealer fixed effects. We report the estimates in Table 9. In the first specification, we find a positive and statistically significant coefficient estimate for order flow which calls for the following interpretation. The basis widens in response to an increase in the hedging demand (i.e., order flow moves south), consistent with the work of Borio, Iqbal, McCauley, McGuire, and Sushko (2018). In the second specification, we add the leverage ratio and its interaction term with the order flow and find that the coefficient on the interaction term, turns out to be positive and statistically significant. Conversely, the capital ratio seems to play no role in this setting, in line with our previous findings. In conclusion, we find that hedging demand is associated with the widening of the basis especially when dealer banks face deleveraging pressure associated with balance costs.

6 Cross-Currency Basis and Balance Sheet Costs

Most of our analysis revolves around short-term dollar basis with a maturity ranging between one week and three months. In this section, we examine the basis based on cross-currency swaps whose maturity typically spans between 1 and 30 years. A cross-currency swap is a derivative between two parties to exchange streams of interest payments in different currencies over an agreed period of time as well as principal amounts in different currencies at maturity using a pre-agreed exchange rate. Floating-for-floating currency swaps (interest rate on both legs are floating) are commonly

[19] There is anecdotal evidence that some central banks have exploited CIP deviations for "return enhancement" on their FX reserves; see, for example, Debelle (2017).

used for major currency pairs and the parties involved are generally large international banks, either acting on their own or as agents for non-financial corporations.

Our confidential dataset also includes contract-level cross-currency swaps. We observe $123,000$ transactions corresponding to an average daily volume of 24 USD billions.[20] The basis of a cross-currency swap is generally quoted on the foreign currency leg against the US dollar: "paying" the basis means borrowing the foreign currency versus lending USD while "receiving" the basis implies lending the foreign currency versus borrowing in USD. Consider, for instance, a 1-year USD/JPY cross-currency swap with a basis of -50 *bps* per annum. Here, the borrower of dollars will pay USD LIBOR and receive JPY LIBOR minus 50 *bps* per annum every three months for one year. A negative basis denotes a strong demand for US dollars as one party is willing to receive a lower interest rates on its foreign currency position. More in general, a non-zero basis goes hand-in-hand with potential deviations from the CIP condition at the long end of the yield curve as one party can take advantage from the swap beyond any exchange risk involved.

Table 10 about here

Table 10 reports summary statistics of daily 1-year, 5-year, and 10-year cross-currency basis in *bps* per annum using both quotes from Bloomberg as in Du, Tepper, and Verdelhan (2018) and transaction-level data averaged intra-day. The spreads are largely comparable across datasets: the cross-currency average based on Bloomberg data ranges between -21 and -24 *bps* per annum respectively for the one-year and ten-year cross-currency basis, whereas the cross-currency average based on transaction-level data goes from -23 and -26 *bps* per annum, respectively, for the 1-year and 10-year cross-currency basis.

We run fixed-effects panel regressions subsumed by the following specification:

$$A^{xccy}_{ij\kappa\ell,t} = \beta_1 L_{j,t-1} + \beta_2 C_{j,t-1} + \beta_3 R_{j,t-1} + \gamma' X_{j,t-1} + FE + \varepsilon_{ij\kappa\ell,t} \tag{10}$$

where $A^{xccy}_{ij\kappa\ell,t}$ denotes the absolute value of all transaction-level cross-currency basis recorded on day t for currency i, dealer j, counterparty κ, and maturity ℓ, and $R_{j,t-1}$ is the capital requirement for dealer j. We complement our specifications with both time-invariant and time-variant fixed effects (FE). The former include currency (α_i), dealer (α_j), maturity (α_ℓ) and hour (α_h) fixed effects. The latter comprises sector-time ($\alpha_{s,t}$) or currency-sector-time ($\alpha_{i,s,t}$) fixed effects obtained

[20] This market is highly concentrated as 82% of transactions are among dealers, 16% between dealers and clients, and less than 2% among clients. Nearly 17% of the transactions have a maturity less than a year, 16% between one year and three years, 14% between three years and five years, 24% between five years and ten years, and 29% longer than ten years. See Figure A.2 in the Internet Appendix for more details.

by interacting currency and/or sector fixed effects with a daily (calendar date) fixed effect.

Table 11 about here

We report our estimates in Table 11 and find a positive and statistically significant coefficient estimate for the capital ratio. This implies that an increase in the capital ratio is followed by an increase in the basis, i.e., a widening of the dollar basis. The significance of the coefficient on the leverage ratio disappears when we control for the capital ratio in the same regression. This result seems consistent with the fact that these cross-currency basis swaps carry higher risk weight which in turn affect the calculation of the capital ratio (e.g., Du, Tepper, and Verdelhan, 2018). To corroborate this hypothesis and argue for causality we then focus on a regression on a variable that is reasonably exogenous with respect to the cross-currency basis, that is a specific form of UK capital requirement set by the regulator at the dealer level. More specifically, UK capital requirements are split into 'Pillar 1' requirements that are common across banks, which are meant to capture credit and market risks; and bank-specific 'Pillar 2' requirements, which are set at the discretion of the regulator to capture risks that are not related to Pillar 1. On the basis of this argument and further empirical analysis, Forbes, Reinhardt, and Wieladek (2017) conclude that Pillar 2 requirements should reflect mostly non-balance-sheet risks and therefore should be exogenous with respect to bank balance-sheet variables.[21] We therefore analyze the impact of Pillar 2 requirements on the basis. The last two columns of Table 11 confirm the positive and statistically significant impact of capital ratio requirements on the basis.

7 Conclusions

The foreign exchange market – the largest financial market by daily turnover – has experienced large and persistent arbitrage deviations since 2014. These deviations arise from the failure of the covered interest rate parity condition, a simple no-arbitrage condition that simultaneously ties together the spot/forward exchange rate markets with the domestic/foreign money markets. While there is some evidence that attributes the existence of a negative dollar basis to dealers' balance sheet costs and hedging demand pressure, the direct relationship between the leverage ratio and the dollar basis at the dealer level has not been tested (e.g., Du, Tepper, and Verdelhan, 2018; Borio, Iqbal, McCauley, McGuire, and Sushko, 2018; Rime, Schrimpf, and Syrstad, 2017). This paper attempts to fill this important gap in the literature and directly examines the causal relationship between the leverage

[21] See also Aiyar, Calomiris, Hooley, Korniyenko, and Wieladek (2014); and Aiyar, Calomiris, and Wieladek (2014).

ratio requirement and the dollar basis. Using a novel dataset on transaction-level data on FX derivatives whose richness in terms of counterparty information is attractive from an identification perspective, we find that the additional funding cost faced by international investors to borrow dollars through the foreign exchange market is directly linked to the leverage ratio rule of dealer banks, and can be thought of as an unintended consequence of the post-crisis financial regulation. Moreover, we quantify the impact of the leverage ratio rule on the dollar basis. Overall, our findings help shed light on the potential costs of the leverage ratio framework while leaving any assessment of the net welfare effect of the leverage ratio rule for future research. In addition, further research could also try to answer the open question on whether market participants will adapt to the new regulation.

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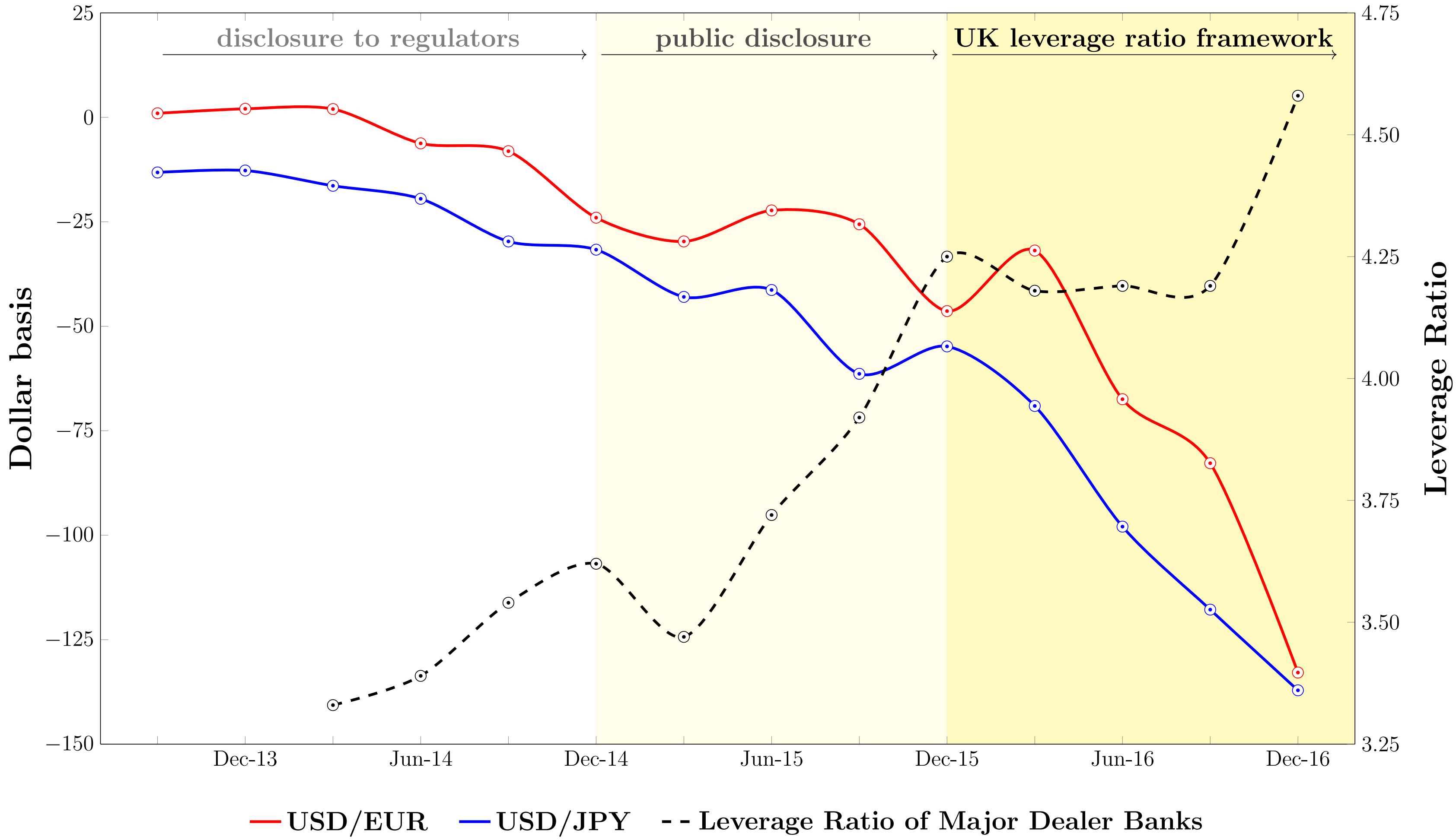

Figure 1: Dollar Basis and Leverage Ratio

This figure displays the dollar basis for the most liquid currency pairs (euro and yen against the dollar), and the average leverage ratio of major dealer banks in London, the global hub for FX trading. The basis is computed as the difference between the one-month US dollar interest rate and its synthetic replication through the FX swap market at the end of each quarter (daily average of the last five business days) using spot, forward and Libor rates from Bloomberg. The leverage ratio is measured quarterly as high-quality capital over total asset exposure and is provided by from the Bank of England. The basis is expressed in basis points per annum whereas the leverage ratio is in percentage points. The public disclosure of the leverage ratio started in January 2015. Prior to this date, banks were only expected to disclose the leverage ratio to regulators. A mandatory minimum requirement for major UK banks was introduced in January 2016, two years ahead of the Basel Committee's proposal.

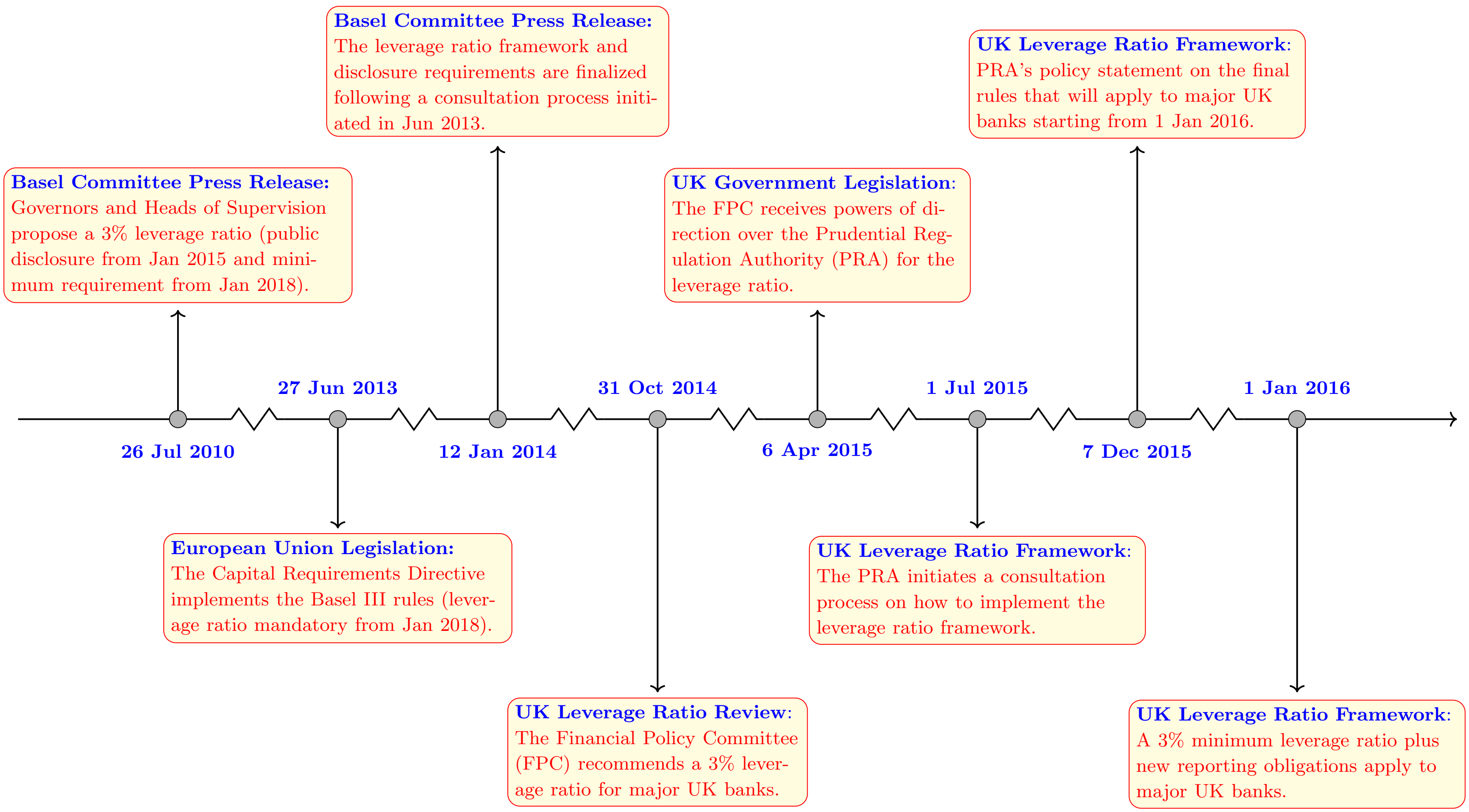

Figure 2: The Timeline of the Leverage Ratio Requirement

This figure summarizes the key dates of the introduction of the leverage ratio requirement, with a special focus on the UK leverage ratio framework.

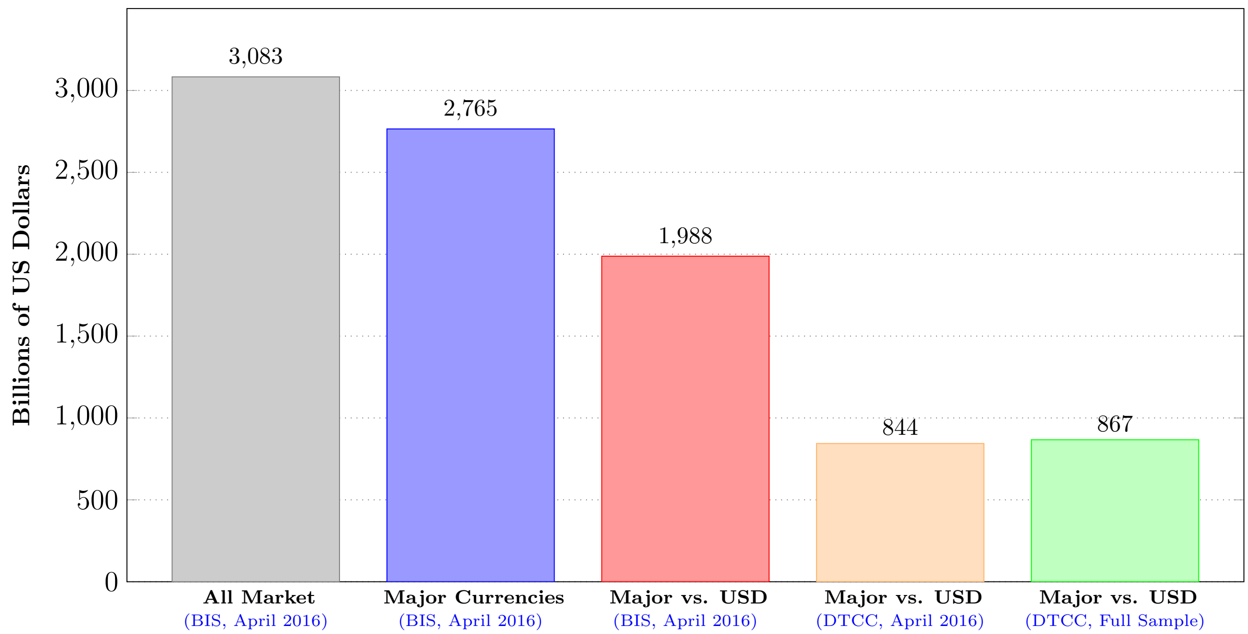

Figure 3: Daily Volume on Forward Contracts

This figure displays average daily volume on forward contracts based on the 2016 Triennial Central Bank Survey (BIS, 2016) and transaction-level data from the Depository Trust & Clearing Corporation (DTCC). The latter includes over-the-counter foreign exchange forward contracts (outright forwards and forward legs of FX swaps) undertaken by UK legal entities under the European Market Infrastructure Regulation (EMIR). The sample comprises major currencies – Australian dollar (AUD), Canadian dollar (CAD), Swiss franc (CHF), euro (EUR), British pound (GBP), Japanese yen (JPY) – relative to the US dollar (USD), and runs between December 2014 and December 2016.

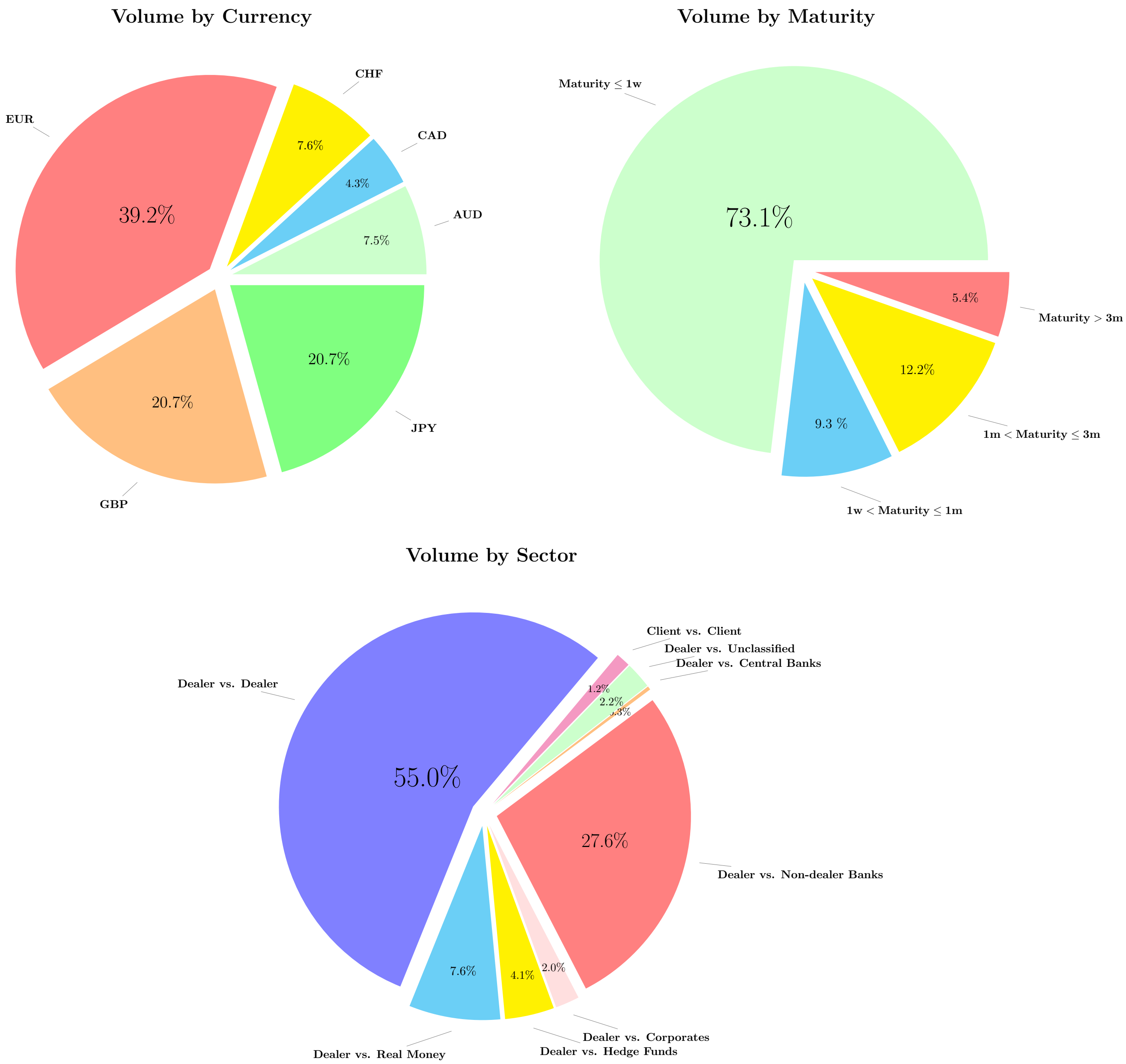

Figure 4: Breakdown of the FX Forward Volume

This figure displays currency, maturity and sector breakdown of daily volume on FX forwards. Volume is constructed using contract-level data from the Depository Trust & Clearing Corporation (DTCC) on OTC outright forwards and forward legs of FX swaps undertaken by UK legal entities under the European Market Infrastructure Regulation (EMIR) on derivatives. The sample runs between December 2014 and December 2016.

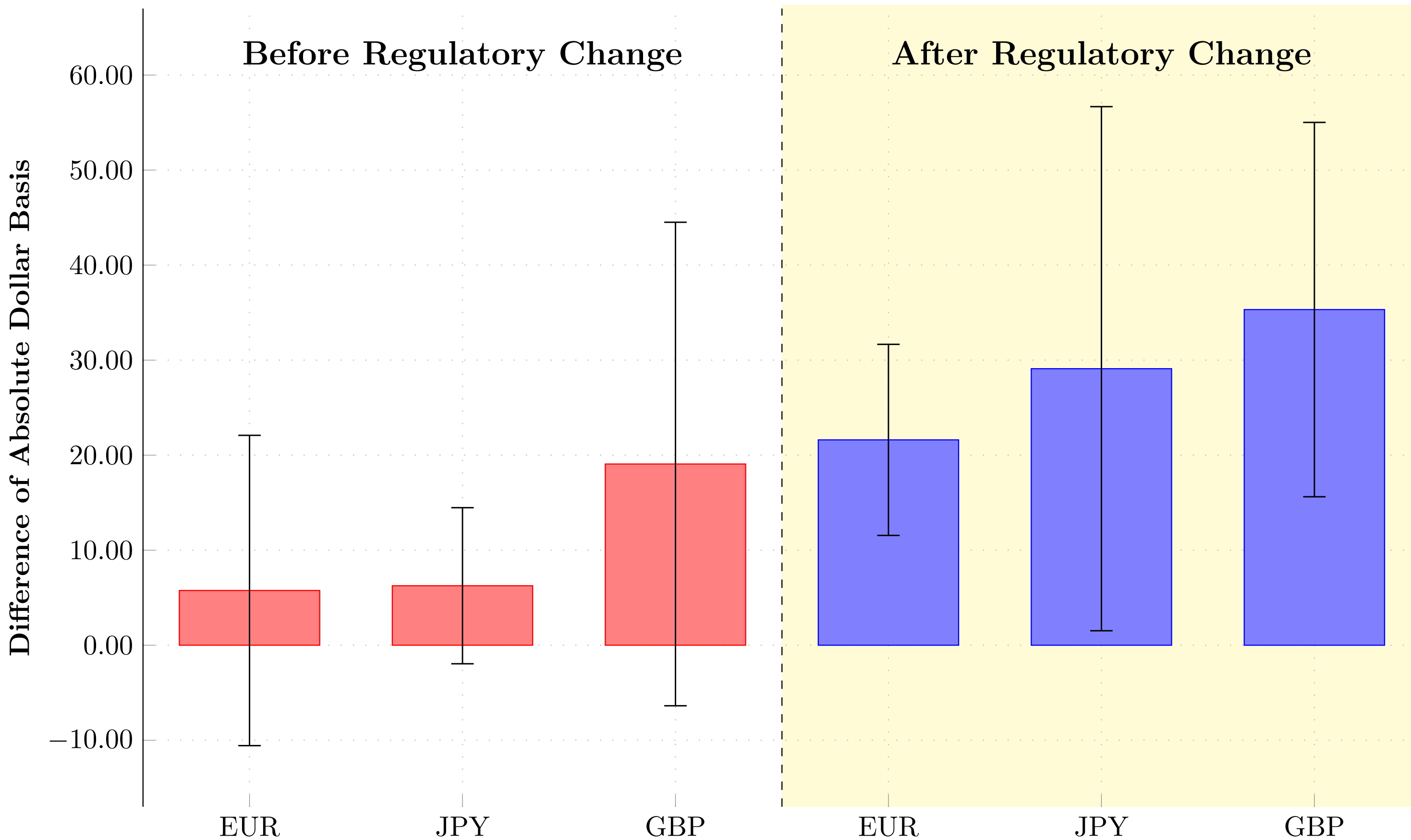

Figure 5: Regulatory Change and Dollar Basis

This figure displays the difference in absolute CIP deviations (in *bps* per annum) between treated and untreated dealers before and after the introduction of the UK leverage ratio framework. Each bar also displays the 95% confidence interval. The treated group includes four UK banks whereas the control group comprises the subsidiaries of seven foreign banks operating in London. The pre-regulatory change period runs from 2 November 2015 to 18 December 2015 whereas the post-regulatory change period runs from 11 January 2016 to 26 February 2016. We exclude the year-end period running from 22 December 2015 to 8 January 2016. CIP deviations are measured using transaction-level FX forwards between 1-week and 1-month from Depository Trust & Clearing Corporation (DTCC) synchronized at second level with OIS and spot exchange rates from Reuters Tick History.

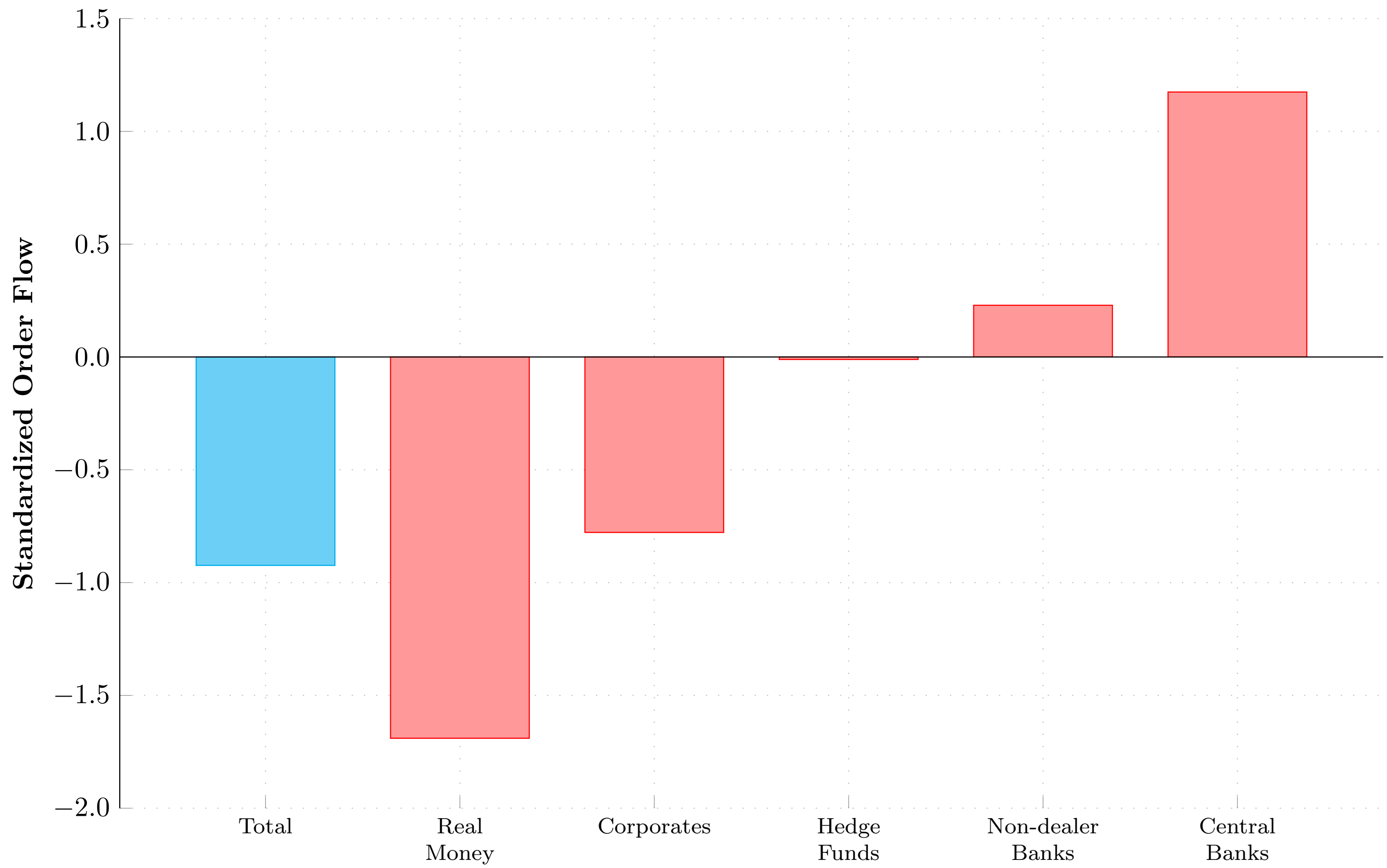

Figure 6: Order Flows in the Forward Market

This figure displays the net order flow between (initiating) clients and dealers in the forward market. The net order flow is the value of buyer-initiated orders minus the value of seller-initiated orders of US dollars against foreign currencies such that a negative (positive) order flow indicates net selling (buying) pressure on the US dollar in the forward market by end-user clients. The order flows are constructed using transaction-level data and buying/selling indicators from Depository Trust & Clearing Corporation (DTCC) on FX forwards (outright forwards and forwards leg of FX swaps) undertaken by UK legal entities under the European Market Infrastructure Regulation (EMIR) on derivatives. For each bucket, we standardize the mean order flow by its sample standard deviation for ease of comparison. The sample runs at weekly frequency from December 2015 to December 2016.

Table 1: Descriptive Statistics: Contract-Level Dollar Basis

This table presents means and standard deviations (in parentheses) of the daily dollar basis against major currencies. The basis is expressed in basis points per annum and is computed using (a) daily LIBOR rates and London closing spot/forward exchange rates from Bloomberg, (b) daily OIS rates (sampled at 11.00 am London time) from Reuters Tick History and London closing spot/forward exchange rates from Bloomberg, and (c) contract-level forwards (outright forwards and forward legs of FX swaps) between major dealer banks and clients from the Depository Trust & Clearing Corporation (DTCC) synchronized with second-level mid-quotes on OIS and spot exchange rates from Reuters Tick History (averaged intra-day for ease of comparison). DTCC data consist of OTC transactions undertaken by UK legal entities under the European Market Infrastructure Regulation (EMIR). The sample runs between December 2014 and December 2016.

	(a) LIBOR		(b) OIS		(c) Contract-level	
Panel A: 1-week Dollar Basis						
EUR	−32.75	(38.72)	−39.23	(48.11)	−35.27	(75.00)
GBP	−21.77	(28.95)	−21.82	(36.99)	−18.27	(99.62)
JPY	−49.86	(57.61)	−54.80	(66.47)	−49.57	(96.93)
Panel B: 1-month Dollar Basis						
AUD	10.61	(15.77)	12.97	(16.14)	−7.00	(53.90)
CAD	−41.76	(13.99)	−15.48	(12.23)	−10.37	(54.97)
CHF	−51.87	(39.02)	−85.30	(41.46)	−63.08	(53.64)
EUR	−40.49	(28.74)	−46.92	(33.42)	−33.06	(38.05)
GBP	−23.17	(22.94)	−24.19	(24.32)	−13.90	(43.04)
JPY	−58.33	(39.14)	−65.73	(41.05)	−47.51	(48.33)
Panel C: 3-month Dollar Basis						
AUD	5.89	(6.53)	10.69	(18.04)	3.07	(48.19)
CAD	−27.19	(6.24)	−13.13	(9.26)	−13.00	(48.68)
CHF	−40.91	(18.68)	−80.64	(24.99)	−72.86	(42.59)
EUR	−29.74	(12.98)	−43.23	(23.36)	−37.02	(28.29)
GBP	−13.07	(11.59)	−20.36	(16.54)	−13.64	(26.45)
JPY	−46.94	(17.50)	−64.60	(25.58)	−60.69	(37.87)

Table 2: Dollar Basis and Balance Sheet Costs: Contract-level Data

This table presents estimates from fixed effects panel regressions. The dependent variable is the absolute contract-level dollar basis described in Table 1. The set of independent variables is described in Table A.1 in the Internet Appendix. We include dealer, maturity, hour, currency, sector interacted with time (calendar date), and sector interacted with both currency and time fixed effects. Standard errors are clustered by currency and time dimension, and reported in parentheses. The superscripts *, **, and *** indicate statistical significance at 10%, 5%, and 1% respectively. The sample runs between December 2014 and December 2016. Data are from the Depository Trust & Clearing Corporation (DTCC), the Bank of England, and Bloomberg.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Leverage Ratio	19.110***	20.457***	20.193***				17.445***	19.391***	18.949***
	(3.885)	(3.480)	(3.176)				(4.306)	(3.415)	(3.145)
Capital Ratio				3.797**	3.374**	3.487***	1.334	0.860	1.030
				(1.489)	(1.535)	(1.229)	(1.711)	(1.562)	(1.234)
Bank Size		38.126**	39.660*		18.062	20.680		37.938**	39.055*
		(15.577)	(21.455)		(19.349)	(23.617)		(14.956)	(20.558)
Liquid Asset Share		−1.123***	−1.377***		−1.347***	−1.585***		−1.099***	−1.352***
		(0.359)	(0.322)		(0.380)	(0.368)		(0.353)	(0.324)
Deposit Share		0.281	0.334**		0.178	0.229		0.282	0.336**
		(0.185)	(0.150)		(0.182)	(0.152)		(0.186)	(0.152)
Δ *Bank CDS*		−0.178	−0.053		−0.216	−0.089		−0.181	−0.056
		(0.216)	(0.167)		(0.218)	(0.168)		(0.213)	(0.165)
Δ *Bank IVOL*		−0.223	−0.209		−0.284	−0.264		−0.224	−0.209
		(0.179)	(0.150)		(0.182)	(0.157)		(0.179)	(0.151)
R^2	0.136	0.137	0.183	0.135	0.136	0.182	0.136	0.137	0.183
Obs	3,474,102	3,474,102	3,473,604	3,474,102	3,474,102	3,473,604	3,474,102	3,474,102	3,473,604
Dealer/Maturity/Hour	Y	Y	Y	Y	Y	Y	Y	Y	Y
Currency	Y	Y	N	Y	Y	N	Y	Y	N
Sector×Time	Y	Y	N	Y	Y	N	Y	Y	N
Currency×Sector×Time	N	N	Y	N	N	Y	N	N	Y

Table 3: Dollar Basis and Balance Sheet Costs: Client Characteristics

This table presents estimates from fixed effects panel regressions. The dependent variable is the absolute volume-weighted dollar basis measured weekly using the contract-level dollar basis described in Table 1. The set of independent variables is described in Table A.1 in the Internet Appendix. We include dealer, currency, client interacted with time (calendar date), and client interacted with both currency and time fixed effects. Standard errors are clustered by currency and time dimension, and reported in parentheses. The superscripts *, **, and *** indicate statistical significance at 10%, 5%, and 1% respectively. The sample runs between December 2014 and December 2016. Data are from the Depository Trust & Clearing Corporation (DTCC), the Bank of England, and Bloomberg.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Leverage Ratio	15.992***	16.198***	16.911***				12.177***	12.698***	12.713***
	(4.362)	(4.329)	(3.985)				(3.811)	(3.647)	(3.330)
Capital Ratio				5.269***	4.941***	5.655***	3.733***	3.410***	4.135***
				(1.473)	(1.499)	(1.535)	(1.276)	(1.256)	(1.355)
Bank Size		17.208*	21.123**		6.369	11.111		16.616*	20.386**
		(9.446)	(8.944)		(10.036)	(9.598)		(8.632)	(7.899)
Liquid Asset Share		−1.105***	−0.909***		−1.222***	−0.991***		−1.051**	−0.845*
		(0.390)	(0.331)		(0.432)	(0.365)		(0.391)	(0.330)
Deposit Share		0.234	0.377		0.106	0.253		0.216	0.356
		(0.167)	(0.234)		(0.170)	(0.245)		(0.165)	(0.235)
Δ *Bank CDS*		−0.052	0.006		−0.095	−0.040		−0.071	−0.018
		(0.183)	(0.148)		(0.184)	(0.145)		(0.178)	(0.154)
Δ *Bank IVOL*		−0.040	−0.341		−0.071	−0.355		−0.018	−0.311
		(0.322)	(0.352)		(0.322)	(0.354)		(0.321)	(0.351)
R^2	0.566	0.566	0.603	0.566	0.566	0.603	0.566	0.566	0.603
Obs	749,895	749,895	344,473	749,895	749,895	344,473	749,895	749,895	344,473
Dealer	Y	Y	Y	Y	Y	Y	Y	Y	Y
Currency	Y	Y	N	Y	Y	N	Y	Y	N
Client×Time	Y	Y	N	Y	Y	N	Y	Y	N
Currency×Client×Time	N	N	Y	N	N	Y	N	N	Y

Table 4: Volume and Balance Sheet Costs: Client Characteristics

This table presents estimates from fixed effects panel regressions. The dependent variable is the percentage log volume of forward contracts between dealer banks and clients measured weekly. The set of independent variables is summarized in Table A.1 in the Internet Appendix. We include dealer, currency, client interacted with time (calendar date), and client interacted with both currency and time fixed effects. Standard errors are clustered by currency and time dimension, and reported in parentheses. The superscripts *, **, and *** indicate statistical significance at 10%, 5%, and 1% respectively. The sample runs between December 2014 and December 2016.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Leverage Ratio	−11.300***	−11.842***	−13.716***				−10.777***	−11.309***	−12.942***
	(1.706)	(1.459)	(1.419)				(1.391)	(1.147)	(0.499)
Capital Ratio				−1.871*	−1.883*	−2.310**	−0.512	−0.520	−0.762
				(1.055)	(1.008)	(0.917)	(1.044)	(1.023)	(0.955)
Bank Size		3.083	2.878		12.299	12.457		3.173	3.014
		(10.520)	(8.381)		(11.224)	(9.757)		(10.608)	(8.420)
Liquid Asset Share		−0.195	−0.204*		−0.051	−0.068		−0.203	−0.216*
		(0.156)	(0.121)		(0.178)	(0.115)		(0.151)	(0.123)
Deposit Share		−0.298***	−0.290*		−0.198	−0.181		−0.296**	−0.286*
		(0.102)	(0.168)		(0.120)	(0.220)		(0.146)	(0.167)
Δ *Bank CDS*		−0.062	−0.002		−0.038	0.026		−0.059	0.003
		(0.217)	(0.167)		(0.201)	(0.150)		(0.208)	(0.159)
Δ *Bank IVOL*		−0.159	−0.428***		−0.115	−0.389**		−0.162	−0.434***
		(0.199)	(0.153)		(0.213)	(0.165)		(0.222)	(0.158)
R^2	0.700	0.700	0.760	0.700	0.700	0.760	0.700	0.700	0.760
Obs	749,895	749,895	344,473	749,895	749,895	344,473	749,895	749,895	344,473
Dealer	Y	Y	Y	Y	Y	Y	Y	Y	Y
Currency	Y	Y	N	Y	Y	N	Y	Y	N
Client×Time	Y	Y	N	Y	Y	N	Y	Y	N
Currency×Client×Time	N	N	Y	N	N	Y	N	N	Y

Table 5: Difference-in-Differences: UK Leverage Ratio Framework

This table presents difference-in-differences estimates associated with the introduction of the UK leverage ratio framework on January 1, 2016. The dependent variable is the volume-weighted absolute dollar basis measured weekly. The sample only includes dealer-to-clients transactions. The *treatment group* includes major UK dealer banks whereas the *control group* comprises the subsidiaries of foreign dealer banks. The *pre-treatment* (*post-treatment*) period covers two months prior (post) to January 1, 2016. We exclude two weeks of data bracketing the year-end. The table also presents difference-in-differences estimates associated with a placebo date (April 1, 2016) using a two-month period prior (post) to this date as a *pre-treatment* (*post-treatment*) sample. We include dealer, currency, client interacted with time (calendar date), and client interacted with both currency and time fixed effects. Standard errors are clustered by currency dimension, and reported in parentheses. The superscripts *, **, and *** indicate statistical significance at 10%, 5%, and 1% respectively.

	(1)	(2)	(3)	(4)
Panel A: Absolute Dollar Basis				
Affected Dealers × Post Regulatory Date	24.115***	23.787**		
	(6.207)	(9.084)		
Affected Dealers × Post Placebo Date			−28.010*	−19.957
			(14.924)	(14.305)
R^2	0.658	0.634	0.661	0.656
Obs	42,825	22,096	42,680	21,226
Panel B: Percentage Log Volume				
Affected Dealers × Post Regulatory Date	5.170	−1.055		
	(10.661)	(8.572)		
Affected Dealers × Post Placebo Date			2.920	0.992
			(2.921)	(1.752)
R^2	0.738	0.767	0.731	0.773
Obs	42,825	22,096	42,680	21,226
Dealer	Y	Y	Y	Y
Currency	Y	N	Y	N
Client×Time	Y	N	Y	N
Currency×Client×Time	N	Y	N	Y

Table 6: Difference-in-Differences: Public Disclosure

This table presents difference-in-differences estimates associated with the public disclosure of the leverage ratio on January 1, 2015. The dependent variable is the absolute volume-weighted dollar basis measured weekly. The sample only includes dealer-to-clients transactions. The *treatment group* includes dealer banks with a low (simple) leverage ratio as of December 2007 whereas the *control group* comprises dealer banks with a high (simple) leverage ratio as of December 2007. These groups are formed using the median value of a (simple) leverage ratio constructed as shareholder claims to total assets. The *pre-treatment* (*post-treatment*) period covers a month prior (post) to January 1, 2015. We exclude two weeks of data bracketing the year-end. The table also presents difference-in-differences estimates associated with a placebo date (February 1, 2016) using a month period prior (post) to this date as a *pre-treatment* (*post-treatment*) sample. We include dealer, currency, client interacted with time (calendar date), and client interacted with both currency and time fixed effects. Standard errors are clustered by currency dimension, and reported in parentheses. The superscripts *, **, and *** indicate statistical significance at 10%, 5%, and 1% respectively.

	(1)	(2)	(3)	(4)
Panel A: Absolute Dollar Basis				
Affected Dealers × Post Regulatory Date	35.842*	54.591***		
	(18.995)	(13.306)		
Affected Dealers × Post Placebo Date			7.620	−10.545
			(25.318)	(21.446)
R^2	0.654	0.695	0.656	0.691
Obs	13,424	5,506	14,806	6,151
Panel B: Percentage Log Volume				
Affected Dealers × Post Regulatory Date	−26.972*	−31.009***		
	(16.222)	(8.194)		
Affected Dealers × Post Placebo Date			−6.488	6.292
			(9.819)	(15.906)
R^2	0.753	0.784	0.754	0.779
Obs	13,424	5,506	14,806	6,151
Dealer	Y	Y	Y	Y
Currency	Y	N	Y	N
Client×Time	Y	N	Y	N
Currency×Client×Time	N	Y	N	Y

Table 7: Dollar Basis and Monetary Policy Shocks

This table presents estimates from fixed-effects panel regressions. The dependent variable is the change in the dollar-euro basis measured around the interest rate announcements of the European Central Bank. The event window starts (ends) at 13:30 (15:30) Central European Time (CET) and the basis at 13:30 (15:30) is constructed as the volume-weighted average of all contract-level dollar-euro basis between 11:30 and 13:30 (15:30 and 17:30) CET for each dealer and sector. MPS is the change in the two-year German zero-yield minus the corresponding US zero-yield between 13:30 and 15:30 CET from Thomson Reuters Tick History, and is common across all dealers. Data are from the Depository Trust & Clearing Corporation (DTCC), Bank of England, and Bloomberg. The regressions include dealer fixed effects. Standard errors, clustered by dealer and time dimension, are reported in parentheses. The superscripts *, **, and *** indicate statistical significance at 10%, 5%, and 1%, respectively. The sample comprises 17 policy announcements between December 2014 and December 2016.

	(1)	(2)	(3)
MPS	32.951***	7.022	−18.633
	(7.965)	(7.489)	(46.886)
Leverage Ratio		0.000	
		(0.001)	
Capital Ratio			0.001
			(0.001)
Leverage Ratio × *MPS*		6.631*	
		(3.821)	
Capital Ratio × *MPS*			4.566
			(4.578)
R^2	0.106	0.117	0.118
Obs	146	146	146

Table 8: Dollar Basis and the US Money Market Fund Reform

This table presents estimates from fixed effects panel regressions. The dependent variable is the absolute contract-level dollar basis described in Table 1. MMF denotes a dummy variable equal to one from the implementation of the US money market fund reform on October 14, 2016. We include hour, maturity, currency, dealer and sector fixed effects. Standard errors are clustered by currency and time dimension, and reported in parentheses. The superscripts *, **, and *** indicate statistical significance at 10%, 5%, and 1% respectively. The sample comprises ±3 days around the 14 October 2016. Data are from the Depository Trust & Clearing Corporation (DTCC), Bank of England, and Bloomberg.

	(1)	(2)	(3)
MMF	4.131**	−4.731	−17.451
	(1.666)	(4.577)	(15.652)
Leverage Ratio		−1.425	
		(1.431)	
Capital Ratio			−1.218
			(1.679)
Leverage Ratio × MMF		2.255**	
		(0.861)	
Capital Ratio × MMF			1.804
			(1.294)
R^2	0.151	0.141	0.141
obs	37,537	37,537	37,537

Table 9: Dollar Basis and Order Flows

This table presents estimates from fixed-effects panel regression. The dependent variable is the change in the dollar basis measured weekly. The set of independent variables includes the order flow of forward contracts, leverage ratio, and capital ratio. Order flow is the value of buyer-initiated orders minus the value of seller-initiated orders of US dollars against foreign currencies, and a positive (negative) order flow indicates net buying (selling) pressure of US dollars in the forward market by end-user clients. Order flows are constructed using data are from the Depository Trust & Clearing Corporation (DTCC), Bank of England, and Bloomberg. The regressions include currency, maturity, and time fixed effects. Standard errors, clustered by currency and time dimension, are reported in parentheses. The superscripts *, **, and *** indicate statistical significance at 10%, 5%, and 1% respectively. The sample runs at weekly frequency between December 2015 and December 2016.

	(1)	(2)	(3)
Order Flow	0.061***	−0.287	0.012
	(0.005)	(0.168)	(0.325)
Leverage Ratio		0.005	
		(0.024)	
Capital Ratio			0.002
			(0.008)
Leverage Ratio × Order Flow		0.084**	
		(0.041)	
Capital Ratio × Order Flow			0.004
			(0.025)
R^2	0.010	0.010	0.010
Obs	1,338	1,338	1,338

Table 10: Descriptive Statistics: Contract-Level Cross-Currency Basis

This table presents average cross-currency basis with standard deviations in parentheses for major currencies relative to the US dollar. The basis is measured in basis points per annum using (a) daily data from Bloomberg as in Du, Tepper, and Verdelhan (2018), and (b) contract-level cross-currency basis swaps between dealer banks and clients from the Depository Trust & Clearing Corporation (DTCC), and then averaged intra-day for ease of comparison. DTCC data consists of OTC transactions undertaken by UK legal entities under the European Market Infrastructure Regulation (EMIR) on derivatives. The sample runs between December 2014 and December 2016.

	Bloomberg Quotes		Contract-Level	
Panel A: 1-year Cross-Currency Basis				
AUD	17.97	(10.15)	18.47	(12.00)
CAD	−12.52	(10.22)	−12.25	(11.52)
CHF	−35.39	(10.63)	−34.54	(14.58)
EUR	−31.92	(9.89)	−35.54	(26.66)
GBP	−9.45	(7.03)	−11.39	(13.55)
JPY	−55.41	(15.97)	−53.54	(22.85)
Panel B: 5-year Cross-Currency Basis				
AUD	23.96	(7.25)	25.57	(13.33)
CAD	1.24	(7.74)	2.00	(8.54)
CHF	−44.28	(13.56)	−42.88	(16.71)
EUR	−36.13	(11.02)	−33.89	(18.57)
GBP	−8.32	(4.76)	−7.84	(8.37)
JPY	−73.74	(18.32)	−71.37	(20.09)
Panel D: 10-year Cross-Currency Basis				
AUD	23.60	(8.14)	23.94	(8.86)
CAD	9.59	(13.08)	6.58	(3.00)
CHF	−53.96	(17.51)	−54.11	(18.50)
EUR	−37.36	(11.32)	−33.79	(15.48)
GBP	−10.32	(3.78)	−8.77	(5.10)
JPY	−74.33	(17.24)	−71.90	(16.65)

Table 11: Dealer Balance Sheets and Cross-Currency Basis Swaps

This table presents estimates from fixed effects panel regressions. The dependent variable is the absolute contract-level cross-currency basis described in Table 10. The sample only includes dealer-to-clients transactions. The set of independent variables is summarized in Table A.1 in the Internet Appendix. We include dealer, maturity, hour, currency, sector interacted with time (date), and sector interacted with both currency and time (date) fixed effects. Standard errors are clustered by currency and time dimension, and reported in parentheses. The superscripts *, **, and *** indicate statistical significance at 10%, 5%, and 1% respectively. The sample runs between December 2014 and December 2016.

	(1)	(2)	(3)	(4)	(5)
Leverage Ratio	4.695***		0.430		0.048
	(0.657)		(2.101)		(1.819)
Capital Ratio		3.657***	3.578***		
		(1.259)	(1.625)		
Capital Requirement				5.794***	5.788***
				(1.955)	(2.161)
Controls	Y	Y	Y	Y	Y
Obs	7,802	7,802	7,802	7,802	7,802
Dealer/Maturity/Hour	Y	Y	Y	Y	Y
Currency×Sector×Time	Y	Y	Y	Y	Y