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The Pricing of FX Forward Contracts: Micro Evidence from Banks' Dollar Hedging

Puriya Abbassi and Falk Bräuning

Abstract:

We use *transaction-level* data on foreign exchange (FX) forward contracts for the period 2014 through 2016 in conjunction with supervisory balance sheet information to study the drivers of banks' dollar hedging costs. Comparing contracts of the same maturity that are initiated during the same hour of the same day, we find large heterogeneity in banks' hedging costs. We show that these costs (i) are higher for banks with a larger FX funding gap, (ii) depend on banks' FX funding composition in terms of the source (interbank versus retail) and rollover structure (long-term versus short-term), (iii) are lower for banks with deeper internal dollar capital markets, and (iv) increase with banks' shadow cost of capital. Our results are important for understanding how shocks are transmitted internationally through the FX hedging market.

JEL Classifications: D40, E43, F30, F31, G15

Keywords: FX markets, foreign exchange, dollar hedging, price determination, global banks, international financial shocks

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I. INTRODUCTION

A striking fact in international finance is that a large share of dollar-denominated intermediation is performed by non-U.S. (global) banks. However, the main funding source of global banks is typically denominated in local (non-dollar) currencies, thereby creating a large dollar funding gap.¹ As a result, global banks rely heavily on synthetic dollar funding; that is, they typically borrow funds in local currency, convert them into dollars, and hedge the resulting foreign exchange (FX) risk with a forward dollar sale. As with direct funding, the cost of synthetic borrowing using the FX derivative market crucially affects banks' portfolio allocation and has important implications for the international transmission of shocks to the wider economy with potential real effects (Ivashina, Scharfstein, and Stein 2015). Yet, empirical evidence on the determinants of banks' hedging costs is scarce, most likely due to the lack of micro data on FX forward contracts traded over the counter, which are crucial for identification.

In this paper, we aim to fill this gap by using novel *contract-level data* on German banks' USD/EUR forwards to study the cost of banks' dollar hedging. In accordance with, for example, Brunnermeier, Nagel, and Pedersen (2008), we argue that funding-related factors are key drivers in currency markets, in particular, in the forward market that is crucial for banks' FX liquidity management. Specifically, we study how dollar hedging costs depend on banks' (i) dollar funding gap, (ii) dollar funding composition, (iii) access to internal capital markets, and (iv) capital. To identify these economic channels, our empirical strategy combines the micro data on forwards with detailed bank-level information from monthly supervisory balance sheet statements.

First, we start with the conjecture that banks with a larger dollar funding gap have a higher demand for hedging their implied FX risk, which will drive up their hedging cost (prices), all else being equal. For identification, we exploit the fact that the regulator imposes capital charges on unhedged FX positions at predetermined quarter-end days, hence generating additional hedging demand. Focusing on contracts initiated just before these key dates, we find that banks with a 1-percentage-point larger ex-ante dollar funding gap pay on average a 38-basis-points higher forward premia, comparing contracts of the same maturity, initiated at the same hour of the same day and with the same counterparty. We do not observe this effect outside quarter-ends. Moreover, for

¹ For example, according to data from the Bank for International Settlements (BIS), European and Japanese banks had a dollar funding gap of \$1.3 trillion at the end of 2016.

quarter-end contracts, we find additional heterogeneity depending on the maturity of the contract and bank capital. Prices for short-term forwards that mature just after quarter-ends are in general higher, but in particular for banks with a high ex-ante dollar funding gap and a low equity ratio (higher leverage). We can rule out that this effect is driven by time-varying supply effects in dollar cash markets, such as counterparties' balance-sheet constraints around quarter-end days (Borio, McCauley, McGuire, et al. 2016; Du, Tepper, and Verdelhan 2017).

Second, we examine how conditions in direct dollar funding markets affect the dollar forward market. For identification, we study this question in the context of the “Brexit” referendum, the United Kingdom’s surprise vote on June 23, 2016, to leave the European Union.² In fact, the Brexit event, which featured a flight to safety toward dollar-denominated U.S. Treasury securities, triggered a squeeze in short-term (direct) global dollar liquidity markets. For example, short-term repurchase agreement (repo) rates spiked to levels similar to those observed at the height of the 2007–2008 financial crisis. To identify the link between interest rates implicit in currency markets and those in money markets, we focus on a narrow timeframe (plus/minus five trading days) around the exogenous Brexit vote. We find that the observed elevated costs of obtaining dollars in direct funding markets also affect the cost of hedging: In the immediate days after the Brexit vote, the cost of dollar hedging for German banks increased on average by 13 percentage points on an annualized basis, mostly in short-term maturities. This effect varies significantly depending on the composition of a bank’s dollar liabilities. While banks with overall higher ex-ante exposure to dollar funding markets are associated with higher hedging costs, we find that costs are particularly higher for banks with larger ex-ante short-term wholesale dollar funding, that is, those that were most exposed to the Brexit-induced surge in short-term dollar funding costs.

Third, we find that, in addition to being affected by funding conditions in external dollar markets, the pricing of FX forwards depends on banks’ access to internal capital markets through transfers of dollar funding across offices (branches and subsidiaries) within the same banking

² Before the Brexit referendum, the polls pointed toward a “stay” vote; see Nate Cohn, “Why the Surprise Over ‘Brexit’? Don’t Blame the Polls,” *The New York Times*, June 24, 2016. Available at <https://www.nytimes.com/2016/06/25/upshot/why-the-surprise-over-brexit-dont-blame-the-polls.html>. Markets and politicians alike were surprised by this outcome; see “Brexit: Europe Stunned by UK Leave Vote,” *BBC News*, June 24, 2016. Available at <http://www.bbc.com/news/uk-politics-eu-referendum-36616018>. The pound, for instance, plummeted to historically low levels; see Roger Blitz, “Pound Tumbles to 30-year Low as Britain Votes Brexit,” *Financial Times*, June 24, 2016. Available at <https://www.ft.com/content/8d8a100e-38c2-11e6-a780-b48ed7b6126f>. But the decision affected global markets as well. For example, U.S. stocks fell 3.6 percent; see Michael Mackenzie and Eric Platt, “How Global Markets Are Reacting to UK’s Brexit Vote,” *Financial Times*, June 24, 2016. Available at <https://www.ft.com/content/50436fde-39bb-11e6-9a05-82a9b15a8ee7>.

group. For contracts of the same maturity that are initiated during the same hour of the same day, we find that a bank pays a forward premium that is 4 basis points lower if its intra-group funding is 1 percent higher. Moreover, the benefits of deep internal capital markets are more pronounced (i) for banks with a higher dollar funding gap, (ii) for banks with low bargaining power (high counterparty concentration) in the dollar forward market, (iii) before financial reporting dates, and (iv) during the period when U.S. money market mutual funds reduced their dollar investments (and thus funding) in German banks to comply with the 2016 money market fund reform.

Fourth, we study the role that banks' shadow cost of capital plays in the pricing of FX forwards. To do so, we observe whether the hedging institution provides an initial margin at the contract's initiation; that is, whether the contract is collateralized or not. We then compare prices of non-collateralized contracts with those of collateralized contracts that have otherwise similar characteristics (time of origination, length of maturity, value, contracting bank, and counterparty). We find significant price gaps between two forward contracts with identical cash flows but different margins. These price gaps increase with the length of maturity and depend on relative capital positions (equity ratios, but not Tier 1 ratios) in the cross section of banks, thus revealing further bank-level heterogeneity. Our estimates point to an economically large shadow cost of capital, with an average differential effect of as many as 1.3 percentage points for otherwise similar contracts. Furthermore, banks with a 1-percentage-point lower equity ratio pay a forward premium that is 5.1 percentage points higher. We can rule out that our results are driven by counterparty risk or any other time-varying bank and counterparty heterogeneity.

These results contribute to the literature in several ways. First, they make a direct contribution to the growing body of research on the dollar's dominance in international financial markets and the special role of global banks in the dollar intermediation chain (Bruno and Shin 2015; Ivashina, Scharfstein, and Stein 2015; Avdjiev, Du, Koch, et al. 2016; Shin 2016; Aldasoro, Ehlers, Eren 2017; Borio, McCauley, and McGuire 2017; Gopinath and Stein 2018). By providing the first empirical evidence of economically relevant cross-sectional variation in the cost of dollar hedging, we propose a substantial re-examination of the mechanics of how international shocks can propagate across markets via dollar-denominated intermediation by global banks. In this respect, we also add to the international finance literature that investigates how market anomalies can be attributed to exchange rate pressures and evolving market dynamics wrought by spillovers

(Caruana 2012; Rajan 2014; Rey and Miranda-Agrippino 2015; Borio, McCauley, McGuire, et al. 2016).

Our paper also relates to the recent literature that uses aggregate data to study violations of covered-interest parity, especially those involving U.S. dollar trading.³ For example, Du, Tepper, and Verdelhan (2017) provide empirical evidence of a link between these deviations and regulatory reporting dates. We complement these studies by using micro data to identify the underlying economic drivers of FX forwards' prices. Based on aggregate data, previous papers argue that deviations from the parity condition are mostly due to constraints on the supply side of dollar cash markets. However, after controlling for time-varying counterparty-side heterogeneity, we show that price differentials still exist and depend on hedging demand. In this regard, our findings add another dimension to the literature that argues exchange rates and interest rates are under pressure because of carry trade themes (Brunnermeier, Nagel, Pedersen 2008; Menkhoff, Sarno, Schmeling, et al. 2012).

Our evidence advances our understanding of how interest rates implicit in currency markets are linked to those in money markets (Fender and McGuire 2010; Mancini-Griffoli and Ranaldo 2011; Stein 2012; Avdjiev, Du, Koch, et al. 2016; Shin 2016; Rime, Schrimpf, and Syrstad 2017). As we document, strains in direct funding markets affect the costs of synthetic borrowing through forward contracts. However, our results highlight that spillovers of shocks across markets crucially depend on the funding composition of a given bank with respect to both the funding source (wholesale versus retail versus intra-group) and its rollover structure (short-term versus long-term). Moreover, our findings suggest that even when a shock originates in one segment of the funding market, it spreads to global funding markets and broader financial markets in ways that are shaped by banks' FX risk hedging behavior.

We also add to the literature that studies the role of banks' internal capital markets in the international transmission of shocks (Cetorelli and Goldberg 2012; Schnabl 2012; Ivashina,

³ The standard international finance textbook view of covered interest parity postulates that the forward premium (a standard measure of the cost of hedging defined as the percentage difference between the forward and spot FX rates) should be equal to only the interest rate differential (foreign versus local). Other papers that use aggregate data to focus on the violations of covered interest parity include Baba, Packer, and Nagano (2008); Baba, McCauley, and Ramaswamy (2009); Coffey, Hrungrung, and Sarkar (2009); Mancini-Griffoli and Ranaldo (2012); Bottazzi, Luque, Pascoa, and Sundaresan (2013); Ivashina, Scharfstein, and Stein (2015); Borio, McCauley, McGuire, et al. (2016); and Bräuning and Puria (2017).

Scharfstein, and Stein 2015; Bräuning and Ivashina 2017). Cetorelli and Goldberg (2012) is the study most closely related to our paper in that it also shows direct evidence of cross-border internal capital markets. While the authors focus on the link between the internal flow of funds and changes in U.S. monetary policy, we provide the first evidence showing how internal capital markets directly affect the costs of global banks' funding practices. Furthermore, we confirm that internal capital markets play a significant role in determining global banks' liquidity and risk management.

Finally, our study relates to the literature on the role of margin requirements and the shadow cost of capital for asset pricing. Assets with similar cash flows can have substantially different margins due to market liquidity (Brunnermeier and Pedersen 2009; Gorton and Metrick 2009) and institutional frictions related to search costs (Duffie, Garleanu, and Pedersen 2005 and 2007; Vayanos and Weill 2008). We complement the literature by providing direct empirical evidence of the explicit pricing model of Gârleanu and Pedersen (2011). We do so by showing that price gaps exist between assets with identical cash flows but different margins and that the size of the gaps depends on relative capital positions in the cross section, thus revealing further bank-level heterogeneity that should not be ignored (Lewellen, Nagel, and Shanken 2010).

The remainder of the paper is organized as follows: Section II describes our data; Section III provides our empirical results; and Section IV concludes.

II. DATA DESCRIPTION

To study the role banks' balance sheets play in determining the cost of dollar hedging, we rely on three data sources. First, we use novel and unique supervisory data on FX derivatives that we obtained from the German central bank (Deutsche Bundesbank), which, in conjunction with the European Central Bank and the German federal financial supervisory authority (BaFin), is the prudential bank supervisor in Germany.⁴ These data include comprehensive micro information on FX derivatives transactions at the individual contract level. In particular, the data include all FX derivatives contracts that were initiated during the period January 2014 through December 2016 and involved at least one party that is a Germany-based bank. For each contract, banks report the initiation day of the contract and include its exact time stamp (to the second), its maturity date, the

⁴ More precisely, the European Markets Infrastructure Regulation (EMIR) grants the Deutsche Bundesbank access to all derivatives trades when at least one of the involved parties is based in Germany. EMIR is the European analogue to the U.S. Dodd-Frank Act; both aim to increase transparency and market resilience.

type of contract, the currency traded, the notional values expressed in both FX currencies, the FX forward rate, and the type of collateralization.

Second, we use the unique legal entity identifier (LEI) associated with each bank to merge the data on FX derivatives with confidential supervisory balance-sheet information that is available at a monthly frequency. The information includes each bank's equity and total assets. We also collect the risk-weighted Tier 1 capital ratio and other bank-level quarterly confidential supervisory data.

Third, from the reports on external positions (Auslandsstatus) maintained by the Deutsche Bundesbank, we obtain data on FX-denominated assets and liabilities held by banks. The reports provide, for any bank in Germany, comprehensive information on all non-euro denominated claims and liabilities (held domestically and abroad) at the currency level in each month (stock at the end of each month).⁵ In addition, the reports include information on the maturity and on the sector (interbank, retail, and affiliates) that are related to the liability or asset position. Affiliated offices include foreign bank branches ("net due to" and "net due from" positions) as well as foreign subsidiaries of the same bank holding company. The data do not differentiate liabilities to foreign branches from liabilities to subsidiaries.

For our analysis, we process the data as follows. We restrict ourselves to the most liquid and most economically relevant FX derivatives market, the USD/EUR market (BIS 2016).⁶ Moreover, we restrict the dataset to forward contracts, which are by far the most frequently used FX derivatives instrument (forwards account for more than two-thirds of all contracts in our sample). Forward contracts are traded over the counter (OTC), and, thus, bilateral contract terms are typically known only to the contracting parties, which is also the reason why data on OTC-traded instruments are usually not available for analysis. Because we are studying banks' dollar hedging, we devote our attention to all forward transactions in which German banks short the U.S. dollar. Economically, this means that our focus is on forward rates of contracts in which German banks take on a dollar liability when they enter an agreement to sell dollars in the forward market. This case is specifically relevant because a forward contract is often part of an FX swap where the bank simultaneously buys U.S. dollars in the spot market, thereby effectively borrowing dollars in the swap market (Ivashina, Scharfstein, and Stein 2015; Borio, McCauley, and McGuire 2017).

⁵ See Krueger, Munzert, and Stahl (2017) for a detailed description of the data on external positions of banks.

⁶ Given that German banks account for about 21 percent of the European FX forward market, our sample covers an economically important part of the overall market.

Moreover, we consider only transactions in which banks act as the principal on their own account, as opposed to contracts where they act as brokers for clients. We restrict our main analysis to transactions across banking groups (excluding intra-group transactions by two banks that are part of the same bank holding group) that are unsecured; that is, neither the seller nor the buyer posts any initial or variation margin. (However, in Section III.4, we further exploit the role of initial margins to examine how bank capitalization and margin requirements affect the pricing of FX forwards.) Finally, to ensure that our results are not driven by outliers, we cut the data symmetrically at the 95 percent level, or 2.5 percent on each side of the distribution of forward rates.

Our final dataset contains 330,773 forward contracts in which 195 different German banks act as forward sellers of U.S. dollars to a total of 15,046 distinct counterparties.⁷ On average, we observe 666 USD/EUR forward contracts per day, with an average notional value of \$9.11 million per trade. Throughout the analysis, we express the forward rate in terms of U.S. dollars per euro, denoting the number of U.S. dollars a given seller must deliver for each euro received. That is, all else being equal, a higher forward rate requires the seller to deliver more U.S. dollars for any given number of euros received, making a USD/EUR forward contract more expensive from the seller's perspective.

[Figure I and II]

In Figure I.A in the Appendix, we show the daily median USD/EUR forward rate for four key maturity segments (one week, one month, three months, and twelve months) from the transactions in our sample. For comparison, Figure I.B in the Appendix presents the corresponding USD/EUR forward rates that we retrieved from Bloomberg. The aggregate forward rates from both sources are similar with respect to their levels and evolution over time. In Figure II, we show the maturity breakdown of the forward contracts in our sample. We find that typical forward contracts in which German banks act as sellers of U.S. dollars are of rather short maturities. For instance, contracts with a maturity of no longer than one week are associated with more than one-half of the market activity, while contracts with a maturity of longer than three months account for less than 15 percent of the overall turnover. This finding is similar to information based on aggregate data on

⁷ We observe detailed information only for German banks, not for their counterparties. However, in our analysis, we account for observable and unobservable counterparty-specific heterogeneity using a comprehensive set of fixed effects.

the forward market worldwide (BIS 2016). From Figures I and II, we conclude that our micro data on forward rates are comparable to the overall pattern that we observe in aggregate data.

[Table I]

Finally, throughout our analysis, we follow the standard practice in the literature on FX forwards (Borio, McCauley, McGuire, et al. 2016; Du, Tepper, and Verdelhan 2017) and rewrite the forward rate as the (annualized) forward premium, that is, the *relative difference* between the rate of the individual USD/EUR forward contract and the USD/EUR spot exchange rate prevailing on the day of the contract initiation. Formally, $Forward\ Premium = \left(\frac{Forward\ Rate}{Spot\ Rate} - 1 \right) * \frac{365}{m}$, where m is the maturity of the forward contract in calendar days. Hence, the forward premium measures the percentage premium (or discount if negative) that the seller pays to lock in the forward rate relative to the spot rate prevailing on the same day. Annualizing the premium facilitates comparison across different maturities, similar to the common practice when dealing with interest rates of different maturities.⁸ Summary statistics presented in Table I show substantial cross-sectional variation in the pricing of forward contracts. This large price variation also prevails if we compare contracts of the same maturity and initiation day and time. We exploit this variation in our empirical strategy.

III. THE ROLE OF BANK BALANCE SHEETS IN THE COST OF DOLLAR HEDGING

In this section, we analyze key determinants of banks' cost of dollar hedging. Specifically, we examine the following four funding-related channels: (i) banks' demand to hedge open FX positions that result from currency imbalances between banks' assets and liabilities, (ii) refinancing conditions in direct dollar funding markets that provide an alternative to derivatives for managing FX liquidity, (iii) banks' access to an internal capital market for dollar funding, and (iv) the capital position of banks that need to post margins at the contract initiation. We examine each of these channels in the following subsections.

III.1 Dollar Funding Gap

⁸The standard practice of annualizing rates does not artificially introduce cross-sectional dispersion. Instead, it shows that fluctuations in the cost of short-term contracts have a much larger economic impact when the implied cost of currency hedges over the entire year are considered.

For (non-U.S.) global banks, the vast majority of foreign assets are denominated in currencies that differ from the denomination of their main funding source. This currency mismatch creates a demand for hedging, because it exposes banks to significant FX risk; that is, the risk that the future exchange rate exhibits volatility associated with potentially costly changes in the value of unmatched currency positions. Indeed, FX risk is one of the major financial risks (Stein 2012; Shin 2016). To mitigate this risk, the financial regulator imposes capital charges when a bank's balance sheet contains currency imbalances, that is, a currency mismatch between a bank's assets and liabilities.⁹ By hedging, a bank can reduce the exposure associated with its (on-balance-sheet) currency mismatch, thereby minimizing regulatory capital charges.¹⁰ The regulatory capital charges introduce an additional demand for hedging FX risk (on top of banks' internal risk-management guidelines) that provides an ideal setup for understanding how hedging demand differentially affects the pricing of FX forwards. For identification, we specifically exploit the period around reporting dates (when the regulatory constraints bind) to examine the effect of hedging demand on the pricing of forward premia.¹¹ By analyzing quarter-end periods, we can study the role hedging demand plays in the pricing of FX forward contracts that depends on the heterogeneity across hedgers and across time. In particular, we expect banks with ex-ante larger net FX positions (higher hedging demand because of on-balance-sheet currency mismatches) to pay higher premia toward these quarter-ends relative to banks with smaller ex-ante net FX positions.

[Table II]

In Table II, we examine whether forward premia are significantly higher at quarter-ends than on days during the quarter. For that purpose, we define period-ends in three different ways: (i) the final three days of any given quarter, (ii) the final week, and (iii) the final two weeks. For each of these definitions, we construct a binary variable that equals 1 whenever one of the definitions

⁹ For German banks, there is a general capital charge of 8 percent on the institution's overall net FX position; for more details, see EBA/Chapter 3 Article 351. Regulatory charges apply to on- and off-balance-sheet exposures on the reporting date; that is, only the positions held at the reporting date matter.

¹⁰ For instance, a bank long in dollar net assets (one with more dollar-denominated assets than dollar-denominated liabilities) could reduce this mismatch by shorting (selling) dollars in the forward market.

¹¹ This is not to say that hedging demand or the need to close currency mismatches is present only near period-ends. Indeed, banks' internal risk-management practices are another key driver of hedging FX risk. Rather, we infer that if hedging demand differentially affects the pricing of FX forwards, the impact should be more pronounced near the end of a regulatory binding quarter (Borio, McCauley, McGuire, et al. 2016). In fact, recent studies find end-of-quarter effects in several financial markets at an aggregate level (using aggregate data); see Du, Tepper, and Verdelhan (2017) and the references therein.

applies, and equals 0 otherwise. In columns (1), (3), and (5), we find that dollar-forward premia are significantly higher at quarter-ends than they are during the rest of the quarter. Our estimates indicate that contracts initiated during the final week of a given quarter are, on average, 3.5 percentage points more expensive than the ones started during the quarter (column 1). Note that our estimation controls for the maturity of the contract, the hour of initiation (to account for intraday patterns), and the bank and counterparty fixed effects (to account for potential heterogeneity in counterparties). That is, for the same maturity during the same hour, we find a differential effect in the pricing of dollar forwards at quarter-ends versus during the quarter. However, we do not find this differential effect if we look at the final two weeks in a given quarter.¹² This suggests that forward premia are significantly higher during the final few days of a given quarter than they are on other days.

In column (2), we examine whether these end-of-quarter effects vary depending on the maturity of the contract. If banks short dollars to bridge financial reporting days, we would expect that this happens mostly with shorter-maturity contracts that just cross the reporting day, which are (in absolute terms) cheaper. To see if this is so, we introduce an interaction term with (the logarithm of) the contract's maturity (in days). Indeed, we find that forward premia at quarter-ends are higher for shorter-maturity contracts, while the effect for longer-maturity contracts is significantly weaker.¹³ This effect is quantitatively similar for the final three days of a given quarter, but it is not present in the final two weeks of a given quarter (column 4 versus column 6). (Appendix Table A.1, Panel A, shows that there is no significant change in contract values at quarter-ends.)

In the next step, to understand the economic channel behind these findings, we examine whether these end-of-quarter effects vary depending on bank characteristics. More precisely, to determine whether additional hedging demand is a key driver for these quarter-end findings in the forward premia, we study whether the premia vary depending on banks' ex-ante dollar funding gap (the share of dollar assets that are not backed by dollar liabilities). We do this by restricting ourselves to the final week in a given quarter.¹⁴ Moreover, to strengthen the identification of the

¹² Note that this does not imply banks are unhedged during the rest of the quarter. Rather, we find that the differential pricing suggests hedging demand near quarter-ends is more binding and thus affects banks' forward premia differentially (which is the question of our paper and the channel we are examining here).

¹³ For instance, a three-month forward rate contract initiated at a quarter-end is not priced differently from contracts initiated on days during the quarter (not reported).

¹⁴ Our results are similar when we consider the final three days of a quarter.

channel, we consider only contracts in which the maturity is longer than one week, because those forward contracts will expire after the quarter-end. Contracts that expire before the quarter-end will *not* reduce the net asset mismatch that banks seek to minimize in order to economize on regulatory capital (indeed, our results are driven by contracts expiring after quarter-ends).¹⁵

In column (1) of Panel B, we present the estimation from studying the impact of the dollar funding gap on the pricing of forward premia at quarter-ends. We find that the estimated coefficient of the funding gap is positive and statistically significant, showing that banks with a higher ex-ante dollar funding gap pay significantly higher forward premia at quarter-ends relative to banks with a lower ex-ante funding gap. The estimated coefficient is also economically meaningful: An increase in the dollar funding gap by 1 percentage point increases the cost of hedging by 38 basis points on average (0.3837×0.01). Note that in this regression, we use fixed effects to control for any time-invariant bank and counterparty characteristics. In addition, we compare the prices of contracts of the same maturity that were initiated at the same hour of the same day. (For example, we compare the forward rates of contracts with a maturity of, say, 12 days initiated between 2 p.m. and 3 p.m. on September 29, 2015.) Thus, we focus entirely on the cross-sectional differences of hedging costs at quarter-ends.¹⁶

One concern in this context could be that banks with higher ex-ante dollar funding gaps are associated with lower capital levels, in which case less-capitalized banks are associated with higher premia rather than unmet dollar-denominated net balance sheet positions. Therefore, in column (2), we add the bank's ex-ante equity ratio. First, we find that our estimated coefficient on the ex-ante equity ratio (inverse of the leverage ratio) is not significant. Second, our result for the funding gap remains unchanged, both statistically and economically. It does not change when we instead (column 3) or also (column 4) control for the regulatory capital. In column (5), we introduce bank size as an additional bank control, and we add the contract value and find that our results remain (statistically and economically) similar. In columns (6) and (7), we replicate our estimation from

¹⁵ We have used alternative specifications to include all contracts in the regressions, and we have used a dummy variable that indicates whether a contract crosses quarter-ends in interaction with maturity of the contract. In our main analysis, we focus on a sample split instead, given the large number of interaction terms.

¹⁶ For this comparison, we need in each maturity segment at least two contracts that are initiated at the same hour of the same day. Concerns may therefore arise that, with this identification strategy, we could bias our estimation sample toward contracts initiated in the most active maturity segments of the market. However, such concerns are diluted by Figure A.1, which shows that the maturity distribution in our estimation sample is similar to the maturity distribution in the full sample.

columns (1) and (5), respectively, but condition our sample to the rest of the quarter (excluding the final week of the quarter). The estimated coefficient on the dollar funding gap is not significant in either specification. This suggests there is no differential pricing effect in forward premia that depends on a bank's funding gap during the quarter, as there is at quarter-ends.

The results from Panels A and B are consistent with FX forward premia's being significantly higher at period-ends, in particular for banks with a greater need for hedging. From Panel A, we already know that premia at quarter-ends are particularly high for short-term forward contracts with shorter maturities. Therefore, in Panel C, column (1), we introduce an additional interaction term using (the logarithm of) the contract's maturity (in days), which allows us to examine whether banks with a higher ex-ante dollar funding gap pay higher premia at quarter-ends, particularly for contracts of shorter maturity. We find that the estimated coefficient on the interaction term "Dollar Funding Gap*Log(Maturity)" is negative and highly significant. Recall that we restricted our analysis to maturities longer than one week. That is, forward premia are particularly higher at quarter-ends for banks with a high dollar funding gap that execute short-term contracts just beyond the one-week horizon. These are contracts that expire right after the regulatory binding quarter-end date and thus help the bank close its open FX positions on the day of the regulatory reporting (from a total cost perspective, these contracts are cheaper than longer-maturity contracts). We illustrate this finding graphically in Figure III.

[Figure III]

In column (2), we strengthen our identification of the channel even more by adding bank*day and counterparty*day fixed effects to our existing fixed effects structure. This allows us to compare the cost of multiple contracts by the same bank with the costs of other contracts initiated on the same day during the same hour that depend on the bank's ex-ante dollar funding gap and the maturity of the contract. Additionally, we net out time-varying counterparty heterogeneity with counterparty*time fixed effects and common movement in forward premia in each maturity using day*maturity*hour fixed effects. Importantly, this identification ensures that our results are not driven by changes in the supply of dollars in the cash markets at quarter-ends. That is, our results cannot be a consequence of limits to arbitrage due to a constrained supply of dollar funding or concerns associated with counterparty risk. Economically, we find that an increase in a bank's dollar funding gap by 1 percentage point is related to an increase in the bank's cost of hedging by

29 more basis points in the one-week segment than in the one-month segment ($-0.2062*0.01*[\log(7)-\log(30)]$).

Finally, in column (3), we examine whether this effect varies depending on a bank's ex-ante equity ratio. We do this by including a triple interaction between the bank's dollar funding gap, its equity ratio, and the maturity of the contract. We find that the pricing differential between long- and short-term contracts is more pronounced for banks with ex-ante higher dollar funding gaps and ex-ante lower equity capital levels. For example, a bank that faces a 1-percentage-point increase in its dollar funding gap and a simultaneous 1-percentage-point lower equity ratio pays 40 basis points more for a one-week forward contract than for a contract with a one-month maturity ($-27.8436*0.01*0.01*[\log(7)-\log(30)]$). Again, we identify this effect by comparing multiple forward contracts for the same bank during the same hour of the same day, while netting out supply factors such as a reduction in the supply of dollars at the quarter-end related to a deleveraging in the market using day*counterparty fixed effects. (We do not find a similar result based on the Tier 1 ratio.)

In column (4), we look for similar effects during the quarter (excluding end-of-quarter days from the sample). Consistent with our previous results, we do not find a significant coefficient on the relevant variables during the quarter. Overall, these results suggest that banks with a higher ex-ante dollar funding gap, especially those with lower ex-ante levels of equity, pay significantly higher premia for short-term forward contracts (that just cross quarter-end reporting dates) in order to meet regulatory requirements. This finding is consistent with the notion that banks window-dress their balance sheets at quarter-ends to reduce their unmatched FX currency positions and economize on regulatory capital surcharges.¹⁷ Panels B and C in Appendix Table A.1 confirm the demand-driven channel that we identified from price differentials by showing that banks with a higher ex-ante funding gap not only pay more, but also increase the total number of hedging contracts at quarter-ends (though not the volumes of contracts; see Panel A of Table A.1).

III.2 Global Dollar Funding Conditions

In this section, we examine how changes in global liquidity affect the pricing of FX derivatives. In particular, we assess the impact of a liquidity shock in global dollar funding markets on the

¹⁷ Abbassi, Iyer, Peydró, et al. (2017) use detailed data on securities and credit registers from Germany and provide direct evidence of banks' window-dressing behavior with the asset side of their balance sheets.

dollar forward market and its differential effect on the pricing of forward contracts. The idea is that when liquidity conditions in direct dollar funding markets tighten, market participants increase synthetic dollar borrowing and manage their FX liquidity through the forward market (Stein 2012; Ivashina, Scharfstein, and Stein 2015). To understand how strains in short-term funding markets spread into the forward market and affect the pricing of banks' FX hedging, we exploit Brexit, the United Kingdom's referendum to leave the European Union. On June 23, 2016, the referendum passed when 52 percent of U.K. citizens voted in favor of it.

Brexit serves as an ideal quasi-natural experiment for identification of the interlinkages between direct dollar funding markets and the FX forward market for several reasons. The result of the vote came as a large surprise to the global financial markets and led to severe disruptions. In particular, it triggered a global flight to safe assets, most notably dollar-denominated U.S. Treasury securities. Indeed, U.S. Treasury data indicate that total foreign private U.S. Treasury bond holdings alone increased by 3 percent between the end of May and the end of July 2016; German banks' holdings increased by 7 percent in the same period. The post-Brexit demand for safe dollar assets was reflected in the sharp increase in prices for U.S. Treasury debt—the 10-year Treasury yield dropped by 25 basis points (14 percent) in the week after Brexit. However, the strong increase in global demand for dollar assets simultaneously triggered a need to fund those assets—funding that ultimately needed to be in dollars and was obtained primarily by tapping short-term wholesale funding markets. As a result, the Brexit vote caused general strains in global wholesale dollar funding markets, including the Libor market and the repo market, the latter of which is the most important dollar liquidity market. For example, short-term repo rates spiked to levels not seen since the height of the 2007–2008 financial crisis.¹⁸

Appendix Figure A.2 illustrates the impact of Brexit on short-term money markets and the FX forward market. It shows the increase in short-term dollar funding rates as measured by the repo rate. It also shows the spillover to the forward market as measured by a subsequent increase in the total number of forward contracts executed.

[Table III]

¹⁸ Overnight general-collateral Treasury repo rates, for instance, averaged 0.81 percent through 10 a.m. ET, according to trading via ICAP Plc. According to market participants, there was an overall scramble for funding; see Liz McCormick, "Brexit Haven Demand for Treasuries Drives Repo Rates to '08 High," *Bloomberg*, June 24, 2016. Available at <https://www.bloomberg.com/news/articles/2016-06-24/brexit-haven-demand-for-treasuries-drives-repo-rates-to-08-high>.

In Table III, we examine the effect of the Brexit vote in detail using a regression framework. For a tight identification of the effects, we restrict ourselves to a brief timeframe around the day of the Brexit vote and examine the pricing of dollar forwards, comparing the five trading days before the vote (beginning with June 16, 2016) with the five following it (through June 30, 2016). Our results are robust to using other symmetric timeframes of different lengths.

In columns (1) and (2), we start our analysis by using daily data to study the effect of the vote on typical dollar funding rates. More precisely, we regress daily repo spreads of different maturities, that is, the daily interest rate spread between the rate for a repo and the correspondingly dated overnight index swap (OIS) rate on a binary variable “post Brexit,” which we define as a binary variable that equals 1 for all days after June 23, 2016, and 0 otherwise. We subtract the OIS rate to account for potential changes in monetary policy expectations (Taylor and Williams 2009). The regression results confirm our findings from Appendix Figure A.2 that the interest rate spread increased substantially in the period after the vote compared with the period before it. More precisely, our estimates indicate that after the Brexit vote the overnight repo spread increases on average by 24 basis points (column 1), the one-week repo spread increases by 9 basis points (column 2), and the three-month repo spread increases by 2 basis points (column 3) compared with the period immediately before the vote day.¹⁹ The stronger rise in short-term repo rates is consistent with the Brexit shock’s being a dollar liquidity shock and thus putting upward pressure on short-term funding markets.

In columns (4) through (7), we use our transaction-level data to look at the effect of the Brexit vote on the USD/EUR forward premium. In column (4), we find that the vote has a highly significant and economically large effect on the forward premia. It prompts an average increase of 13.42 percentage points at an annualized basis. In column (5), we find that the impact on forward premia is more pronounced for short-term contracts. (Indeed, the effect is not significant for contracts with maturities of three months or longer.) This is consistent with the notion that the Brexit vote caused a general squeeze in short-term funding markets. Note that small changes to the forward premium of shorter-length contracts are associated with larger economic effects when they are considered in annualized terms. For example, an increase of 13.42 percentage points at an

¹⁹ Due to data availability, overnight and one-week repo rates are based on Treasury repos, while the three-month repo rate is based on mortgage-backed securities. In unreported results, we also verified that other dollar-funding markets, such as the Libor market, exhibited significant widening of spreads. However, consistent with the Brexit shock being a liquidity shock rather than a credit risk shock, Libor-OIS spreads did not widen more than repo spreads.

annualized basis would correspond to an 18-basis-point increase for a five-day forward contract ($13.42 \times 5/365$). The effect on longer-term contracts is not significant, thus indicating the forward premia indeed do not increase due to the sharp drop in the spot rate. Rather, the evidence is consistent with the notion that the increase is related more to a higher demand for shorting the dollar than changes in supply. In column (6), we regress the forward premia directly on the lagged overnight repo spread instead of using a Brexit dummy variable. The results again confirm that a higher dollar funding cost spills over to the forward market and increases the forward premium. Moreover, we find that this result is stronger for forward contracts with shorter maturities. (Similar to our analysis in the previous section, we do not find that contract notional amounts increased after the Brexit vote and therefore focus on the price effects in the analysis that follows.)

In Panel B, we examine whether there are differential effects on the price of dollar hedges post Brexit that depend on bank characteristics. More precisely, we examine whether pricing differs across banks in the period after the vote depending on a bank's ex-ante exposure to dollar funding markets. The idea is that a global dollar funding shock with elevated pressures on dollar funding markets (as measured by the repo spread, for example) should have a differential impact on banks with an ex-ante higher reliance on dollar funding markets to roll over their short-term debt. Therefore, we study whether, for the same bank and the same maturity during the same hour of the day, banks that rely more on dollar funding prior to the Brexit vote date, as measured by their ex-ante level of total dollar-denominated liabilities (in logarithms), are associated with higher forward premia in the aftermath of the referendum. We use the lagged overnight repo spread as our Brexit crisis variable, but the results are similar when using a post-Brexit dummy variable.

The positive coefficient on the estimated interaction term of "ON Repo Spread*Log(Dollar Liabilities)" in column (1) of Table III indicates that banks with more ex-ante dollar funding face significantly higher forward premia in the period after the Brexit vote. Our coefficient estimate of 0.4429 indicates that a bank with 10 percent higher dollar-denominated liabilities pays, on average a 1-percentage-point higher forward premium for shorting dollars compared with what it paid in the period before the referendum date ($0.2368 \times 0.4429 \times 0.1$, as ON repo spread increased by 23.68 basis points on average after Brexit). Because we control for bank fixed effects and counterparty fixed effects, in addition to day and maturity*hour fixed effects, the coefficient estimate is not driven by unobserved bank heterogeneity in the tight (plus/minus five days) window surrounding the Brexit referendum.

One may argue that the effect should be more pronounced for banks that have a higher reliance on wholesale funding markets, that is, banks that are most exposed to the Brexit-induced surge in the wholesale dollar funding cost. To test this, we interact our variable “Log(Dollar Liabilities)” with the share of wholesale funding markets as measured by the ex-ante level of interbank dollar funding as a fraction of total dollar-denominated liabilities. In column (2), we find that the estimated coefficient on the triple interaction is positive and highly significant. This suggests that in the post-Brexit-vote period, banks with higher reliance on wholesale funding markets pay significantly higher premia than they did before the Brexit vote.

If a major economic channel for these spillovers is indeed banks’ seeking to roll over short-term debt, one may argue that banks with an ex-ante higher reliance on *short-term* interbank funding should be associated with premia that are higher in the period after the Brexit vote than they were in the period before it. Therefore, in column (3), we replicate our estimation from column (2) but interact our main variable “Log(Dollar Liabilities)” with the share of overnight wholesale funding markets, that is, the level of overnight wholesale dollar funding as a fraction of total dollar-denominated liabilities. We find that the estimated coefficient on the triple interaction term is positive and statistically significant. This result is consistent with our earlier finding that the Brexit vote had a stronger effect on dollar interest rate spreads of shorter maturities. The strains in this short-term funding market most strongly affect banks that have an ex-ante higher reliance on funding markets, specifically the short-term wholesale interbank funding markets. In columns (4) and (5), we find that these effects are present for short-term contracts, but not for longer-term contracts.²⁰

III.3 Internal Dollar Capital Markets

Our results so far highlight the role of external dollar funding markets in the pricing of currency hedges. However, banks’ dollar liquidity management is not confined to *external* capital markets. In fact, banks’ frequently make use of their *internal* capital markets; that is, they borrow funds

²⁰ Because the Brexit referendum happened in the second-to-last week of 2016:Q3, we run various robustness tests to ensure that our results are not picking up regular quarter-end effects. First, results hold when we use a longer window and exclude the final week of 2016:Q3, and when we use a shorter window that excludes the final week of 2016:Q3. Second, results are robust to comparing the post-Brexit week with other end-of-quarter weeks of previous quarters in 2016. Third, we do not find that banks’ dollar funding gap matters during the specific week post Brexit, unlike other quarter-ends (see Section III.1). Fourth, repo spreads during other quarter-end periods move in the opposite direction of how they move in 2016:Q3, the quarter-end immediately after the Brexit vote.

internally from related offices. The international finance literature, in this context, highlights the role of internal capital markets for effective liquidity management, especially for global banks with cross-currency positions (which are at the center of our analysis). As discussed in the data section, the Bundesbank requires banks to report all borrowing from related offices, including branches and subsidiaries.

[Table IV]

In the context of the FX forward markets, we expect that the dollar funding structure affects the costs a bank faces when hedging its FX exposure. In Table IV, column (1), we start with a bank's access to internal dollar capital markets, which we measure by a bank's lagged value of intra-group dollar liabilities (in logarithms), that is, the value of borrowing from related foreign offices (branches and within the same banking group).²¹ We find that for contracts of the same maturity initiated during the same hour of the same day, a bank with larger ex-ante amounts of intra-group dollar liabilities is associated with forward premia that are significantly lower than those of a bank with fewer intra-group liabilities. We identify this result after controlling for bank and counterparty fixed effects. In economic terms, we estimate that banks with 1-percentage-point higher intra-group dollar liabilities pay a forward premium that is 4 basis points lower (-0.04×0.01). In column (2), we introduce an additional bank-level control (bank size) and contract value, and find that our results remain qualitatively unchanged.

In column (3), we also control for a bank's interbank dollar liabilities, as a measure for its access to interbank dollar funding (excluding borrowing from intra-group interbank funding), and for its non-bank dollar liabilities, as a measure for its access to retail dollar funding (both in logarithms). We find that while the volume of neither wholesale nor retail dollar funding plays a significant role in the pricing of FX forward premia, the coefficient on intra-group dollar funding remains statistically significant and quantitatively similar. In column (4), we examine the interrelation between internal capital markets and hedging demand on banks' cost of dollar hedging. To this end, we interact our variable "Log(Internal Capital Transfer)" with "Dollar Funding Gap," our measure (from above) for hedging demand, and find that banks with higher ex-ante intra-group liabilities pay significantly lower premia when they have relatively higher demand for hedging. A different interpretation of this finding is that banks with relatively higher hedging

²¹ Only 24 of 195 banks have non-zero intra-group liability positions. This limits our analysis of those types of banks, and it is also the reason why we cannot use this variable in the Brexit analysis.

demand face lower premia when they have an alternative source of funding, namely internal capital markets. The estimates indicate that the effect of intra-group liabilities on the forward premia is elevated by 4 basis points for a bank with a 1-percentage-point higher dollar funding gap.

Indeed, if internal capital markets serve as an alternative (direct) dollar funding source and thus represent an outside funding option, an undiversified network in the FX derivatives market should be less important for a bank seeking to hedge FX risk.²² Therefore, in column (5) we interact our variable “Log(Internal Capital Transfer)” with the standard measure used in the literature to assess a bank’s bargaining power, that is, its Herfindahl-Hirschman Index (HHI).²³ We compute a bank’s HHI based on its trading partners (number of counterparties) in the forward market, as observed in the year prior to the contract. Higher HHI values mean that a bank’s counterparty portfolio in the FX forward market is more concentrated, resulting in less bargaining power for the bank. On the other hand, a lower HHI means that a bank has more trading relationships and therefore strong bargaining power. We find that the coefficient of the interaction term is negative and significant. Hence, banks with higher ex-ante levels of intra-group liabilities face lower premia despite having higher HHI values (more-concentrated networks). This is consistent with the notion that banks with relatively lower bargaining power benefit from internal capital markets. The effect of internal capital markets is also economically large, about 3.5 percentage points stronger for banks with a 1-standard-deviation higher HHI (-0.7428×0.048).

On the basis of our finding on period-end effects in the pricing of forwards, we also examine whether banks with higher ex-ante intra-group liabilities can fetch better prices near quarter-ends. We do this by replicating our estimation from column (2) in column (6) but adding an interaction term “Log(Internal Capital Transfer)*End-of-Quarter,” where “End-of-Quarter” is a binary variable that equals 1 on any day during the final week of a given quarter, and 0 otherwise. Again, we find a negative and statistically significant estimated coefficient, which suggests that banks with relatively higher ex-ante levels of intra-group liabilities are associated with significantly lower premia near period-ends. This effect of internal capital markets on the cost of dollar hedging is about 25 percent higher ($1.25/5.06$).

²² In fact, standard bilateral Nash bargaining models (Bech and Klee 2011; Abbassi, Bräuning, and Schulze 2017; Rime, Schrimp, and Syrstad 2017; among others) predict that the effect of a bank’s bargaining power on prices should depend on its outside options.

²³ In robustness tests (not reported), we used alternative measures of a bank’s bargaining power, such as the (log) number of counterparties. Our results remained qualitatively similar.

Finally, in column (7), we examine whether banks with deeper internal capital markets could better withstand the strains in the dollar forward market induced by the U.S. money market fund (MMF) reform that became effective in 2016.²⁴ The reduction of dollar funding by the MMFs to the German banking system represented a change in local funding conditions for German banks and thus initiated a reallocation of dollar funding sources among market participants (BIS 2017). To measure the funding drain, we focus on the relevant period (2016) and compute the variable “U.S. MMF Investments,” which is a measure at a monthly frequency obtained from the U.S. Money Market Fund Monitor that captures (the logarithm of) the total value of MMF investments in all German banks during each month of 2016.²⁵ In unreported results, we find that the level effect of the variable “U.S. MMF Investments in Germany” is indeed negative: when MMF funding declines, starting about March 2016, the cost of synthetic dollar funding through the forward market increases. However, we are specifically interested in whether banks with deeper internal capital markets are more insulated from the higher cost of synthetic funding induced by the MMF investment behavior. Therefore, we interact the variable “U.S. MMF Investments” with “Log(Internal Capital Transfer).” In column (7), we find that the coefficient on the interaction term is positive and statistically significant. This suggests that after the drain in MMF investments, banks that had ex-ante deeper internal dollar capital markets benefited from lower costs of dollar hedging in the forward market. Economically, the coefficient indicates that a reduction in U.S. money market funding by 25 percent (a change in logs of 0.25) increases the impact of access to internal capital markets on the cost of hedging by about 6 basis points (0.0257×0.25).

III.4 Margin Requirements and Shadow Cost of Capital

A bank’s reservation price for entering into a forward contract depends on its alternative dollar funding costs (both direct and synthetic associated with the use of derivatives) and the detailed contract conditions of those alternative funding options. In particular, if a bank needs to post collateral for a specific instrument and has a higher shadow cost of capital, it may find that it’s

²⁴ See Joe Rennison, “US Money Market Fund Reform—an Explainer,” *Financial Times*, October 14, 2016. Available at <https://www.ft.com/content/93679bf0-0be4-11e6-9456-444ab5211a2f>.

²⁵ In Section III.2 above, we established how changes in other funding markets can feed back into the FX forward market. At this point, we are interested in examining the differential pricing of such a shock depending on banks’ internal capital markets, that is, whether the drain of U.S. MMF-related liabilities affects banks differently depending on their internal capital markets.

worthwhile to pay more for an unsecured contract with otherwise similar contract details (Gârleanu and Pedersen 2011). For example, while the dollar repo market is a deep and liquid direct-dollar-funding market, borrowing in the repo market binds collateral. As a result, a bank with an ex-ante higher shadow cost of capital may find it more attractive to execute an uncollateralized funding contract at a rate that is higher than one for a bank with a lower shadow cost of capital.

In this section, we examine the role of banks' shadow cost of capital in determining the forward premium, that is, the hedging costs. In our previous analysis, we focused on uncollateralized forward contracts only so that we could compare assets of the same maturity during the same hour of the same day. However, our database also contains forward contracts for which the initial margin is provided. In this section, to identify the effect of heterogeneous capital (margin) valuation on the pricing of forwards, we extend our analysis to collateralized transactions and compare the forward premia of uncollateralized and collateralized contracts that have otherwise similar features (initiation time, maturity, value, contracting banks, counterparty). In particular, we focus on contracts that are one-way collateralized by the seller; that is, the seller must post collateral (initial margin) while the counterparty does not provide any form of margin. Note also that these trades do not require either party to post variation margins.²⁶ This allows us to clearly study the differential pricing of collateralized versus uncollateralized contracts of hedge-seeking banks, while keeping the counterparties' collateralization constant. Everything else being equal, we would expect that the requirement to post collateral will make the contract less attractive, and so the seller will require a discount compared with a similar uncollateralized contract (Gârleanu and Pedersen 2011; Ivashina, Scharfstein, Stein 2015). That is, any price gap in the aggregate between two assets with identical cash flows but different margins captures the average shadow cost of capital. And, price gaps in the cross section of secured contracts depend on relative margin valuations (due to differences in capital), which follows directly from Brunnermeier and Pedersen (2009) and Gârleanu and Pedersen (2011).

[Table V]

In Table V, Panel A, we begin our analysis by examining whether there is a spread between the forward premia of collateralized contracts and uncollateralized contracts. We adopt the same

²⁶ Contracts of this kind are considered one-way collateralized trades and account for 8.45 percent of our data. Collateral used for initial margins consists of relatively homogenous cash-like assets, such as cash and top-rated government bonds.

identification procedure as before and net out any time variation in each maturity by including day*maturity*hour fixed effects. This allows us to study the differential effect between uncollateralized and collateralized premia while holding everything else constant. However, one may argue that the differential effect that depends on uncollateralized versus collateralized contracts is more pronounced for longer-term contracts than for short-term forwards, that is, when the margin (capital) to trade, and thus the shadow cost of capital, is most sensitive. Therefore, we explore price gaps for three major maturity buckets: up to but not including one week (column 1), one week to three months (column 3), and longer than three months (column 5). Our main variable of interest is “Initial Margin,” a binary variable that equals 1 whenever the contract is collateralized—that is, when the seller provides initial margin—and 0 otherwise. We find that collateralized contracts, ones in which the seller posts an initial margin, trade at a lower forward premium than do uncollateralized contracts. Moreover, this differential level effect increases with maturity and is significant for contracts with a maturity longer than one week (columns 3 through 6), when the shadow cost of capital is most sensitive. This effect is robust to the inclusion of the contract value that may differ across contracts (compare columns 2, 4, and 6). Column (4) indicates that collateralized contracts with a maturity longer than one week but shorter than three months have a forward premium that is, on average, about 87 basis points smaller than that of uncollateralized contracts with otherwise identical characteristics. For contracts with a maturity longer than three months, the differential effect amounts to 1.37 percentage points, on average (column 6).

In the next step, we examine the role of relative margin (capital) valuations for the cross section in price gaps. That is, we explore whether there is additional heterogeneity in price gaps that depends on the hedging banks’ capital. We expect that the differential effect is larger for less-capitalized banks that are considered to have a higher shadow cost for capital. To see if this is so, we focus on the maturity segment with the largest economic effects, maturities that are longer than three month.²⁷ In column (1) of Panel B, we replicate the estimation from column (6) of Panel A, but interact our variable “Initial Margin” with the bank’s equity ratio. We also add bank and counterparty fixed effects to control for unobserved time-invariant bank characteristics. The

²⁷ We use this maturity bucket for identification purposes. Our results remain qualitatively similar if we do not restrict ourselves to only this maturity bucket. By focusing on contracts of a maturity longer than 90 days, we also ensure that none of the results is driven by potential end-of-quarter dynamics in the pricing of collateralized versus uncollateralized contracts.

positive coefficient on the interaction term shows that the price differential is larger for banks with lower levels of equity capitalization. Economically, a bank with a 1-percentage-point lower equity ratio pays a forward premium that is 5.1-percentage-points higher than that of a bank with a higher equity ratio. In column (2), we include a Tier 1 capital ratio to examine whether the cross section of these price gaps also depends on the shadow cost of Basel regulatory capital requirements. We find that the estimated coefficient is not significant. Note, however, that the interaction term with the equity ratio remains significant and quantitatively similar.

One concern could be that the bank's equity ratio is a good proxy for its credit risk, in which case the cross section of price gaps would be a function of credit risk and not of relative margin valuations. However, it's unlikely that counterparty credit risk would be a key driver of the pricing of forward contracts when no principal amount is exchanged at the contract initiation. Nevertheless, in column (3), we replicate our estimation from column (2) but add the bank's daily (logarithm of the) lagged credit default swap (CDS) spread that we obtained from Markit; CDS spreads, in general, are a standard measure for assessing credit risk (Veronesi and Zingales 2010). We do not find a significant impact from the CDS spread on the price gap between collateralized and uncollateralized forward contracts. Importantly, even after we control for the potential correlation between a bank's capital ratio and default risk, our main result still holds, suggesting that the price wedge between uncollateralized and collateralized contracts depends on relative margin valuations determined by the bank's equity ratio.

In column (4), we show that our result is also robust to the inclusion of bank*day fixed effects and counterparty*day fixed effects. Hence, this tight specification controls for any time-varying unobserved bank and counterparty heterogeneity and compares collateralized to uncollateralized contracts for the same bank on the same day. Indeed, the estimated effect becomes quantitatively six times larger under this tighter identification. In sum, we find significant price gaps between two forward contracts with identical cash flows but different margins. Moreover, these price gaps increase with maturity and depend on relative capital positions (equity ratios, but not Tier 1 ratios) in the cross section of banks, thus revealing further bank-level heterogeneity.

IV. CONCLUSION

We study the role that banks' balance sheets play in determining their cost for dollar hedging. To do so, we exploit a unique dataset on banks' FX forward contracts for the period 2014 through 2016 and supervisory bank balance sheet information from Germany. Contrary to the standard international finance textbook view, we find economically large cross-sectional variation in the cost of dollar hedging for contracts of the same maturity that are initiated during the same hour of the same day. We show that this differential cost depends on (i) banks' dollar funding gap, (ii) their dollar funding composition, (iii) their access to internal capital markets, and (iv) their capital.

Our findings have broad implications. The mechanisms we identify are directly relevant to the current policy debate regarding global funding markets and the importance of the U.S. dollar to broader financial markets and the real economy (Shin 2016). In particular, our results show that when a shock affects one segment of the funding market it is transmitted to broader financial markets in ways that are shaped by global banks' FX management, including their hedging behaviors and direct FX funding structures. This in turn has important implications for financial-stability-risk monitoring, systemic risk, macroprudential stress-test designs, and the way we assess international spillovers across banks, currencies, and markets.

Moreover, economically sizable differences in FX hedging costs across banks, as documented in this paper, are likely to have implications for the local and international efficacy of regulatory and monetary policy transmission. For example, the transmission of monetary policy through the bank lending channel in particular (and through portfolio allocation in general) is likely to depend on the cross section of banks' synthetic funding costs when they use the FX derivative market. We leave these interesting topics open for future research.

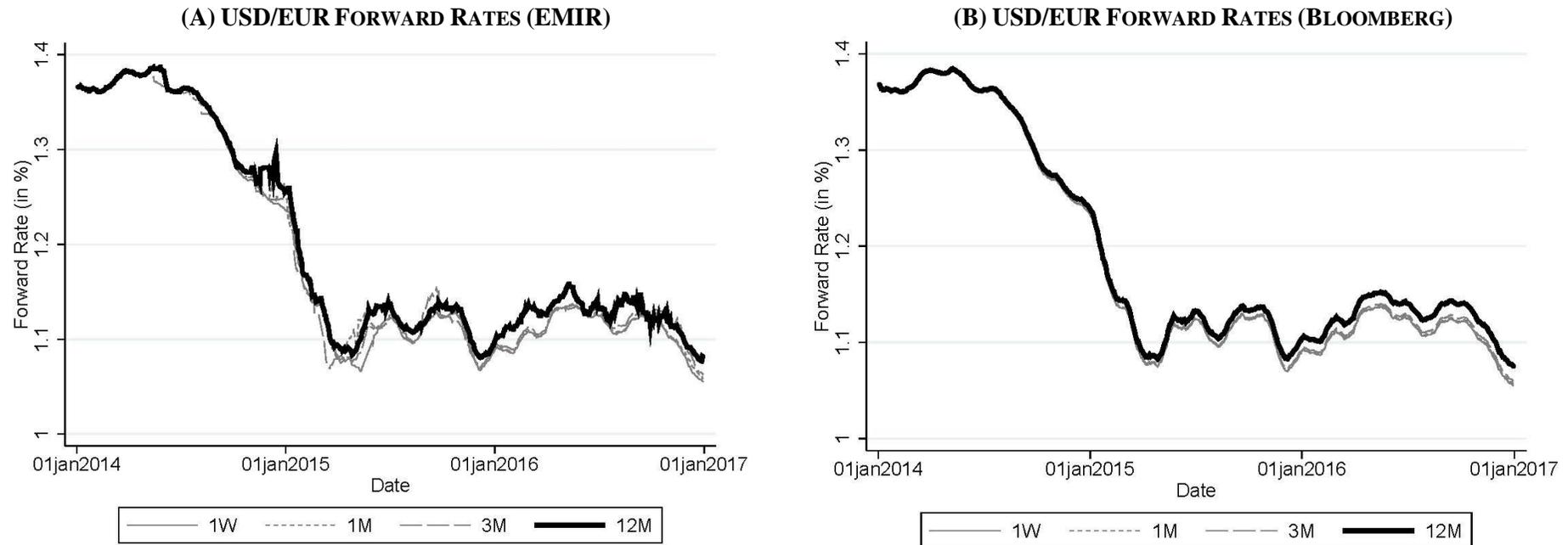
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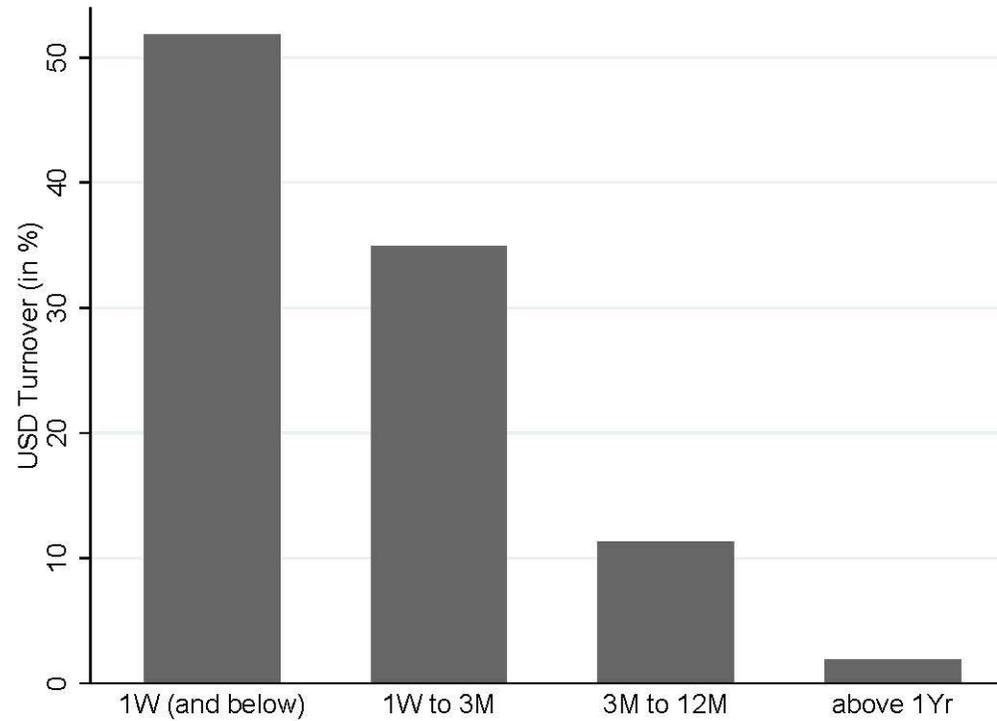
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FIGURE I
USD/EUR FORWARD RATES



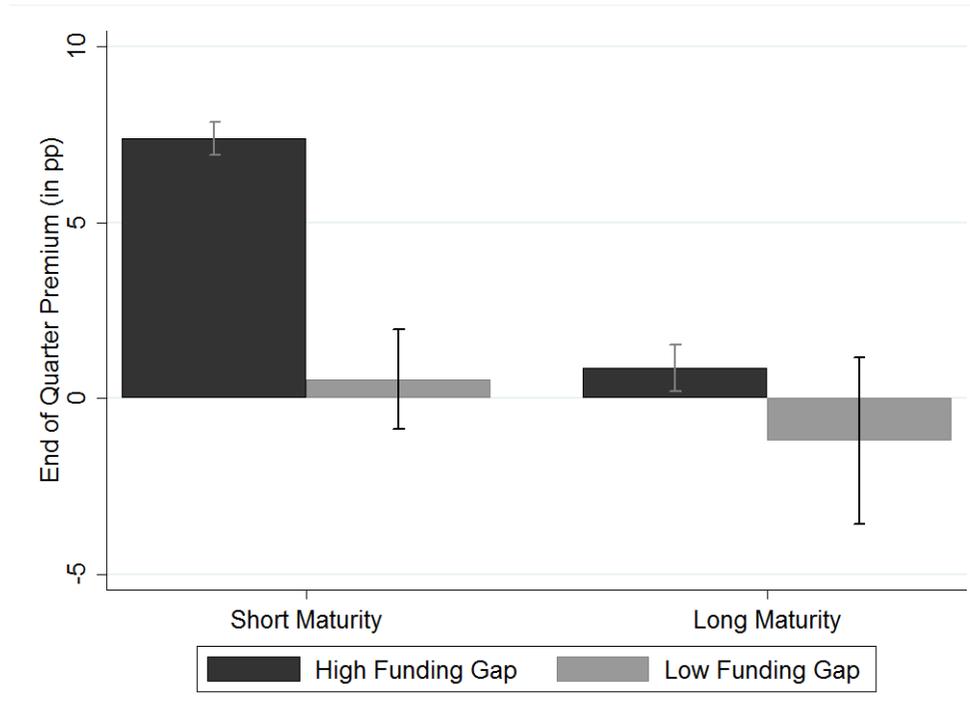
Note: This figure presents the daily time series (30-day moving average) of interest rates implicit in USD/EUR forward contracts of different maturities initiated in the period January 1, 2014, through December 31, 2016. The gray solid line refers to one-week forwards, the gray dotted line to one-month forwards, the gray dashed line to three-month forwards, and the black solid line to twelve-month forwards. Subfigure (A) refers to the daily median of respective forward rates from our contract-level data. Interest rates are annualized to facilitate comparison across different maturities. Subfigure (B) presents the correspondingly dated annualized forward rates obtained from Bloomberg.

FIGURE II
MATURITY BREAKDOWN OF MARKET TURNOVER



Note: This figure presents the maturity breakdown of USD notional amounts implicit in USD/EUR forward contracts initiated in the period January 1, 2014, through December 31, 2016. The maturity bucket “1W (and below)” refers to contracts of as long as one week (inclusive); “1W to 3M” refers to contracts of one week (exclusive) to three months (inclusive); “3M to 12M” refers to contracts of three months (exclusive) to twelve months (inclusive); and “above 1Yr” refers to contracts of longer than 12 months (exclusive).

FIGURE III
PRICE DIFFERENTIALS AT THE END OF THE QUARTER



Note: This figure shows the differential forward premium (in percentage points) of end-of-quarter USD/EUR forward contracts versus those during the quarter for banks with a high versus low dollar funding gap. The bars refer to estimated beta coefficients arising from the following regression: $Forward\ Premium_{i,j,m,h,t} = \beta * MaturityBucket_{i,j,m,h,t} * EndOfQuarter_t + \alpha_i + \alpha_j + \alpha_{m,h} + \epsilon_{i,j,m,h,t}$. The dependent variable is the annualized forward premium implicit in USD/EUR forward contracts between bank “i” and counterparty “j” of maturity “m” initiated during the hour “h” on any given day “t” in the period January 1, 2014, through December 31, 2016. α_i is a bank fixed effect, α_j is a counterparty fixed effect, $\alpha_{m,h}$ is a maturity/hour fixed effect. Estimated beta coefficients refer to two separately estimated regressions, one in which we restrict the sample to banks with a dollar funding gap above the 75th percentile (“High Funding Gap,” black bars), and another in which we restrict the sample to banks with a dollar funding gap below the 75th percentile (“Low Funding Gap,” gray bars). “MaturityBucket” is a categorical variable that takes the value of 1 for contracts with a maturity shorter than one month (inclusive), the value of 2 for contracts with a maturity between one month (exclusive) and three months (inclusive), and the value of 3 for contracts with maturities longer than three months (exclusive). “End of Quarter” is a dummy variable that equals 1 for any day during the final week of a given quarter, and 0 otherwise. “Short Maturity” refers to the respective estimated beta coefficient where “MaturityBucket”=1, and “Long Maturity” refers to the respective estimated beta coefficient where “MaturityBucket”=3. For more information, refer to Section III.1.

TABLE I
SUMMARY STATISTICS

USD/EUR Forwards Market						
<i>Panel A: Variable (contract level)</i>	Mean	25%	Median	75%	Std	N
Forward premium (in decimals, annualized)	0.04	-0.01	0.01	0.05	0.24	330,773
Forward premium (in decimals, annualized, cleaned for Mat*Day*Hour FE)	0.00	-0.01	0.00	0.01	0.12	226,288
Amount (in logarithm of USD notional amount)	12.36	10.61	12.35	14.29	3.12	330,773
Maturity (in days)	76.59	5.00	27.00	92.00	131.73	330,773
USD/EUR Forwards Participant						
<i>Panel B: Variable (bank and contract level)</i>	Mean	25%	Median	75%	Std	N
HHI	0.04	0.00	0.00	0.01	0.11	330,773
Size (in logarithm of EUR)	26.05	25.55	27.45	27.52	2.26	330,773
Equity ratio	0.05	0.05	0.05	0.06	0.01	330,773
Tier 1 ratio	0.16	0.14	0.15	0.16	0.05	330,773
USD total liabilities (in EUR billion)	134	13	189	209	98	330,773
USD liabilities to foreign affiliates (in EUR billion)	14	0	18	21	11	330,773
USD liabilities to banks (excl. aff., in EUR billion)	16	1	21	24	13	330,773
USD liabilities to non-banks (excl. aff., in EUR billion)	106	9	146	172	78	330,773
USD total liabilities (in logarithm of EUR thousand)	17.37	16.38	19.06	19.16	2.76	330,773
USD liabilities to foreign affiliates (in logarithm of EUR thousand)	16.53	16.66	16.76	17.04	1.42	225,739
USD liabilities to banks (excl. aff., in logarithm of EUR thousand)	14.99	14.55	16.87	16.98	3.36	317,431
USD liabilities to non-banks (excl. aff., in logarithm of EUR thousand)	17.18	16.03	18.80	18.96	2.69	330,773
USD funding gap	0.43	0.24	0.59	0.64	0.31	330,773
CDS spread	114.85	71.52	87.68	164.57	54.89	251,147

Note: This table provides summary statistics of the main variables used in the paper. In Panel A, we provide descriptive statistics on the contract-level variables for USD/EUR forward contracts initiated in the period January 1, 2014, through December 31, 2016. In Panel B, we present summary statistics (contract weighted) on balance sheets of hedging banks, that is, those that sell a USD/EUR forward.

TABLE II
PANEL A: END-OF-QUARTER EFFECTS

Dependent Variable:	Forward Premium (Decimal Per Annum)					
	"End of Quarter" defined as					
	Last Week in Quarter		Last 3 Days in Quarter		Last 2 Weeks in Quarter	
	(1)	(2)	(3)	(4)	(5)	(6)
End of Quarter	0.0347*** (4.52)	0.0974*** (3.58)	0.0333*** (3.90)	0.0977*** (3.28)	0.0095 (1.60)	0.0193 (0.96)
End of Quarter * Log(Maturity)	--	-0.0202*** (-3.17)	--	-0.0215*** (-3.00)	--	-0.0032 (-0.69)
Maturity * Hour FE	Yes	Yes	Yes	Yes	Yes	Yes
Bank FE	Yes	Yes	Yes	Yes	Yes	Yes
Counterparty FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	323,182	323,182	323,182	323,182	323,182	323,182
R-squared	0.137	0.138	0.137	0.138	0.137	0.137

Note: The estimations report the differential effect of forward premia depending on quarter-ends and maturity. The dependent variable is the annualized forward premium implicit in USD/EUR forward contracts between bank “i” and counterparty “j” of maturity “m” initiated during the hour “h” on any given day “t” in the period January 1, 2014, through December 31, 2016. The forward premium refers to the relative difference between the forward rate and the spot rate, prevailing at the time of the forward contract (in decimal p.a.). “End of Quarter” is a dummy variable that equals 1 for any day during the last week of a quarter (columns 1 and 2), last three days (columns 3 and 4), or the last two weeks (columns 5 and 6), and 0 otherwise. Log(Maturity) is the logarithm of the maturity of the forward contract (in days). All regressions are estimated using ordinary least squares. Fixed effects are either included (“Yes”), not included (“No”), or spanned by another set of fixed effects (“-”). A constant is included, but its coefficient is left unreported. Robust t-statistics based on standard errors clustered at maturity, hour, and day are reported in parentheses. Statistical significance at the 10 percent, (5 percent), and [1 percent] levels is indicated by *, (**), and [***], respectively.

TABLE II
PANEL B: THE ROLE OF BANKS' DOLLAR FUNDING GAP

Dependent Variable:	Forward Premium (Decimal Per Annum)						
	End of Quarter (Last Week)				During the Quarter		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Dollar Funding Gap	0.3837*** (2.81)	0.3751*** (2.72)	0.3389** (2.50)	0.3194** (2.30)	0.3445** (2.42)	0.0062 (0.39)	0.0063 (0.39)
Equity Ratio	--	2.0283 (0.86)	--	2.9274 (1.11)	-13.6518 (-1.56)	--	-0.8645 (-0.94)
Tier 1 Ratio	--	--	-0.9535 (-1.10)	-1.1056 (-1.20)	-0.8857 (-0.93)	--	-0.0230 (-0.16)
Contract Value Control	No	No	No	No	Yes	No	Yes
Bank Size Control	No	No	No	No	Yes	No	Yes
Day * Maturity * Hour FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Bank FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Counterparty FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	6,709	6,709	6,709	6,709	6,709	109,291	109,291
R-squared	0.840	0.840	0.840	0.840	0.841	0.724	0.724

Note: The estimations report the effect of hedging demand on forward premia depending on quarter-ends versus during the quarter. The dependent variable is the annualized forward premium implicit in USD/EUR forward contracts between bank “i” and counterparty “j” of maturity “m” initiated during the hour “h” on any given day “t” in the period January 1, 2014, through December 31, 2016. The forward premium refers to the relative difference between the forward rate and the spot rate, prevailing at the time of the forward contract (in decimal p.a.). In columns (1) through (6), we restrict our sample to the last week of any given quarter. In columns (7) and (8), we restrict our estimation to all days but the last week of the respective quarter. In all columns, we exclude forward contracts with maturities shorter than a week. “Dollar Funding Gap” denotes the difference between dollar assets and dollar liabilities, as a fraction of total dollar assets. “Equity Ratio” is the bank’s equity-to-assets ratio, and “Tier 1 Ratio” is the bank’s Tier 1 ratio (core capital as a fraction of total risk-weighted assets). Bank balance sheet variables are lagged and time varying. All regressions are estimated using ordinary least squares. Time-varying controls (lagged logarithm of bank size, contemporaneous logarithm of contract value) and fixed effects are either included (“Yes”) or not included (“No”). A constant is included, but its coefficient is left unreported. Robust t-statistics based on standard errors clustered at maturity, hour, and day are reported in parentheses. Statistical significance at the 10 percent, (5 percent), and [1 percent] levels is indicated by *, (**), and [***], respectively.

TABLE II
PANEL C: THE ROLE OF BANKS' DOLLAR FUNDING GAP DEPENDING ON MATURITY AND BANK CAPITAL

Dependent Variable:	Forward Premium (Decimal Per Annum)			
	End of Quarter (Last Week)		During the Quarter	
	(1)	(2)	(3)	(4)
Dollar Funding Gap * Log(Maturity)	-0.1029*** (-2.81)	-0.2062** (-2.16)	-1.8768* (-1.76)	0.0525 (0.64)
Dollar Funding Gap * Log(Maturity) * Equity Ratio	--	--	27.8436* (1.67)	-0.8259 (-0.61)
Equity Ratio * Log(Maturity)	--	--	-14.7729 (-1.35)	-0.7211 (-1.28)
Contract Value Control	Yes	Yes	Yes	Yes
Day * Maturity * Hour FE	Yes	Yes	Yes	Yes
Bank * Day FE	No	Yes	Yes	Yes
Counterparty * Day FE	No	Yes	Yes	Yes
Observations	6,709	4,966	4,966	63,027
R-squared	0.842	0.908	0.908	0.848

Note: This table replicates the estimation from Panel B but examines the effect of hedging demand on forward premia depending on the contracts' maturity and banks' ex-ante capital levels. The dependent variable is the annualized forward premium implicit in USD/EUR forward contracts between bank "i" and counterparty "j" of maturity "m" initiated during the hour "h" on any given day "t" in the period January 1, 2014, through December 31, 2016. The forward premium refers to the relative difference between the forward rate and the spot rate, prevailing at the time of the forward contract (in decimal p.a.). In columns (1) through (3), we restrict our sample to the last week of any given quarter. In column (4), we restrict our estimation to all days but the last week of the respective quarter. In all columns, we exclude forward contracts with maturities shorter than a week. "Dollar Funding Gap" denotes the difference between dollar assets and dollar liabilities, as a fraction of total dollar assets. "Equity Ratio" is the bank's equity-to-assets ratio. Log(Maturity) is the logarithm of the maturity of the forward contract (in days). Bank balance sheet variables are lagged and time varying. All regressions are estimated using ordinary least squares. Time-varying controls (lagged logarithm of bank size, contemporaneous logarithm of contract value) and fixed effects are either included ("Yes") or not included ("No"). A constant is included, but its coefficient is left unreported. Robust t-statistics based on standard errors clustered at maturity, hour, and day are reported in parentheses. Statistical significance at the 10 percent, (5 percent), and [1 percent] levels is indicated by *, (**), and [***], respectively.

TABLE III
PANEL A: THE ROLE OF GLOBAL DOLLAR LIQUIDITY CONDITIONS AROUND BREXIT

Dependent Variable:	Sample: Brexit Referendum Day +/- 5 Days						
	ON Repo Spread	1W Repo Spread	3M Repo Spread	Forward Premium	Forward Premium	Forward Premium	Forward Premium
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Post Brexit	0.2368*** (3.26)	0.0919** (2.89)	0.0202*** (4.03)	0.1342*** (3.29)	0.2136*** (3.04)	--	--
Post Brexit * Log(Maturity)	--	--	--	--	-0.0432** (-2.35)	--	--
ON Repo Spread	--	--	--	--	--	1.0823*** (5.23)	1.7052*** (4.65)
ON Repo Spread * Log(Maturity)	--	--	--	--	--	--	-0.3304*** (-3.45)
Maturity * Hour FE	No	No	No	Yes	Yes	Yes	Yes
Bank FE	No	No	No	Yes	Yes	Yes	Yes
Counterparty FE	No	No	No	Yes	Yes	Yes	Yes
Observations	11	11	11	5,119	5,119	5,119	5,119
R-squared	0.542	0.481	0.644	0.529	0.533	0.554	0.563

Note: The estimations report the effect of the Brexit vote on respective repo spreads and forward premia. The dependent variable in column (1) is “ON Repo Spread,” that is, the interest rate on an overnight dollar repo contract over the mid-point of the federal funds target range (in percentage points) in column (2) is “1W Repo Spread,” that is, the interest rate on a one week dollar repo contract over the correspondingly dated OIS rate (in percentage points), and in column (3) is “3M Repo Spread,” that is, the interest rate on a three-month dollar repo contract over the correspondingly dated OIS rate (in percentage points). The dependent variable in columns (4) through (7) is the annualized forward premium implicit in USD/EUR forward contracts between bank “i” and counterparty “j” of maturity “m” initiated during the hour “h” on any given day “t.” For all columns, the sample covers the period of plus/minus five trading days around the Brexit vote on June 23, 2016 (from June 16, 2016, through June 30, 2016). The forward premium refers to the relative difference between the forward rate and the spot rate, prevailing at the time of the forward contract (in decimal p.a.). “Post Brexit” is a dummy variable that equals 1 for all days after the Brexit vote on June 23, 2016, and 0 otherwise. Log(Maturity) is the logarithm of the maturity of the forward contract (in days). All regressions are estimated using ordinary least squares. Fixed effects are either included (“Yes”) or not included (“No”). A constant is included, but its coefficient is left unreported. Robust t-statistics based on standard errors clustered at maturity, hour, and day are reported in parentheses. Statistical significance at the 10 percent, (5 percent), and [1 percent] levels is indicated by *, (**), and [***], respectively.

TABLE III
PANEL B: THE ROLE OF GLOBAL DOLLAR LIQUIDITY CONDITIONS AND BANKS' FUNDING COMPOSITION

Dependent Variable:	Sample: Brexit Referendum Day +/- 5 Days				
	Forward Premium (Decimal Per Annum)				
	(1)	(2)	(3)	Maturity <5 days (4)	Maturity >5 days (5)
ON Repo Spread * Log(Dollar Liabilities)	0.4429** (1.96)	0.2340 (1.18)	0.2524 (1.25)	-0.3102 (-0.33)	0.3839** (2.16)
ON Repo Spread * Log(Dollar Liabilities) * Share of Dollar Interbank Funding	--	3.7096*** (3.30)	--	--	--
ON Repo Spread * Log(Dollar Liabilities) * Share of Short-Term Dollar Interbank Funding	--	--	5.1837*** (3.32)	6.6555** (2.16)	1.6548 (1.10)
ON Repo Spread * Share of Dollar Interbank Funding	--	-62.2954*** (-3.35)	--	--	--
ON Repo Spread * Share of Dollar Short-Term Interbank Funding	--	--	-82.6664*** (-3.35)	-104.1829** (-2.04)	-26.1708 (-1.09)
Time-Varying Controls	Yes	Yes	Yes	Yes	Yes
Maturity * Hour FE	Yes	Yes	Yes	Yes	Yes
Day FE	Yes	Yes	Yes	Yes	Yes
Bank FE	Yes	Yes	Yes	Yes	Yes
Counterparty FE	Yes	Yes	Yes	Yes	Yes
Observations	5,119	5,119	5,119	1,897	2,771
R-squared	0.651	0.653	0.653	0.740	0.719

Note: The estimations report the effect of banks' funding composition on forward premia. The dependent variable is the annualized forward premium implicit in USD/EUR forward contracts between bank "i" and counterparty "j" of maturity "m" initiated during the hour "h" on any given day "t." The sample covers the period of plus/minus five trading days around the Brexit vote on June 23, 2016 (from June 16, 2016, through June 30, 2016). The forward premium refers to the relative difference between the forward rate and the spot rate, prevailing at the time of the forward contract (in decimal p.a.). "ON Repo Spread" denotes the interest rate on an overnight dollar repo contract over the mid-point of the federal funds target range (in percent). All regressions are estimated using ordinary least squares. Time-varying controls (lagged logarithm of bank size, contemporaneous logarithm of contract value) and fixed effects are either included ("Yes") or not included ("No"). A constant is included, but its coefficient is left unreported. Robust t-statistics based on standard errors clustered at maturity, hour, and day are reported in parentheses. Statistical significance at the 10 percent, (5 percent), and [1 percent] levels is indicated by *, (**), and [***], respectively.

TABLE IV
THE ROLE OF BANKS' INTERNAL CAPITAL MARKETS

Dependent Variable:	Forward Premium (Decimal Per Annum)						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Log(Internal Capital Transfer)	-0.0464** (-2.06)	-0.0584** (-2.32)	-0.0561** (-2.30)	-0.0370* (-1.70)	-0.0231 (-1.51)	-0.0506** (-2.00)	-0.0613 (-1.17)
Log(Interbank Borrowing)	--	--	-0.0169 (-0.90)	--	--	--	--
Log(Nonbank Borrowing)	--	--	-0.0222 (-0.88)	--	--	--	--
Log(Internal Capital Transfer) * Dollar Funding Gap	--	--	--	-0.0408* (-1.79)	--	--	--
Dollar Funding Gap	--	--	--	0.5713* (1.67)	--	--	--
Log(Internal Capital Transfer) * HHI	--	--	--	--	-0.7428* (-1.66)	--	--
HHI (Herfindahl-Hirschman-Index)	--	--	--	--	9.1975 (1.57)	--	--
Log(Internal Capital Transfer) * End-of-Quarter	--	--	--	--	--	-0.0125** (-2.12)	--
Log(Internal Capital Transfer) * U.S. MMF Investments	--	--	--	--	--	--	0.0257* (1.70)
Bank Size Control	No	Yes	Yes	Yes	Yes	Yes	Yes
Contract Value Control	No	Yes	Yes	Yes	Yes	Yes	Yes
Day * Maturity * Hour FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Day FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Bank FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Counterparty FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	141,602	141,602	141,598	141,602	141,602	141,602	64,951
R-squared	0.875	0.875	0.875	0.875	0.875	0.875	0.890

Note: The estimations report the effect of internal capital markets on forward premia. The dependent variable is the annualized forward premium implicit in USD/EUR forward contracts between bank “i” and counterparty “j” of maturity “m” initiated during the hour “h” on any given day “t” in the period January 1, 2014, through December 31, 2016. In column (8), we restrict our sample to 2016, the year when the money market mutual fund reform became binding. The forward premium refers to the relative difference between the forward rate and the spot rate, prevailing at the time of the forward contract (in decimal p.a.). “Internal Capital Transfer” is a bank’s internal dollar borrowing from related intra-group foreign offices. “Interbank Borrowing” is a bank’s interbank liabilities (excluding intra-group). “Nonbank Borrowing” is a bank’s nonbank liabilities. “Dollar Funding Gap” denotes the difference between dollar assets and dollar liabilities, as a fraction of total dollar assets. “HHI” measures a bank’s concentration in the forward market. “End of Quarter” is a dummy variable that equals 1 for any day during the last week of any given quarter. “U.S. MMF Investments” is the logarithm of U.S. money market mutual funds investments in Germany. All regressions are estimated using ordinary least squares. Time-varying controls (lagged logarithm of bank size, contemporaneous logarithm of contract value) and fixed effects are either included (“Yes”) or not included (“No”). A constant is included, but its coefficient is left unreported. Robust t-statistics based on standard errors clustered at maturity, hour, and day are reported in parentheses. Statistical significance at the 10 percent, (5 percent), and [1 percent] levels is indicated by *, (**), and [***], respectively.

TABLE V
PANEL A: THE ROLE OF BANKS' SHADOW COST OF CAPITAL

Dependent Variable:	Forward Premium (Decimal Per Annum)					
	Below 1 Week	Below 1 Week	1 Week to 3 Months	1 Week to 3 Months	Above 3 Months	Above 3 Months
	(1)	(2)	(3)	(4)	(5)	(6)
Initial Margin (0/1)	-0.0020 (-0.38)	-0.0034 (-0.62)	-0.0069*** (-3.73)	-0.0087*** (-4.60)	-0.0131*** (-2.68)	-0.0137*** (-2.78)
Contract Value Control	No	Yes	No	Yes	No	Yes
Day * Maturity * Hour FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	144,612	144,612	96,228	96,228	32,713	32,713
R-squared	0.860	0.860	0.627	0.627	0.702	0.702

Note: The estimations report the effect of internal margins on forward premia. The dependent variable is the annualized forward premium implicit in USD/EUR forward contracts between bank “i” and counterparty “j” of maturity “m” initiated during the hour “h” on any given day “t” in the period January 1, 2014, through December 31, 2016. The forward premium refers to the relative difference between the forward rate and the spot rate, prevailing at the time of the forward contract (in decimal p.a.). “Initial Margin” is a dummy variable that equals the value for any contract where, ceteris paribus, the forward seller posts initial margin (one-way collateralization), and 0 otherwise. All regressions are estimated using ordinary least squares. Time-varying controls (contemporaneous logarithm of contract value) and fixed effects are either included (“Yes”) or not included (“No”). A constant is included, but its coefficient is left unreported. Robust t-statistics based on standard errors clustered at maturity, hour, and day are reported in parentheses. Statistical significance at the 10 percent, (5 percent), and [1 percent] levels is indicated by *, (**), and [***], respectively.

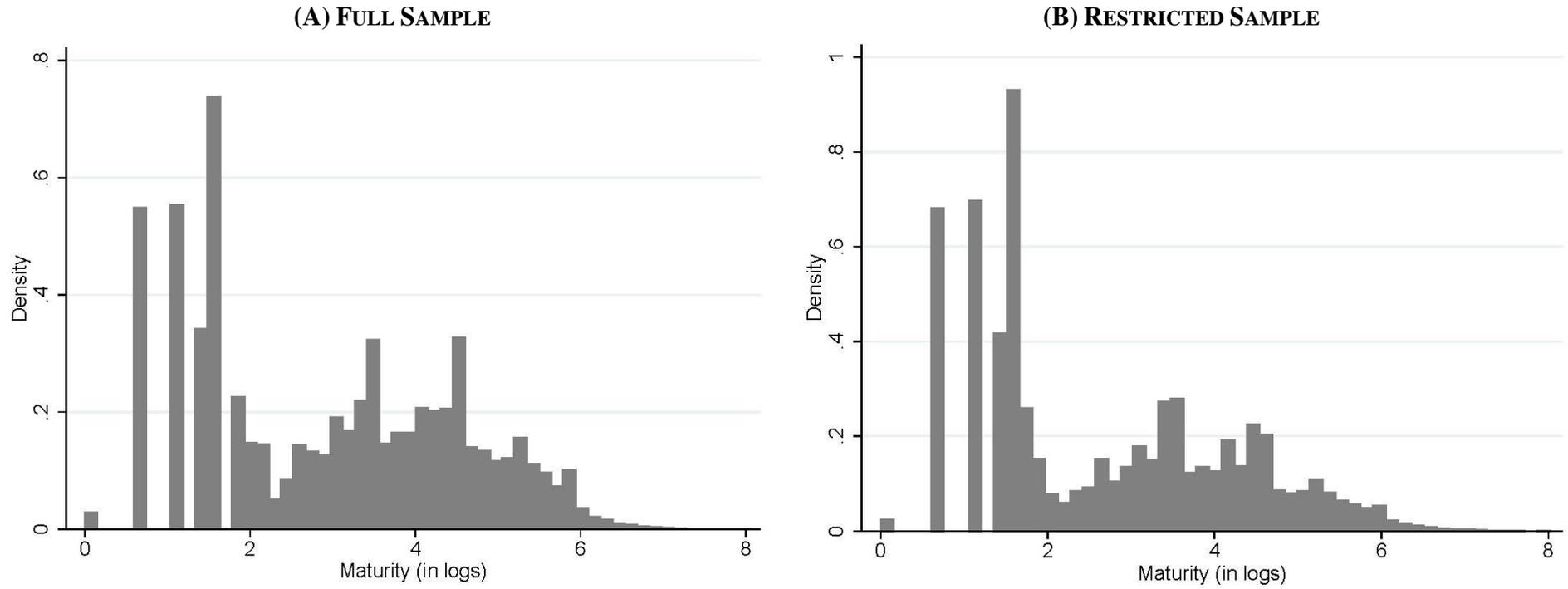
TABLE V
PANEL B: THE ROLE OF BANKS' SHADOW COST OF CAPITAL AND BANK HETEROGENEITY

Dependent Variable:	Forward Premium (Decimal Per Annum)			
	(1)	(2)	(3)	(4)
Initial Margin (0/1)	-0.2642*	-0.1748	-0.0908	-1.6989***
	(-1.94)	(-1.52)	(-0.54)	(-6.73)
Equity Ratio	1.2545**	1.2709**	1.0253	--
	(2.27)	(2.30)	(1.25)	
Initial Margin * Equity Ratio	5.1640*	4.7771*	5.5211*	32.8764***
	(1.92)	(1.92)	(1.84)	(6.69)
Tier 1 Ratio	--	0.1717	0.3911*	--
		(1.18)	(1.76)	
Initial Margin * Tier 1 Ratio	--	-0.4852	-1.1168	--
		(-1.22)	(-1.29)	
Log(CDS Spread)	--	--	-0.0031	--
			(-0.32)	
Initial Margin * Log(CDS Spread)	--	--	-0.0061	--
			(-0.34)	
Contract Value Control	Yes	Yes	Yes	Yes
Day * Maturity * Hour FE	Yes	Yes	Yes	Yes
Bank FE	Yes	Yes	Yes	-
Counterparty FE	Yes	Yes	Yes	-
Bank * Day FE	No	No	No	Yes
Counterparty * Day FE	No	No	No	Yes
Observations	30,210	30,210	25,501	21,840
R-squared	0.845	0.846	0.859	0.903

Note: The estimations report the effect of *relative* internal margins on forward premia depending on bank heterogeneity. The dependent variable is the annualized forward premium implicit in USD/EUR forward contracts between bank “i” and counterparty “j” of maturity “m” initiated during the hour “h” on any given day “t” in the period January 1, 2014, through December 31, 2016. The forward premium refers to the relative difference between the forward rate and the spot rate, prevailing at the time of the forward contract (in decimal p.a.). “Initial Margin” is a dummy variable that equals the value for any contract where, ceteris paribus, the forward seller posts initial margin (one-way collateralization), and 0 otherwise. “Log(CDS Spread)” refers to lagged, bank-level time-varying five-year senior secured CDS spread. All regressions are estimated using ordinary least squares. Time-varying controls (contemporaneous logarithm of contract value) and fixed effects are either included (“Yes”) or not included (“No”). A constant is included, but its coefficient is left unreported. Robust t-statistics based on standard errors clustered at maturity, hour, and day are reported in parentheses. Statistical significance at the 10 percent, (5 percent), and [1 percent] levels is indicated by *, (**), and [***], respectively.

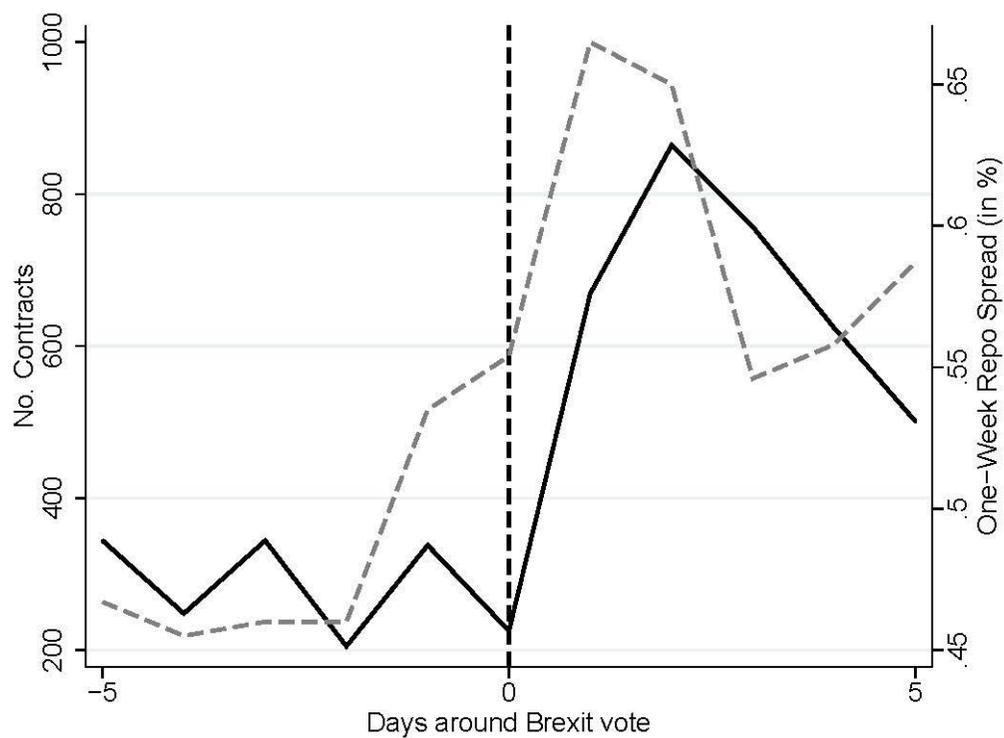
APPENDIX

FIGURE A.1
MATURITY DISTRIBUTION FOR DIFFERENT SAMPLES



Note: This figure presents the distribution of maturities implicit in USD/EUR forward contracts initiated in the period January 1, 2014, through December 31, 2016. Subfigure (A) presents the full sample including all forward contracts, while Subfigure (B) refers to a sample restricted to comply with our identification maturity*day*hour fixed effects.

FIGURE A.2
NUMBER OF FORWARD CONTRACTS AROUND BREXIT REFERENDUM



Note: This figure shows the evolution of the daily number of USD/EUR forward contracts (solid black line, left scale) for the period of plus/minus five trading days around the Brexit vote on June 23, 2016 (from June 16, 2016, through June 30, 2016). The vertical dashed line refers to the day of the Brexit referendum. “One-Week Repo Spread” (dashed gray line, right scale) denotes the interest rate on a one-week dollar repo contract over the correspondingly dated OIS rate (in percentage points).

TABLE A.1
CONTRACT AMOUNT AND NUMBER OF CONTRACTS AT THE END OF QUARTER

PANEL A: CONTRACT VALUE (CONTRACT LEVEL)

Dependent Variable:	Log(Value of Forward Contract)					
	"End of Quarter" defined as					
	Last Week in Quarter		Last Week in Quarter		Last Week in Quarter	
	(1)	(2)	(3)	(4)	(5)	(6)
End of Quarter	-0.0044 (-0.17)	0.0191 (0.34)	0.0119 (0.48)	-0.0146 (-0.28)	-0.0106 (-0.62)	-0.0361 (-0.93)
End of Quarter * Log(Maturity)	--	-0.0078 (-0.56)	--	0.0086 (0.67)	--	0.0084 (0.89)
Maturity * Hour FE	Yes	Yes	Yes	Yes	Yes	Yes
Bank FE	Yes	Yes	Yes	Yes	Yes	Yes
Counterparty FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	323,182	323,182	323,182	323,182	323,182	323,182
R-squared	0.767	0.767	0.767	0.767	0.767	0.767

PANEL B: NUMBER OF CONTRACTS (BANK LEVEL)

Dependent Variable:	Number of Forward Contracts					
	"End of Quarter" defined as					
	Last Week in Quarter		Last 3 Days in Quarter		Last 2 Weeks in Quarter	
	(1)	(2)	(3)	(4)	(5)	(6)
End of Quarter	0.4174** (2.45)	2.5931** (2.19)	0.2365* (1.73)	1.6012 (1.63)	0.1579 (1.52)	1.0900 (1.43)
End of Quarter * Log(Maturity)	--	-0.5190** (-2.11)	--	-0.3194 (-1.58)	--	-0.2181 (-1.40)
Maturity FE	Yes	Yes	Yes	Yes	Yes	Yes
Bank FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	105,361	105,361	105,361	105,361	105,361	105,361
R-squared	0.322	0.323	0.322	0.322	0.322	0.322

Note: This table replicates the estimation of Table II Panel A for two different dependent variables. In Panel A, the dependent variable is the logarithm of the notional amount implicit in USD/EUR forward contracts between bank “i” and counterparty “j” of maturity “m” initiated during the hour “h” on any given day “t” in the period January 1, 2014, through December 31, 2016. In Panel B, the dependent variable is the logarithm of the number of USD/EUR forward contracts of bank “i” of maturity “m” initiated on any given day “t” in the period January 1, 2014, through December 31, 2016. “End of Quarter” is a dummy variable that equals 1 for any day during the last week of a quarter, and 0 otherwise. Log(Maturity) is the logarithm of the maturity of the forward contract (in days). All regressions are estimated using ordinary least squares. Fixed effects are either included (“Yes”), not included (“No”), or spanned by another set of fixed effects (“-”). A constant is included, but its coefficient is left unreported. Robust t-statistics based on standard errors clustered at maturity and day are reported in parentheses. Statistical significance at the 10 percent, (5 percent), and [1 percent] levels is indicated by *, (**), and [***], respectively.

TABLE A.1 – CONTINUED
PANEL C: THE ROLE OF BANKS’ DOLLAR FUNDING GAP FOR NUMBER OF CONTRACTS

Dependent Variable:	Number of Forward Contracts						
	End of Quarter (Last Week)					During the Quarter	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Dollar Funding Gap	2.0071*** (3.41)	1.6825*** (2.71)	2.0021*** (3.39)	1.6764*** (2.67)	1.3794** (2.31)	0.9237*** (8.75)	0.8718*** (7.96)
Equity Ratio		35.7836 (1.51)		35.8240 (1.50)	63.6192*** (2.83)		-2.2216 (-0.36)
Tier 1 Ratio			0.8589 (0.14)	0.9833 (0.16)	-1.9729 (-0.27)		2.3311 (1.42)
Bank Size Control	No	No	No	No	Yes	No	Yes
Maturity FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Bank FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	5,520	5,520	5,520	5,520	5,520	92,034	92,034
R-squared	0.134	0.134	0.134	0.134	0.134	0.080	0.080

Note: This table replicates the estimation of Table II Panel B for the number of forward contracts at the bank level. The dependent variable is the logarithm of the number of USD/EUR forward contracts of bank “i” of maturity “m” initiated on any given day “t” in the period January 1, 2014, through December 31, 2016. In columns (1) through (5), we restrict our sample to the last week of any given quarter. In columns (6) and (7), we restrict our estimation to all days but the last week of the respective quarter. “Dollar Funding Gap” denotes the difference between dollar assets and dollar liabilities, as a fraction of total dollar assets. “Equity Ratio” is the bank’s equity-to-assets ratio, and “Tier 1 Ratio” is the bank’s Tier 1 ratio (core capital as a fraction of total risk-weighted assets). Bank balance sheet variables are lagged and time varying. All regressions are estimated using ordinary least squares. Time-varying controls (lagged logarithm of bank size, contemporaneous logarithm of contract value) and fixed effects are either included (“Yes”) or not included (“No”). A constant is included, however, its coefficient is left unreported. Robust t-statistics based on standard errors clustered at maturity and day are reported in parentheses. Statistical significance at the 10 percent, (5 percent), and [1 percent] levels is indicated by *, (**), and [***], respectively.