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The pricing of FX forward contracts: micro evidence from banks' dollar hedging

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Non-technical summary

Research question

A significant share of German banks' assets (credit, securities and alike) is denominated in U.S. dollars, while they mainly fund themselves in euros. As a result, these banks rely heavily on synthetic dollar funding, whereby they convert borrowed euros into dollars using the foreign exchange (FX) spot market. The resulting FX risk is then hedged by initiating a forward dollar sale. By using a forward contract, the exchange rate at which the future cross-currency cash flow can be converted back into euros is specified today. That is, these two legs of the transaction ("swap") allow switching currencies for a pre-specified period. The standard international finance textbook view postulates that the price for these contracts should vary only with the interest rate differential of the involved currencies. In this paper, we examine whether the price also depends on key characteristics of those banks that use these contracts to hedge their synthetic dollar funding.

Contribution

Our study helps us to improve our understanding of how and at what price different banks fund their foreign currency-denominated assets and whether this reveals so far unknown risks to financial stability. Empirical evidence on the determinants of banks' hedging costs is scarce, most likely due to the lack of micro data on FX forward contracts, which are typically traded over-the-counter and thus notoriously hard to obtain. Our paper fills this gap by using novel data (available under European Market Infrastructure Regulation, EMIR) on German banks' U.S. dollar forwards sales at the contract level.

Results

Our findings strongly suggest that hedging costs vary with bank-specific characteristics. Price deviations beyond variations in the interest rate differential indeed vary across banks and can be linked to key bank-level variables. Our study shows that price dispersion and thus the cost of dollar hedging increases with banks' dollar funding gap and the lack of alternative refinancing options to immediate trade. This result is particularly present in the period shortly before the regulatory quarter-end reporting day. We can show that the costs of dollar hedging depend on banks' dollar funding composition in terms of the source and rollover structure, are lower for banks with deeper internal dollar capital markets, and increase with banks' shadow cost of capital. These results bear three important implications: (i) good capitalization of the bank renders it more resilient against funding liquidity shocks; (ii) when running a large US dollar book, a solid on-shore dollar funding base and internal capital markets are key to avoid being caught wrong-footed when dollar funding liquidity dries up in off-shore markets; (iii) supervisory point-in-time reporting policy of regulatory measures induces further price variation before these key reporting days.

NICHTTECHNISCHE ZUSAMMENFASSUNG

FORSCHUNGSFRAGE

Ein bedeutender Teil der Aktiva (Kredite, Wertpapiere und Ähnliches) deutscher Banken ist in US-Dollar denominiert, während sie sich hauptsächlich in Euro refinanzieren. Daher sind sie stark auf eine synthetische Dollarfinanzierung angewiesen, wobei sie ihre Euro-Einlagen am Devisenmarkt in US-Dollar umtauschen. Das so entstandene Währungsrisiko wird dadurch eliminiert, dass Banken die US-Dollar am Terminmarkt wieder in Euro zurücktauschen. Am Terminmarkt wird für einen künftigen Zeitpunkt bereits heute der Preis für den Rücktausch festgelegt. Durch den zeitgleichen Abschluss beider Geschäfte (Swaps) werden so die Einlagen zweier Währungen für einen festgelegten Zeitraum risikofrei getauscht. Nach gängiger Lehrbuchmeinung variiert der Preis für den zeitweisen Tausch von Einlagen verschiedenen Währungen nur mit der Zinsdifferenz zwischen den betreffenden Währungspaaren. Wir untersuchen in unserer Arbeit, ob der Preis zudem von den Eigenschaften der Banken abhängt, die solche Swaps nutzen, um ihre US-Dollarfinanzierung abzusichern.

BEITRAG

Die Untersuchung hilft uns deutlich besser als bisher zu verstehen, wie und zu welchem Preis unterschiedliche Institute ihre Fremdwährungsaktiva refinanzieren und ob dadurch neue Risiken entstehen können oder bestehende Risiken größer sind als bislang angenommen. Bislang existiert hierüber kaum empirische Evidenz, nicht zuletzt aufgrund mangelnder Mikrodaten. Da diese Verträge in der Regel nicht an Börsen, sondern unmittelbar zwischen den Parteien abgewickelt werden, lagen bislang keine Informationen auf Einzelvertragsbasis vor. Für unsere Analysen nutzen wir einen neuen Datensatz (auf Basis der European Market Infrastructure Regulation, EMIR) über US-Dollar-Absicherungsgeschäfte deutscher Banken auf Einzelvertragsebene.

ERGEBNISSE

Unsere empirische Untersuchung liefert starke Hinweise dafür, dass die Preise durchaus mit bankspezifischen Eigenschaften variieren. Die Abweichung der Preise vom Zinsdifferential zwischen dem US-Dollar und dem Euro lässt sich über Banken hinweg nachweisen und hängt stark von bankspezifischen Einflussgrößen ab. Unsere Analyse zeigt, dass die Preisabweichungen und damit der Preis für das Geschäft größer sind, wenn die US-Dollar Finanzierungslücke groß ist und kaum alternative Refinanzierungsmöglichkeiten offen stehen. Dies gilt insbesondere in die Zeit unmittelbar vor regulatorischen Stichtagen. Wir können zeigen, dass Preise von der Zusammensetzung sowie der Fristigkeit der Dollarfinanzierungsquelle einer Bank abhängen, für Banken, denen interne Kapitalmärkte zur Verfügung stehen, geringer sind und mit der geforderten Kapitalrendite steigen. Diese Ergebnisse haben drei wichtige Implikationen: (i) besser kapitalisierte Banken können Liquiditätsschocks besser absorbieren; (ii) eine solide interne Dollarfinanzierungsbasis ist für alle Banken mit einem Dollaranlagebuch entscheidend, wenn externe Dollarfinanzierungsquellen austrocknen; (iii) müssen regulatorischer Kennziffern gegenüber der Aufsicht nur stichtagsbezogen offengelegt werden, so begünstigt dies zusätzliche Preisvariation in der Zeit unmittelbar vor dem Stichtag.

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

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Abstract

Using *transaction-level* data on foreign exchange (FX) forward contracts, we document large demand-driven heterogeneity in banks' dollar hedging costs. For identification, we exploit regulatory end-of-quarter reporting that penalizes banks' currency exposure with capital surcharges. Contracts that reduce quarter-end currency exposure trade at higher prices, specifically for banks with high dollar funding gaps and high leverage, while access to internal dollar capital markets and bargaining power reduces prices. Spreads between similar contracts with and without initial margin widen with leverage. Our results suggest that banks' shadow costs of capital are important for the international propagation of shocks through FX derivatives markets.

Key words: FX markets, hedging, price determination, global banks, international finance

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

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I. INTRODUCTION

A striking fact in international finance is that a large share of dollar-denominated intermediation is performed by internationally active 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, these 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 derivatives 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 individual banks' hedging costs is scarce, most likely due to the lack of micro data on FX forward contracts traded over the counter (OTC), which are crucial for identification.

In this paper, we aim to fill this gap by empirically investigating the cost of banks' dollar hedging using novel *contract-level data* on all German banks' USD/EUR forward sales.[2] The starting point of our analysis is the international finance textbook view on FX forward pricing, which postulates that the forward premium—the relative difference between the dollar forward and spot exchange rate—relates to only time-varying factors, specifically to the respective interest rate differential (covered interest parity). In contrast to this view, we show that forward premia vary substantially across banks for contracts of the same maturity initiated on the same day. In fact, even if we compare contracts with the same counterparty (i.e., controlling for supply effects) in addition to the same maturity and the same day, we find an economically large cross-sectional dispersion (standard deviation of 74 basis points) in the forward premia.[3] This price variation is not driven by peculiar types of banks or contracts in our sample (e.g., small or domestically focused banks, client trades, etc.) but instead is a broad phenomenon among German banks, which account for about 21 percent of the entire turnover in the European FX forward market.

[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.
[2] Note that we observe actual transactions. Given the OTC-structure of the forward market, it is impossible to assess to how many other counterparties an investor reached out prior to the actual transaction and failed to initiate trade.
[3] Supply effects in the FX derivatives market have been studied recently by Du, Tepper, and Verdelhan (2018).

Our analysis on the determinants of the cross-sectional variation in banks' dollar hedging builds heavily on insights from the theoretical OTC asset pricing literature according to which search and bargaining frictions can lead to price dispersion for otherwise similar assets. Most theories of price formation for OTC-traded assets are based on modeling the bilateral bargaining process between the investor and its counterparty. In particular, these theories suggest that the price an investor is able to bargain depends on the investor's valuation of outside options (alternatives) to entering the contract, resulting, for example, from the availability of other trading partners, both in the same market (Duffie, Gârleanu, and Pedersen 2005 and 2007) and in different asset markets (Weill 2002, Vayanos and Weill 2008, Lagos and Rocheteau 2009). Moreover, in many models the extent to which outside options influence the bargaining process and affect transaction prices depends crucially on the relative bilateral bargaining power of the contracting counterparties (e.g., Afonso and Lagos 2015). We adopt the view that differences in (availability and valuation of) outside options are key determinants of heterogeneous hedging demand that, if bargaining frictions persist, leads to price dispersion of FX forwards.[4]

To analyze the effect of outside options on banks' heterogeneous hedging costs, we exploit a key feature of the current banking regulation: The financial regulator imposes capital charges on any bank with a mismatch between foreign-currency-denominated assets and liabilities. Importantly, for German banks, as opposed to U.S. and U.K. banks, the financial regulator assesses banks' currency mismatch only on the final day of each calendar quarter using end-of-quarter snapshots of both on-balance-sheet and off-balance-sheet positions. As a result, German banks face large capital charges if on-balance-sheet currency exposure remains unhedged on the regulatory reporting day, in particular, because German banks have economically meaningful dollar funding gaps; that is, their on-balance sheet dollar assets exceed their on-balance-sheet dollar liabilities, thereby creating currency exposure (e.g., for 10 percent of the banks in our sample, we find that this dollar funding gap is larger than 60 percent).[5] By entering into a dollar forward sale (an off-balance-sheet dollar liability) that matures after the regulatory assessment

[4] In the context of FX forwards, a bank's outside option to immediate trade is determined, on the extensive margin, by the fundamental choice to either hedge or leave the currency exposure unhedged, and, on the intensive margin, by the contract type for the hedge (e.g., maturity, counterparty, or collateralization).

[5] A comparison with aggregate BIS data available for other countries also shows that economically sizable dollar funding gaps hold for several other banking systems and is not specific to the German banking system. For example, aggregate BIS banking statistics indicate that, in 2016:Q2, Japanese banks' consolidated dollar funding gap exceeded 45 percent of their total dollar assets, Canadian banks' consolidated dollar funding gap was about 25 percent of their total dollar assets, and for British banks the number was about 10 percent. For other euro area countries, BIS data indicate that Italian and Spanish banks had a funding gap of 19 percent and 9 percent, respectively.

day, a bank can decrease its currency exposure, thereby reducing regulatory capital charges.[6] Thus, a bank's demand for cross-quarter contracts depends crucially on its shadow cost of capital.

Therefore, as a first step, we examine the average differential pricing of forward dollar contracts that cross the upcoming quarter-end day (cross-quarter contracts). Across all banks, we find that, on average, cross-quarter forward contracts trade at a 10-basis-point-higher forward premium compared to similar contracts (same maturity, contract value, bank, and counterparty). In annualized terms, this cross-quarter premium amounts to a sizeable 2.9 percentage points. While this differential pricing of cross-quarter forwards is irrespective of the actual contract maturity, we also show that, in general, shorter-term forwards are cheaper in absolute terms, i.e., actual rate paid instead of relative annualized premium. Thus, for a bank that seeks to hedge its currency exposure only for a short period of time (e.g., around quarter-ends), entering a short-term contract is a cost-effective strategy. Consistent with this argument, we document that during the final week of each quarter, on average, notional values of banks' dollar forward sale contracts increase by 9 percent, which is driven specifically by an expansion of short-term contracts.

In the next step, we examine the role of differences in banks' dollar funding gaps in the heterogeneous pricing of similar cross-quarter forward sales. This helps test whether a bank's valuation of entering a forward contract—as opposed to leaving on-balance-sheet currency exposure unhedged—depends on its shadow cost of capital. We find that, consistent with a higher valuation for cross-quarter contracts, ex-ante high-dollar-funding-gap banks, i.e., banks that would face higher capital charges if their FX risk exposure were left unhedged, pay significantly higher premia for short-term cross-quarter forward contracts compared to low-dollar-funding-gap banks. Our estimates suggest that a bank with a one-standard-deviation-higher funding gap pays 34 basis points more for a one-week cross-quarter contract compared to a three-month cross-quarter contract. Moreover, the differential effect between high- and low-dollar-funding-gap banks is more than twice as large for high-leverage banks, i.e., banks with a larger funding gap pay significantly more for their cross-quarter dollar hedging if they have lower capital levels. Importantly, we identify these cross-sectional differential effects by

[6] For example, a bank with a positive dollar funding gap, which, before the regulatory quarter-end day, agrees to deliver dollars at some point in the future after the quarter-end day, effectively enters a dollar liability and thereby reduces its currency exposure.

comparing contracts of the same maturity, initiated on the same day, and with the same counterparty (by employing counterparty*maturity*day fixed effects). Thus, we can ensure that our results are not driven by potential time-varying, counterparty-specific changes in the supply of forward contracts around quarter-ends (e.g., capital-constrained dealers that reduce the supply of forward contracts to comply with their own regulatory requirements as in Du, Tepper, and Verdelhan 2018).[7]

Moreover, we exploit supervisory information on banks' dollar funding from related offices of the same banking group (intragroup transfers) to analyze the role of access to direct U.S. dollar funding as an alternative to the forward market. Using a similar identification strategy, we find that banks with ex-ante higher funding gaps are able to negotiate better prices for cross-quarter forward contracts if they have the ability to draw on internal dollar funding. In particular, we find that a bank with a one-standard-deviation-larger dollar funding gap would face on average a 8-basis-point-lower forward premium if the bank has a one-standard-deviation higher intragroup dollar funding share (relative to all dollar liabilities), but the differential effects are smaller for contracts of shorter maturities. The same holds if we look at the net intragroup liability share, thereby accounting for the possibility that banks with a large share of intragroup liabilities could also be important provider of intragroup funding. If we restrict our sample to banks that have (non-zero) intragroup liabilities, we find that, in particular, banks with access to short-term intragroup funding pay less for cross-quarter contracts.

Further, to better understand how heterogeneous demand for cross-quarter forward contracts can create such large price differentials for similar forward contracts, we examine—in accordance with the OTC-literature, e.g., Afonso and Lagos (2015)—whether bargaining frictions interact with demand heterogeneity to generate price dispersion. To that end, we compare contracts of the same maturity, traded with the same dealer bank on the same day and find that banks with a one-standard-deviation-higher funding gap pay on average 159 basis points less if they are dealer banks themselves (as compared to being a client bank). Moreover, high-dollar-funding-gap banks that are more sophisticated in terms of having access to more counterparties in the forward market, are able to obtain better prices for their cross-quarter forward dollar sales. Interestingly, we also find that our proxies for bank-level bargaining power

[7] In our regressions, we also control for differences in contract value, time-varying bank size, and any time-invariant unobserved bank heterogeneity, thus accounting for compositional shifts in the sample of banks that may differ for cross-quarter contracts.

are economically and statistically less important for the pricing of forward contracts of short maturity. We explain this finding by showing that the short-term segment of the FX forward market is the most liquid as measured by having more available dealers and counterparties on both sides of the market, a larger number of trades, and lower variation in forward premia.

Finally, we extend our analysis to include contracts for which collateral is posted (previous results are all based on unsecured contracts for a clean comparison). This allows us to examine the effect of heterogeneous capital valuation—i.e., the shadow cost of capital—on the pricing of forward contracts more generally.[8] We find that, for the same bank, the spread between the forward premia of uncollateralized contracts and contracts where the bank posts collateral increases (becomes more negative) with maturity, irrespective of whether the contracts cross the upcoming quarter-end. That is, in general, collateralized contracts trade at a discount that increases with maturity, after one accounts for compositional differences in the sample of banks that sell collateralized versus uncollateralized contracts, as well as differences in counterparties and contract maturities and values. Moreover, consistent with Gârleanu and Pedersen (2011), we find that spreads between contracts with initial margin and those without it are larger for low-equity (i.e., high-leverage) banks. Our coefficient estimate suggests that a one-standard-deviation (0.77 percentage points) fall in equity ratio increases the differential by 5.5 basis points, on average across all maturities. These results are robust to netting out common counterparty-specific time-varying and maturity-specific supply effects, as well as time-varying bank heterogeneity.

RELATED LITERATURE

Our results contribute to the literature in several ways. First, we contribute to the growing body of research on the dollar's dominance in international financial markets and the special role (non-U.S.) banks play in global dollar intermediation. For example, Shin (2016) and Avdjiev et al. (2016) discuss the relationship between the strength of the dollar and global financial conditions. Ivashina, Scharfstein, and Stein (2015) and Bräuning and Ivashina (2017) document

[8] Note that we have already been examining this in the context of cross-quarter forward contracts and banks with different dollar funding gaps. A bank that has a positive dollar funding gap reveals that its cost (i.e. funding valuation) for direct dollar funding are higher than the costs for raising dollars through synthetic funding. This implicitly measures a bank's shadow cost of dollar funding, which has been shown to be closely related to the shadow cost of capital (Gârleanu and Pedersen 2011, Ivashina, Scharfstein, Stein 2015).

a strong dollar dominance in international bank credit, which Gopinath and Stein (2018) link to the importance of the dollar as the invoicing currency in global trade. Non-U.S. banks' crucial reliance on direct wholesale dollar funding markets due to their lack of a strong dollar deposit base is discussed, e.g., in Aldasoro, Ehlers, and Eren (2017) and Rime, Schrimpf, and Syrstad (2017). We add to this literature by providing micro evidence that the cost of synthetic dollar funding using the FX derivatives market depends on banks' dollar funding gaps, in particular, through banks' shadow cost of capital. Thereby, our results highlight the role of shadow cost of capital in the international transmission of shocks and as a source of financial stability risks. In this respect, we also add to the 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).

Second, our paper relates to the recent literature that studies the pricing of FX forwards and swaps; in particular, it relates to the recent research that focuses on persistent violations of covered interest parity (CIP). For example, using aggregate data, Borio et al. (2016) and Du, Tepper, and Verdelhan (2018) argue that deviations from the parity condition are caused by constraints on the supply side where arbitrageurs cannot expand their balance sheet due to leverage constraints. Consistent with these supply-side arguments, Cenedese, Della Corte, and Wang (2018) show that CIP deviations are larger for high-leverage dealers after a change in the U.K. leverage ratio framework. We complement these studies by using novel contract-level data to identify significant price variation in similar forward contracts. In particular, we show that, after we control for time-varying supply-side heterogeneity at the counterparty level, cross-sectional price differentials still exist and depend crucially on banks' dollar hedging demand.

Third, our paper is related to the literature that studies the effect of regulation on financial markets and banking in a broader context (e.g., Allen and Saunders 1992 and Hamilton 1996 in banking, Koijen and Yogo 2016 in insurance). In particular, the focus of recent studies has highlighted that post-crisis banking regulation has substantially tightened capital and liquidity requirements, thereby affecting banks' cost of capital (Kisin and Manela 2016). Abbassi et al. (2018) find that banks adjust their asset holdings of riskier securities and loans before supervisory audits, but undo these changes after the audits. Similarly, recent papers have argued that end-of-period effects in several financial markets are related to this increased bank capital regulation (e.g., Munyan 2015 in the repo market, Anderson and Huther 2016 for the Fed's reverse repo facility). Using unique contract-level data, which is crucial for identification, we are able to show the effect of banking regulation, in particular, end-of-quarter reporting, on the FX forward market. Our results suggest that the increased cost of forwards that cross the quarter-end are driven by banks' desire to close FX exposure and avoid capital surcharges when the regulator assesses banks' on- and off-balance-sheet positions (i.e. window dressing).

Fourth, our study relates to the asset-pricing literature that studies the role of an OTC market structure as well as margin requirements. In particular, this literature has shown that assets with similar cash flows can have substantially different prices due to market liquidity (Brunnermeier and Pedersen 2009, Gorton and Metrick 2012) and institutional frictions such as search and bargaining frictions in OTC markets (Duffie, Gârleanu, and Pedersen 2005 and 2007, Vayanos and Weill 2008). Consistent with the theoretical OTC asset pricing literature, we provide empirical evidence that heterogeneous outside options in combination with bargaining power generates price dispersion in the FX forward market.[9] Moreover, we provide direct empirical evidence of the margin-based asset pricing model of Gârleanu and Pedersen (2011) by showing that price gaps exist between forwards with identical cash flows but different margins (collateralized versus uncollateralized forwards) and that the size of the gaps depends on relative capital positions in the cross-section of banks.

Finally, we 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, Bräuning and Ivashina 2017). The study by 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' foreign currency liquidity and risk management.

The remainder of the paper is organized as follows: Section II describes our data. Section III lays down the economic framework and develops testable hypotheses. Section IV provides our empirical results, and Section V concludes.

[9] Hau et al. (2018) show that dealers exert price discrimination against clients in OTC derivatives markets.

II. DATA DESCRIPTION AND SUMMARY STATISTICS

We study the pricing of FX forward contracts using supervisory data on FX derivatives that we obtained from the 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. More precisely, the European Markets Infrastructure Regulation (EMIR)—the European analogue to the U.S. Dodd-Frank Act—grants the Deutsche Bundesbank access to all derivatives trades when at least one of the involved parties is based in Germany. The raw data that we observe include all FX derivatives contracts that were initiated during the period January 2014 through December 2016, including information on the contracting parties, the initiation day, contract maturity, the type of contract, the currency traded, the notional value (expressed in both currencies), the forward rate, and the type of collateralization.

For our analysis, we process this raw data as follows: We focus on the most liquid and economically most relevant FX derivatives market, the USD/EUR market (BIS 2016), and restrict the dataset to forward contracts, which is by far the most frequently used FX derivatives instrument (forwards account for more than two thirds of all contracts in our sample). Given our research question, we also devote our attention to all forward transactions in which a German bank *sells a dollar forward*. 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. A bank that agrees to sell dollars forward has a revealed demand for euro, most notably, because the bank relies heavily on euro funding.

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. Because we observe forward contracts at the institution (bank) level, we also exclude intragroup transactions, that is, contracts between two banks that are part of the same bank holding company. In our main analysis, we exclude collateralized transactions and only focus on forward contracts, where neither the seller nor the buyer posts any initial or variation margin.[10] By focusing on uncollateralized forwards, we can compare prices of contracts with otherwise similar characteristics, i.e., same counterparty, same maturity, same contract value, same initiation time and date. For collateralized contracts, one would need the exact type of collateral pledged and

[10] However, in Section IV.4, we further exploit the role of initial margins to examine how bank capitalization and margin requirements affect the pricing of FX forwards.

the haircuts imposed for a similarly clean comparison across contracts, which we do not observe in the data. Moreover, uncollateralized contracts are the major bulk of contracts in our sample (46 percent of all trades, while 43 percent are collateralized and 11 percent undefined, see Table 1). Finally, to ensure that our results are not driven by outliers, we trim the data by removing contracts with the largest and smallest 2.5 percent of forward rates.

Throughout the analysis, we express the forward exchange rate in terms of U.S. dollars per euro. That is, all else being equal, a higher forward rate requires the seller to deliver more U.S. dollars for any given value of euros received, making a USD/EUR forward contract more expensive from the seller's perspective. In Figure 1 we show that daily median USD/EUR forward rates from the transactions in our sample follow closely the aggregate forward rates that we retrieved from Bloomberg, providing external validity for our sample of contracts. Following the standard practice in the literature (e.g., Du, Tepper, and Verdelhan 2018), we express the forward rate as the forward premium throughout our analysis; that is, we rewrite it as the *relative difference* (in basis points) between the rate of the individual USD/EUR forward contract and the USD/EUR spot exchange rate prevailing on the day of contract initiation: $Forward\ Premium = (Forward\ Rate/Spot\ Rate - 1) * 10{,}000$. Hence, the forward premium measures the 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.

In Table 2, we provide summary statistics on key contract characteristics, notably the forward premium, contract value and maturity. Our final dataset contains 261,467 forward contracts between 145 different German banks and a total of 14,485 distinct counterparties. On average, we observe 732 forward contracts per day, with an average notional value of USD 8.89 million per trade. The average maturity is 81 days, but 50 percent of all contracts have maturities below one month, while contracts with a maturity of longer than three months account for less than 15 percent of all contracts. Thus, the forward market, similar to other liquidity markets, is very short-term in nature (see also Appendix Figure A.1 for the maturity breakdown). The average forward premium amounts to 51 basis points and varies substantially with a standard deviation of 203 basis points during our sample period; that is, on average, a forward dollar sale settles at 51 basis points above the respective FX spot rate prevailing on the same day.

However, based on aggregate data, we already know that forward premia differ across contracts, in particular, depending on contract maturity and initiation day, as suggested by covered interest parity. Moreover, the forward premium may also vary across different counterparties (e.g., dealers versus non-dealers). Therefore, we clean the forward premium by counterparty*maturity*day fixed effects to isolate the variation of forward premia for contracts of the same maturity, initiated with the same counterparty on the same day.[11] The remaining variation is thus related to different premia across banks for otherwise identical contracts, precisely the variation that we are interested in explaining in this paper. Table 3 shows that even these cleaned forward premia have substantial cross-sectional variation with a standard deviation of 74 basis points. This price dispersion is economically meaningful, in particular, considering that the premia are charged for contracts with the same counterparty, for the same maturity, initiated on the same day. Moreover, as Figure 2 shows, the cross-sectional price dispersion is a persistent phenomenon throughout the entire sample period.

Given the significant price variation across banks for otherwise similar forward contracts, we merge the contract-level data on forward sales with confidential bank-level information, which allows us to relate pricing differences to individual bank characteristics. First, we merge our dataset on forward contracts with confidential supervisory balance-sheet information that is available at a monthly frequency.[12] The information includes each bank's equity and total assets. Second, from reports on external positions (Auslandsstatus) maintained by the Deutsche Bundesbank, we obtain data on each bank's FX-denominated assets and liabilities. These reports provide, for each 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). In addition, the reports include information on the maturity and on the sector (interbank, retail, and affiliated offices) that are related to the liability or asset position.

In Table 3, we present summary statistics for the 145 German banks that participated in the dollar forward market during our sample period (statistics are computed at the bank-institution level; for each bank, we take the mean of balance sheet statistics across time). The summary statistics reveal substantial heterogeneity in bank size (total assets), with the mean and median of total assets of EUR 26 billion and EUR 4 billion, respectively, and a standard deviation of EUR 95 billion. While there are also smaller banks in the sample, our sample includes large banks,

[11] We achieve this by regressing the forward premium on counterparty*maturity*day fixed effects. The residuals of this regression will then be filtered by this dimension and any remaining variation comes from a dimension that is related to the dollar forward selling bank.

[12] Beier, Krueger, and Schaefer (2017) provide a detailed description of the dataset.

with 10 percent of the banks (i.e., 14 banks) having total assets exceeding EUR 25 billion. Moreover, contract-weighted summary statistics, reported in Table 2, show that larger banks are also more active in the forward market than smaller banks. In fact, Appendix Table A.1 shows that the largest 25 percent of banks account for about 95 percent of all forward transactions in our dataset.

Further, Table 3 shows that the average bank in our sample has about 3 percent of its total assets invested in dollar-denominated assets. However, there are a number of banks in the sample which hold a sizable amount of dollar-denominated assets, both in terms of total balance sheet size (e.g., for 10 percent of the banks, dollar assets represent more than 9 percent of total assets) as well as in terms of equity (e.g., for 10 percent of the banks dollar assets are more than 150 percent of equity). Thus, dollar intermediation is an economically significant part of the business model of a broader set of German banks and not only peculiar to the largest one or two German banks. Contract-weighted summary statistics in Table 2 reveal that banks with a large dollar book are also more active in dollar forward sales, with 75 percent of all contracts being initiated by banks with more than 9 percent dollar assets relative to total assets. A correlation analysis shows that banks with a larger dollar book tend to be larger in terms of total assets (see Appendix Table A.2).

Table 3 reveals another important characteristic of our sample of banks: while a significant share of German banks invests substantially in dollar-denominated assets, many German banks do not fund this activity fully through direct dollar liabilities. We measure the mismatch between on-balance-sheet dollar investments and funding by the dollar funding gap, which we compute as (total dollar assets–total dollar liabilities)/total dollar assets*100. Thus, this variable measures the percentage of dollar-denominated on-balance-sheet assets that is *not* directly funded through dollar-denominated on-balance-sheet liabilities. Table 3 shows that, on average, 4 percent of banks' total dollar assets are not directly funded by dollars, but need to be raised synthetically. For 25 percent of all banks in our sample the funding gap is larger than 6 percent, and for 10 percent of the banks the dollar funding gap is larger than a sizable 60 percent.[13] Consistent with the supposition that banks use forward contracts to hedge dollar exchange rate risk, Table 2

[13] The dollar funding gap accounts on average (median) for 159 percent (198 percent) of total equity, respectively. Using a simple correlation analysis, we further find that banks with larger dollar funding gap are positively correlated with total assets and total dollar assets (see Appendix Table A.2). As a result, the funding gap of the median bank in our sample is smaller than aggregate data suggest (e.g., BIS report 2016:Q2). However, the level of the dollar funding gap for the entire German banking system will be driven by the large institutions and thus yield to a higher level in aggregate data.

shows that banks with larger dollar funding gaps also dominate trading in the forward market, as contract-weighted summary statistics of the dollar funding gap are substantially higher than corresponding bank-level statistics (e.g., mean of 46 percent, median of 60 percent).

We further enrich our dataset with the list of global FX dealers that are reporting institutions in the 2016 BIS Triennial Central Bank Survey of Foreign Exchange and Derivatives Market Activity. This comprehensive list comprises 1,283 FX dealers globally, of which 37 institutions are Germany-based (including German banks and German offices of foreign banks).[14] Information on dealer banks allows us to identify inter-dealer trades and dealer-to-customer trades (client trades). Table 1 shows that about 15 percent (34.9 * 45.8 percent) of the trades in our sample of uncollateralized contracts are inter-dealer trades; thus our sample includes both inter-dealer and client trades, information that we will exploit in our empirical analysis.

Despite the heterogeneity in market participants and contracts, Appendix Table A.1 shows that the price variation prevails, although to a varying degree, for different types of banks and contracts (e.g., large and small banks, high- vs. low-funding-gap banks, dealer and non-dealer banks, contracts that do or do not cross quarter-ends, etc.). That is, the price variation that we discover in our contract-level data is not driven by peculiar groups of banks or contracts, but is a broad phenomenon of the forward market. In the next section, we will briefly discuss the key insights from the theoretical literature on asset pricing in over-the-counter markets to set the economic framework that we use to empirically examine the price dispersion across banks more thoroughly.

III. THEORETICAL DISCUSSION AND HYPOTHESES DEVELOPMENT

To understand the price formation in the FX forward market, it is important to note that FX forward contracts are traded over the counter. In stark contrast to centralized exchanges, such as the market for equity shares, in an OTC market, counterparty search, bargaining on the contract terms as well as trade execution occur bilaterally. As a result of the OTC-structure, bilateral contract terms may vary depending on the two contracting counterparties.

[14] Reporting dealer are primarily large commercial and investment banks (but also other financials) that participate in the inter-dealer market and which maintain an active business with financial and nonfinancial firms, and government entities. For Germany, the central bank requires mandatory reporting for banks with more than EUR 1 billion in foreign-currency-denominated asset and liabilities (combined), see https://www.bundesbank.de/Redaktion/DE/Standardartikel/Service/Meldewesen/triennial_central_bank_survey_biz.html

A large body of theoretical research has studied the pricing of OTC-traded assets. The key insight from this literature is that the price an investor is able to achieve depends on his outside options, resulting from availability (and valuation) of other trading partners, both now and in the future as well as across different markets. For example, Duffie, Gârleanu, and Pedersen (2005, 2007) show that search frictions affect the trading agents' outside options, thereby impacting bilateral prices. In their model, an investor is able to obtain a more favorable price if the investor can find other investors available for trade more easily. The role of alternative trading opportunities across different asset markets as discussed by Weill (2002) and Vayanos and Weill (2008), and Lagos and Rocheteau (2009) show that prices can increase with trade size. The extent to which outside options are influencing the bargaining process and affecting transaction prices depends in many models crucially on the relative bilateral bargaining power (e.g., Afonso and Lagos 2015 use a Nash bargaining model where outside options and bargaining power interact with each other).

We use these conceptual insights from the OTC asset pricing literature to articulate several hypotheses, which will guide our empirical analysis. In particular, we adopt the view that outside options are key determinants of the differential pricing of FX forwards that we have documented in the previous section. In the context of FX forward market, a bank's outside options to immediate trade is determined, on the extensive margin, by the fundamental choice to either hedge or leave the currency exposure unhedged, and, on the intensive margin, by the contract type for the hedge (e.g., maturity, counterparty, collateralized, etc.). Both margins should matter for the pricing of forwards.

To examine the role of outside options for the pricing of banks' dollar forwards, we exploit a key feature of the current banking regulation. Because FX risk is widely acknowledged as one of the major financial risks (Stein 2012, Shin 2016), the financial regulator imposes capital charges on any bank with currency imbalances between assets and liabilities.[15] For German banks, as opposed to U.S. and U.K. banks, the financial regulator assesses banks' currency imbalances and judges compliance with regulatory requirements at the final day of each calendar quarter using end-of-quarter snapshots of both banks' on- and off-balance-sheet items. In particular, there is a general capital charge of 8 percent on the institution's overall net FX position, computed based on both on- and off-balance-sheet positions. Thereby, the regulator introduces additional hedging

[15] 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 are used to check compliance.

demand. This is not to say that hedging demand or the need to close currency mismatches is present only near quarter-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 (due to demand shifts).

By selling a dollar forward, a bank can reduce the exposure associated with a positive on-balance-sheet funding gap (more dollar assets than liabilities), thereby reducing regulatory capital charges. Therefore, if banks want to economize on regulatory capital charges, they should have a higher valuation (and thus a higher willingness to pay) for a forward dollar sale that allows them to reduce their net FX position and associated capital charges, which should be reflected in transaction prices if bargaining frictions in the over-the-counter market persist; that is, if counterparties can extract part of the surplus from the seller. However, given the end-of-quarter reporting, only contracts that mature after the quarter-end reporting date are useful for this purpose. Thus, a bank's valuation of such forward contracts should depend crucially on its shadow cost of capital. The corollary of this argument is that—as compared to a forward contract that matures before the regulatory binding reporting day—one should expect a premium for all dollar forward contracts that allow the bank to cross the upcoming end-of-quarter reporting day (henceforth "cross-quarter" contracts). In fact, for any given contract maturity, there should be an average differential effect between a dollar forward sale that matures *before* the upcoming quarter-end versus one that matures *after* the upcoming quarter-end, which leads us to the following first hypothesis:

<u>Hypothesis 1:</u> *Forward contracts that mature after the upcoming quarter-end are on average traded at higher prices than those maturing before the upcoming quarter-end.*

If banks' motives to engage in cross-quarter dollar forward sales are indeed driven by incentives to reduce the ex-ante dollar funding gap to economize on capital charges, one should expect banks with an ex-ante higher dollar funding gap to have higher valuation for cross-quarter forward contracts (given their higher shadow cost of capital), as compared to banks with a lower ex-ante dollar funding gap. The reason is that the fundamental outside option to an immediate forward sale for banks with an ex-ante higher dollar funding gap is one where the investor does not hedge and accepts the associated additional capital charges. Therefore, we expect that high-dollar-funding gap banks pay more for their cross-quarter forward contracts than low-dollar-funding gap banks. This leads us to the next hypothesis:

Hypothesis 2: *Cross-quarter forward premium is higher for banks with an ex-ante higher funding gap than for banks with an ex-ante lower funding gap.*

In addition to a bank's ex-ante dollar funding gap, there are other factors that affect a bank's valuation of outside options, in turn influencing the valuation of cross-quarter contracts. In particular, a large literature in international banking has highlighted the role of internal capital markets for effective liquidity management (e.g., Cetorelli and Goldberg 2012), especially for global banks with cross-currency positions (which are at the center of our analysis). In the context of the dollar forward market, access to internal dollar capital markets improves a bank's ability to manage dollar liquidity, thereby improving the outside options to immediate trade in the forward market.[16] Therefore, one may expect that banks that may be able to easily draw on internal dollar funding should have more outside options and thus a better bargaining position in the forward market. This should allow especially high-dollar-funding-gap banks to negotiate more favorable prices for cross-quarter contracts, which allows us to form the following hypothesis:

Hypothesis 3: *Banks with ex-ante higher funding gap negotiate more favorable prices for cross-quarter forward contracts, when they have access to internal dollar funding.*

These hypotheses help us to form a-priori predictions regarding the link between price dispersion for similar cross-quarter dollar forward contracts and bank-specific hedging demand factors resulting from differences in outside options. However, a key question is how heterogeneous demand can lead to price dispersion for one and the same asset. The OTC literature in this regard highlights the importance of bargaining frictions that interact with demand heterogeneity to generate differential pricing (e.g., Afonso and Lagos 2015). In particular, the OTC literature argues that dealers have more bargaining power and are thus able

[16] For example, a bank may be able to obtain dollar funding from a U.S. office with deep access to deposit and/or wholesale funding. Such internal dollar funding is presumably easier to draw upon (e.g., on short notice, lower cost, or more volume) than on alternative sources such as from external funding markets, in particular, during our 2014-2016 sample period, off-shore dollar funding markets were tight due to the U.S. money market mutual fund reform that led to massive withdrawal of dollar funding to European banks. Moreover, a bank with related offices that provides internal dollar funding may have access to a larger set of counterparties in dollar cash and derivatives markets.

to achieve more favorable prices, for example, because they are able to find other investors more easily (e.g., Duffie, Gârleanu, and Pedersen 2005 and 2007). In the FX forward market, one could argue that it should manifest itself in such a way that, for otherwise similar forward contracts, dealer banks are able to bargain more favorable prices than clients because they have better outside options on the intensive margin. This leads us to the next hypothesis:

Hypothesis 4: *Dealer banks with ex-ante higher dollar funding gap achieve more favorable forward premium on cross-quarter contracts than non-dealer banks (clients).*

The bank may also engage in a different type of forward contract than an uncollateralized contract. Cross-quarter forward contracts are again helpful to understand how outside options may affect the price dispersion across forward sellers through heterogeneous shadow cost of capital. In particular, one alternative to an immediate uncollateralized trade could be to engage in a collateralized forward contract. In fact, this would be a more general and broader way to measure the role of shadow cost of capital for heterogeneous forward pricing. If a bank needs to post collateral (margin) for a specific instrument and has a positive shadow cost of capital, it may find that it's worthwhile to pay more for an unsecured contract with otherwise similar contract details (Gârleanu and Pedersen 2011). 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. Put it differently, a bank that is able to post collateral should be able to negotiate more favorable prices than a bank with high shadow cost of capital which will prefer uncollateralized over collateralized trades. In result, one may hypothesize this as follows:

Hypothesis 5: *Banks with lower shadow cost of capital achieve more favorable forward premium on cross-quarter contracts than banks with higher shadow cost of capital.*

These hypotheses provide the broad structure for the subsequent empirical analysis. In the following, we first describe our empirical strategy to test these a-priori predictions and then discuss the results.

IV. EMPIRICAL STRATEGY AND RESULTS

IV.1 Cross-Quarter Contracts

As discussed in the previous section, we expect that cross-quarter forward contracts carry a premium. That is, forward contracts that mature after the current quarter-end should trade on average at higher prices than those maturing during the current quarter, irrespective of the actual maturity (our first hypothesis). We test this hypothesis using a regression model, which we build up by sequentially including richer sets of controls. Our main specification is given by:

$$\text{Forward Premium}_{i,j,m.t} = \beta_0 \text{Cross-Quarter}_{m,t} + \beta_1 \text{Cross-Quarter}_{m,t} * \text{Log(Maturity}_{i,j,m,t}) \\ + \text{Controls}_{i,j,m,t} + \alpha_i + \alpha_j + \alpha_m + \varepsilon_{i,j,m,t} \quad (1)$$

where 'Forward Premium' refers to the premium (in basis points) that the dollar forward seller 'i' (henceforth bank) pays to the dollar forward buyer 'j' (henceforth counterparty) to lock in the forward rate maturing in 'm' days relative to the spot rate prevailing on the same day 't'. 'Cross-Quarter' is a binary variable that equals the value of one if the contract matures after the upcoming quarter-end day, and zero otherwise (i.e., when it matures during the ongoing quarter). 'Maturity' denotes the maturity of the dollar forward contract in days, and 'Controls' is the contract value (notional). If our a-priori prediction regarding cross-quarter contracts is correct, we would expect β_0 to be positive and statistically significant. To control for potential confounding factors, such as bank-specific time-invariant heterogeneity, we include bank fixed effects. We also include counterparty fixed effects to control for observed and unobserved time-invariant counterparty characteristics. Furthermore, we include maturity fixed effects to account for maturity-specific differences in forward premia. We estimate equation (1) using the method of least squares and cluster standard errors at bank-maturity level.[17]

Regression results are presented in Table 4. In column (1), where we control for 'Log(Maturity)', we find that contracts that cross the upcoming quarter-end trade at a significantly higher forward premium. Our estimate of the cross-quarter premium amounts to 18 basis points. One concern could be that only specific banks sell cross-quarter forward contracts.

[17] Our results are also robust to two-way clustering at bank and day level and multiway clustering at bank, maturity, and day level.

Therefore, we next control for bank and counterparty fixed effects. Following the theoretical literature, we also control for the ‘Log(Value)’ of the contract given that cross-quarter forward contracts may differ in value from their counterparts that mature during the current quarter, thereby introducing price variation (e.g., Lagos and Rocheteau 2009). In column (2), we find that, after including these controls, our estimated effect is somewhat smaller with a cross-quarter premium of 10 basis points, which suggests that indeed compositional differences and size effects are at play for which one needs to account. Nevertheless, the coefficient estimate remains highly significant (p-value smaller than 1 percent) and is robust to including maturity fixed effects instead of controlling for ‘Log(Maturity)’ as a continuous variable (column 3).

We next investigate if the premium paid on cross-quarter contracts varies with contract maturity. If banks have higher valuation for a cross-quarter contract because it allows the bank to close its open dollar positions on financial reporting days, we would expect that this valuation is independent of maturity of the contract given that any contract that matures after the upcoming quarter-end day closes the funding gap. In column (4), which resembles equation (1), we include the interaction term ‘Cross-Quarter * Log(Maturity)’ and find—in line with our conjecture—that there is no additional heterogeneity along the maturity dimension. Thus, on average, cross-quarter contracts of different maturities carry the same cross-quarter premium, which is consistent with a constant valuation of cross-quarter contracts. The estimated premium on cross-quarter contracts may be interpreted as a lower bound for the (contract-weighted) average shadow cost of capital of the banks in our sample.

To shed more light on the market microstructure of cross-quarter dollar forward contracts, it is important to understand how the forward premium varies depending on contract maturity. The coefficient estimates on ‘Log(Maturity)’ in column (1) and (2) are positive, revealing that forward premia increase in contract maturity, i.e., are higher for longer-term contracts. We show this increasing maturity premium graphically in Figure 3, where we plot estimates of the forward premium obtained from a more flexible fractional polynomial regression, after controlling for bank fixed effects, counterparty fixed effects, and the logarithm of the contract value. The increasing maturity premium and the constant cross-quarter premium suggest that if a bank intends to sell a dollar forward to hedge its FX risk exposure only on the regulatory reporting day, it can minimize its cost by selling a short-term forward contract that is initiated right before the quarter-end day, and then matures right after the quarter-end day. This would both minimize the cost of hedging and, at the same time, allow the bank to cover its FX risk exposure on the regulatory reporting day.[18]

In Appendix Table A.3, we provide empirical evidence confirming this intuition. On the immediate days preceding the final day of a quarter (for example, the last 5 days of a quarter), we find that banks increase the total number of forward contracts by about 3 percent as well as the total notional value associated with the forward contracts by about 9 percent, on average across all maturities (results are robust to using different end-of-quarter definitions). However, as we show, the total increase in dollar forward selling is mainly done using contracts of short maturities, i.e., precisely those that are the cheapest in absolute (not annualized) terms.[19] Because we control for bank, maturity, and day fixed effects, this effect is identified from comparing the differential change in forward selling on the same day, across different maturities after netting out any time-invariant bank heterogeneity. Note that, while we find an increased activity in short-term cross-quarter contracts, we do not find a differential cross-quarter premium for these types of contracts. Thus, the additional volume in shorter maturities at quarter-ends does, on average, not seem to differentially affect market prices of short-term dollar forward contracts.

It is important to highlight that our estimates of the cross-quarter premium in Table 4 (and all following tables) are based on forward premia that are *not* annualized and thus are in *absolute* terms. If we estimated the cross-quarter effects on annualized forward premia, i.e., the forward premia in *relative* per-annum terms, we would find that the mark-up for cross-quarter contracts amounts to a sizable 293 basis points.[20] This is an effect of the annualization that disproportionally scales the forward premia of short maturities in combination with the previously established result that most cross-quarter contracts are executed in very short

[18] Pushing this argument to the extreme, one may argue that a bank would want to hedge its exposure *only* on the reporting day. However, liquidity differences across maturities, risk aversion, search frictions, or other frictions are likely at play.

[19] The increased volume of short-term dollar forward sales at quarter-ends implies that, at the beginning of the new quarter, a bank will need to deliver U.S. dollars, which it can obtain either by (i) buying them in the spot market (or by entering a respective shorter-term forward dollar purchase right *after* the quarter end) or (ii) by borrowing the dollars directly, e.g., in the dollar money market. Options (i) means that the bank is taking FX risk due to the exchange rate movements between the forward dollar sale and the day of its delivery, and option (ii) implies that the bank is following a roll-over strategy that leads to increasing leverage in the long-run.

[20] To put these numbers into perspective, a back-of-the-envelope comparison with prevailing dollar and euro money market rates during our sample period may be insightful. For example, the average three-month interest rate differential between the U.S. dollar and euro was 45.6 basis points (per annum) during our sample period (LIBOR rate of 43 basis points and average EURIBOR rate of -2.5 basis points). Thus, the estimated cross-quarter premium amounts to more than 640 percent relative to the interest rate differential (an implied synthetic dollar funding cost of 290.5 basis points compared to direct dollar funding rates of 43 basis points).

maturities. However, while in annualized terms the cross-quarter effects are very large, banks only pay these high prices for a few days each year (at quarter-ends).

In light of these results from Table 4 and Figure 3, there is an important corollary that stands out: long-term forward contracts are more expensive than short-term contracts, manifesting itself in higher forward premia in absolute terms, i.e., actually paid. But in relative terms, i.e., when translating these premia paid into annualized terms, the premia inherent to short-term contracts are substantially larger than those observed for long-term contracts. Thus, there is a trade-off for banks depending on the initial intention for selling the forward contract to begin with. If the investor seeks to manage its FX risk for a longer period while minimizing its costs, the investor is better off using long-term contracts as the relative costs will be lower. But if an investor intends to manage risk only over a short-term horizon, then the investor may be better off using short-term contracts that in absolute terms are cheaper. However, this also suggests that a roll-over strategy with short-term contracts is not as cost-efficient as a long-term contract over the same horizon.

IV.2 Dollar Funding Gap

The results on cross-quarter contracts are consistent with banks paying higher prices for dollar forwards that allow them to reduce or close their FX risk exposure associated with their funding gap at the regulatory reporting day. Therefore, we would expect that the forward premium should vary with bank's ex-ante dollar funding gap (our second hypothesis). We examine this prediction by introducing the variable 'Dollar Funding Gap' in equation (1), both in levels and in interaction terms. We saturate our specification progressively with different fixed effects that address, in particular, time-varying supply-side heterogeneity that is crucial for identification as discussed in the text below. Our regression equation with the tightest set of fixed effects is given by:

$$\begin{aligned} \text{Forward Premium}_{i,j,m.t} &= \beta_0 \text{Dollar Funding Gap}_{i,t-1} + \beta_1 \text{Cross-Quarter}_{m,t} * \text{Dollar Funding Gap}_{i,t-1} \\ &+ \text{Controls}_{i,j,m,t} + \alpha_i + \alpha_{j,t,m} + \varepsilon_{i,j,m,t} \qquad (2) \end{aligned}$$

where $\alpha_{j,t,m}$ are counterparty*maturity*day fixed effects that capture any unobserved time-varying supply-side heterogeneity at the counterparty-maturity-level. Note that these fixed effects also absorb the level effects of 'Cross-Quarter' and 'Log(Maturity)'.

In Table 5, we present the results. In column (1), we start by using the same fixed effects as in the last column of Table 4, thereby controlling for time-invariant bank and counterparty characteristics. In addition to contract value, we also control for bank size (logarithm of total assets), which is correlated with a bank's dollar funding gap (Appendix Table A.2). We find that the estimated coefficient on the funding gap is positive and statistically significant, showing that banks with a higher ex-ante dollar funding gap pay significantly higher forward premia relative to banks with a lower ex-ante funding gap. Moreover, the significant positive coefficient estimate on the interaction term between funding gap and cross-quarter dummy shows that high-funding-gap banks pay a higher cross-quarter premium than low-funding-gap banks. The estimated coefficient is also economically meaningful: banks with a one-standard-deviation-larger funding gap (27 percentage points) pay 13-basis-point-higher forward premia for contracts that expire within the same quarter in which they were initiated, and an additional 5 basis points more for cross-quarter contracts. In column (2), we additionally introduce maturity*day fixed effects and hence control for a time-varying mean in each individual maturity. This controls specifically for maturity-specific interest rate differentials between dollar and euro. We find that the cross-quarter effect increases from 5 basis points to 7 basis points.

A key challenge in identifying hedging demand as a driver of the cross-quarter premium is the possibility that the supply of dollar forwards may be different for cross-quarter contracts. For example, capital-constrained dealers may reduce the supply of cross-quarter forward contracts to comply with regulation (e.g., Du, Tepper, and Verdelhan 2018). We exploit our micro data to address this concern by comparing the prices of contracts for the same maturity initiated on the same day and with the same counterparty, and exploiting the price heterogeneity within the same counterparty-maturity-day dimension. This effectively allows us to control for any time-varying supply-driven changes in prices and to isolate hedging demand effects depending on bank characteristics, such as the dollar funding gap. Technically, we implement this approach, which will also be our benchmark throughout the rest of the paper, by including counterparty*maturity*day fixed effects in our regressions.

In column (3), which corresponds to equation (2), we find that, after controlling for any maturity-specific, time-varying supply-side effects at the individual counterparty level, the cross-quarter premium does not vary significantly with a bank's dollar funding gap.[21] Thus, the significant estimates that we found in column (3) are driven by variation in the supply of forward contracts. The estimated coefficient in column (3) presents an average differential cross-quarter effect (depending on bank's funding gap) across all maturities. However, our previous discussion already showed that if cross-quarter contracts are initiated with the sole purpose of hedging open dollar positions on a financial reporting day, this would typically happen in short maturities that are more cost-effective.

In column (4), we therefore restrict the sample to contracts with a maturity of less than one month and re-estimate the same specification as column (3), i.e., with counterparty*maturity*day fixed effects. Unlike in column (3), now the estimated coefficient on 'Cross-Quarter * Dollar Funding Gap' is positive and significant at the 5 percent significance level. Thus, for short-term contracts that are relevant for potential window-dressing purposes, we estimate a significantly stronger cross-quarter premium for banks with an ex-ante higher dollar funding gap compared with banks with an ex-ante lower dollar funding gap. The coefficient estimate suggests that a bank with a one-standard-deviation higher funding gap pays 3.5 basis points more on cross-quarter contracts. Given that we fully control for the supply side, this finding supports the demand-driven argument that high-dollar-funding-gap banks seek to hedge their open positions on quarter-ends and are therefore willing to accept higher prices for short-term cross-quarter contracts. The variation in prices they accept then reflects the heterogeneity in banks' shadow cost of capital.

In column (5), we show the same result but using the full sample of contracts in combination with the triple interaction term 'Cross-Quarter * Dollar Funding Gap * Log(Maturity)'. That is, we are now obtaining identification not only from comparing prices of short-term cross-quarter contracts depending on banks' dollar funding gap, but also by comparing the cross-quarter price differentials (depending on banks' ex-ante dollar funding gap) across the full range of contract maturities. The negative coefficient estimate on the triple interaction confirms that, as compared to low-funding-gap banks, high-funding-gap banks pay more for cross-quarter contracts of

[21] This finding is not due to the different sample in column (3) that is a consequence of the tighter fixed effects. In fact estimating the specification from column (2) on the sample from column (3) will lead to positive estimates on the interaction term.

shorter maturities.[22] This is a result that was hidden by estimating an average differential effect across all maturities in column (3), which highlights the importance of cross-sectional differences (both across contracts and banks) in the pricing of dollar forward sales. In quantitative terms, the coefficient estimate on the triple interaction means that a bank with a one-standard-deviation-higher funding gap (27 percentage points) pays 34 basis points more for a cross-quarter contract of 7 days compared to a cross-quarter contract of 90 days (-0.4992*27*(log(7)-log(30))).

Because regulation imposes additional capital charges on unhedged dollar positions, one may argue further that, for any given size of the ex-ante dollar funding gap, high-leverage (i.e., low equity-to-assets ratio) banks should have stronger incentives to hedge their FX risk exposure on financial reporting days than low-leverage banks. That is, one would expect that the documented effect from column (5) should be more pronounced for high-leverage banks. We examine this by sorting, in each month, banks according to their equity-to-asset ratio and creating a dummy variable that equals the value of one for all banks that fall into the lowest 25th percentile of banks' equity ratio, and zero otherwise. Column (6) shows that indeed these high-leverage banks are paying significantly higher prices for short-term cross-quarter contracts if they have a high ex-ante dollar funding gap.[23] Quantitatively, we estimate that the differential effect found in column (5) is more than twice as large (-1.1086/-0.4992) for high-leverage banks compared with column (5). As before, the coefficient is identified by comparing prices of contracts of the same maturity with the same counterparty initiated on the same day, and after controlling for time-invariant cross-sectional heterogeneity in prices using bank fixed effects (i.e., the identification comes from variation in prices of the same bank that is related to differences in the funding gap, leverage, and contract maturity of the same bank). These results are in line with our a-priori hypothesis insofar as they show that a bank's ex-ante dollar funding gap affects bank's valuation of dollar forwards. That is, the outside option for a bank to leave the FX risk exposure uncovered helps in the bargaining process to negotiate more favorable prices as compared to when the bank cannot easily draw on this option. In Appendix Table A.4, we also show that, on average, high-

[22] Similar to the rest of the paper we have included in the regression but absorbed from the table output all lower-order interaction terms for clarity of presentation.

[23] Because our specification includes all lower-order interaction terms, in particular, 'Cross-Quarter * High Leverage' and 'Cross-Quarter * Log(Maturity) * High Leverage', our result is not capturing a general increase in premia for (short-term) cross-quarter contracts by high-leverage banks. Instead, we are measuring the heterogeneity among high-leverage banks depending on their ex-ante dollar funding gap.

dollar-funding-gap banks also pay significantly more for forward dollar sales on the final days of the quarter, after controlling for bank and day fixed effects. Our estimate suggests that, on average, across all maturities, a bank with a one-standard-deviation (27 percentage points) higher dollar funding gap pays about 13 basis points more for hedging its dollar exposure on quarter-ends. Thus, the documented contract-level effects carry over to the aggregate bank-level showing that banks' aggregate hedging costs are affected.

IV.3 Internal Dollar Capital Markets

In line with our third hypothesis, we test whether banks with access to internal dollar capital markets and a high dollar funding gap are able to negotiate lower forward premia on their cross-quarter contracts than high-dollar-funding-gap banks without internal capital markets, for otherwise similar contract details, i.e., same counterparty, same maturity and same day. [24] To that end, we build upon our previous specification but add our baseline measure for bank's access to internal dollar capital markets, i.e., 'Intragroup Share', which denotes the (lagged) share of bank's intragroup dollar liabilities relative to its total dollar liabilities (in percentages). We also follow the previous identification strategy and control for supply-side drivers by including counterparty*maturity*day fixed effects, and for contract value, time-varying bank size, as well as any time-invariant bank heterogeneity using bank fixed effects.

In Table 6, column (1), we find a negative and significant coefficient estimate on the triple interaction 'Cross-Quarter * Dollar Funding Gap * Intragroup Share'. The negative coefficient suggests that banks with a larger dollar funding gap pay less on their cross-quarter contracts if they have a higher share of intragroup dollar liabilities. For example, a bank with a one-standard-deviation larger dollar funding gap (27 percentage points) would face an 8-basis-point-lower forward premium if the bank has a one-standard-deviation (3.64) higher intragroup dollar funding share, on average across all cross-quarter contracts. Column (2) shows that this result holds if we look at the share of net intragroup dollar liabilities (net of intragroup dollar claims),

[24] We study the role of internal dollar funding as it is presumably easier available and more advantageous (e.g., on short notice, lower cost, or more volume) than other alternative sources such as external funding markets. A bank that intends to close its dollar funding gap on a quarter-end could borrow dollars through an internal capital market (leading to an initial increase in both dollar liabilities and assets) and then convert the obtained dollar into euro, thereby decreasing the dollar funding gap. Simultaneously, the bank could then buy back the dollar on the forward market after the quarter-end to unwind the transaction. Consistent with this channel, we find that, among high-funding-gap banks, institutions with internal dollar capital markets increase their number of forward purchases of dollars by about 15 percent on average during the last week of the quarter relative to banks without internal capital markets. This result holds after controlling for bank size as well as bank, maturity, and day fixed effects.

thereby measuring whether the bank is net receiver or net sender of dollar liquidity from or to related offices. In column (3), we can see that the effect of having intragroup dollar liabilities becomes significantly smaller for shorter maturities. This effect is also reflective in summary statistics presented in Table 2.

In columns (4) through (6), we restrict our sample to those bank-quarters that have a positive share of intragroup dollar liabilities. Thus, we are now interested whether the depth of the internal dollar capital markets matters. In column (4), we find that the estimated coefficient, while directionally similar to the results in column (1), is not significant at the conventional level of five percent. This suggests that among banks with positive intragroup dollar liabilities, there is no additional differential effect depending on the relative size of their intragroup funding. However, there are only 13 banks with positive internal capital market liabilities; thus, there is less variation across banks than in the full sample of banks, which leads to larger standard errors.

We next look at the maturity composition of banks' intragroup dollar liabilities. The idea is that if a bank can tap intragroup funding, in particular in short maturities, this should improve its outside options and improve its bargaining position in the forward market for cross-quarter contracts. Note that the working hypothesis here builds upon the findings from the previous section, where we have shown that banks that seek to close their funding gap for regulatory reporting days do so by using short-term forward contracts. Therefore, we compute the short-term (overnight) intragroup share as the overnight intragroup dollar intragroup dollar liabilities relative to all intragroup dollar liabilities (in percentages). In column (5), we find that high-dollar-funding-gap banks face significantly lower forward premia when they have more short-term intragroup liabilities (conditional on a given share of total intragroup liabilities). Column (6) shows that there is no additional heterogeneity that varies significantly with contract maturity. In sum, our results are consistent with our a-priori notion that banks with ex-ante higher funding gap are able to negotiate more favorable prices for cross-quarter forward contracts, when they have the ability to draw on internal dollar funding.

IV.4 Bargaining Power

In this section, we test our fourth hypothesis and examine whether a high-funding-gap bank that is a dealer is associated with higher bargaining power and thus able to negotiate more favorable prices on cross-quarter forwards as compared to a non-dealer bank (henceforth client). For a clean comparison, we focus on client-to-dealer and dealer-to-dealer contracts; that is, we are restricting the dollar buying side to the sample of dealer banks but allow the dollar selling side to vary between clients and dealer banks. Moreover, we include counterparty*maturity*day fixed effects (as before) to compare prices for contracts with the same counterparty and the same maturity on the same day. The results are presented in Table 7.

In column (1), we find that higher-dollar-funding gap banks pay significantly less for their cross-quarter contracts when they are dealers as compared to when they are clients. The effect is also economically sizable: a bank with a one-standard-deviation-higher funding gap (27 percentage points) pays on average 159 basis points less if it is a dealer bank versus if it is a client bank. To test the robustness of this result, we take a different stance and compare in column (4) client-to-client and client-to-dealer contracts; that is, we are now restricting the dollar selling side to the sample of dealer banks but allow the dollar buying side to vary between clients and dealer banks. Analogously to our results from column (1), we find that higher-funding-gap client banks pay higher prices for their cross-quarter contracts when they approach a dealer versus a non-dealer bank. Note that these results refer to the specification where we are netting out bank*maturity*day fixed effects (analogously to counterparty*maturity*day fixed effects in column 1). Both of these results are consistent with our a-priori expectations.

The theoretical literature (e.g., Duffie, Gârleanu, and Pedersen 2005) also argues that bargaining power should depend on the number of potential trading partners, i.e., how easy a bank can find other counterparties. Therefore, in column (2), we introduce the variable ‘Log(#Counterparties)’, which we compute as the logarithm of the number of trading partners in the last year (results are robust to other reference periods). Consistent with theory, we find that the differential effect between dealer and client trades increases further when the dealer bank has access to more counterparties in the forward markets. In contrast, if the dealer bank has relatively few counterparties, its bargaining power is limited as reflected in a lower spread relative to client banks. Column (5) shows an analogous pattern when we compare client-to-client contracts with client-to-dealer contracts: banks with a larger number of counterparties are able to achieve higher rates from their client counterparties compared to when they have fewer counterparties.

An interesting question in this context is whether there is additional heterogeneity depending on the maturity dimension. The discussion of the summary statistics in Section II highlighted the importance of the short-term forward market, with about 85 percent of all contracts having maturity of less than 3 months and about 50 percent having maturity of one week or less. In Appendix Table A.5, we provide further summary statistics on measures related to market liquidity for different maturity buckets, notably of one week or less and 1 month through 3 months. We find that very short maturities are associated with larger turnover, larger number of market participants, and larger number of dealers. Moreover, we find that the forward premium varies less (by means of standard deviation) in the shortest maturity bucket, both in absolute terms and if normalized by the different level of the premium across maturities (summary statistics are similar if we restrict ourselves either on cross-quarter contracts only or on non-cross-quarter contracts) . These stylized facts together strongly suggest that the short-term dollar forward market is more liquid than longer-dated segments.

Given the higher liquidity in the short-term segment, one may argue that bargaining frictions should be less pronounced. Indeed, in column (3), we find that the differential pricing between dealer and client banks is decreasing for shorter maturities. That is, compared with client banks, we find that the degree to which dealer banks can capitalize on their bargaining power depends significantly on the maturity of the market segment. This is consistent with the notion that highly liquid markets suffer less from bargaining frictions and thus from heterogeneity in asset prices. We find qualitatively similar results for the sample where we compare client-to-dealer trades to client-to-client contracts, albeit statistically not significant at a conventional level (column 6).

In fact, the findings that we gather from this analysis allow us to put our previous result into perspective. First, they provide direct evidence on the key frictions in the forward market that allow demand heterogeneity to manifest in price dispersion for otherwise identical contracts. Second, these findings provide additional insights for our results on the benefits of access to internal dollar funding for the pricing of short-term cross-quarter forward contracts. In column (3) of Table 6, we found that for ex-ante high-funding-gap banks the effect of intragroup dollar liabilities on cross-quarter forward contracts is less pronounced for shorter maturities as compared to longer maturities. Consistent with the notion that short-term segments are more liquid and thus less subject to bargaining frictions, we find that banks with intragroup funding are simply not able to use these outside options to bargain for favorable prices in short maturities to the same extent to which they are able in longer-term segments.

IV.5 Margin Requirements and Shadow Cost of Capital

In this section, we examine the role of banks' shadow cost of capital for forward pricing more generally. To that end, we exploit a unique feature of our data set. As discussed in Section II, we have restricted our main analysis to uncollateralized contracts only to ensure a clean comparison across contract details. However, our database also contains forward contracts for which initial margin is provided. To identify the effect of heterogeneous capital valuation on the pricing of forwards, in this section, we extend our analysis to collateralized transactions and compare the forward premium of uncollateralized and collateralized contracts that have otherwise similar features. 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.[25] This allows us to cleanly study the differential pricing of collateralized versus uncollateralized contracts of the sell side, while keeping the counterparties' collateralization constant.

Recalling our fifth hypothesis, everything else being equal, we would expect that the requirement to post collateral will on average 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). In Table 8, we estimate the price differential between collateralized and uncollateralized contracts. Our specification and identification strategy follows closely our approach so far and builds upon equation (2).

One concern that may arise is that the sample of banks that initiate contracts where initial margin is posted differs from the sample of banks that sell dollar forwards without pledging any initial margin.[26] Thus, the price differential of collateralized versus uncollateralized contracts may just be a results of the difference in bank characteristics and not be driven by shadow cost of capital. In column (1), we address this issue by including bank fixed effects, in addition to maturity*day fixed effects, thereby accounting for potential compositional differences; that is, we estimate the price differential for the same bank. We also include counterparty fixed effects, as well as the contract value and time-varying bank size as additional controls. We find that, on

[25] Contracts of this kind are considered one-way collateralized trades and account for about 8 percent of our data. Collateral used for initial margins consists of relatively homogenous cash-like assets, such as cash and top-rated government bonds.

[26] Indeed, in unreported results, we find that smaller and less-capitalized banks are more likely to enter a contract with initial margin while dealer banks are less likely.

average across all maturities and banks, there is no significant price differential. However, for cross-quarter contracts, we do find a significant differential effect of 12 basis points.

As initial margin requirements bind collateral until the contract matures, one may argue that price differentials of longer-term contracts should be more pronounced. The reason for this being that for collateralized contracts the collateral is not available throughout the entire lifetime of the contract and banks with a positive margin valuation should require a larger discount in order for them to be willing to engage in a collateralized transaction compared with one which is not collateralized. We examine this in column (2) and we find that the coefficient on the interaction term 'Initial Margin * Log(Maturity)' is negative, which suggests that spreads between uncollateralized and collateralized, but otherwise similar contracts, increase (i.e., are more negative) with contract maturity. Economically, a one-standard-deviation increase in maturities widens the spread by 17.16 basis points. Interestingly, we also find that once we include the interaction term with maturity, price differences are not significantly different for contracts that cross the quarter (which tend to be longer-term contracts) or whether it does not (which tend to be shorter maturity).

We further explore the heterogeneous margin valuation in the cross-section of banks. Banks with ex-ante high leverage (low equity-to-assets ratio and thus high shadow cost of capital) presumably have a higher margin valuation and, all else equal, require a larger discount for entering a collateralized contract. In column (3), where we add the interaction term between the initial margin dummy and a bank's ex-ante equity ratio, we find exactly this intuition to be confirmed: spreads between contracts with and without margin are larger for ex-ante low-equity banks. In column (4), we show that this key result holds when we control for counterparty*maturity*day fixed effects, similar to our previous regression tables, thereby netting out common counterparty-specific time-varying and maturity-specific supply effects.[27] In fact, our point estimates increase by more than 50 percent. Our coefficient estimate suggests that a one-standard-deviation (0.77 percent) fall in equity ratio increases the differential by 5.5 basis points. We do not find that this effect is significantly different for contracts that cross the quarter-end.

[27] We cannot include counterparty*maturity*day*collateralized fixed effects, which would impose too heavy restrictions on the number of observations that are not met in our dataset.

Finally, in column (5), we show that the price differential varies with both equity and maturity. This is consistent with the notion that low-equity banks only enter a long-term contract that requires initial margin (thus, binds collateral) at a larger discount than ex-ante high-equity banks. Quantitatively, we estimate that a bank with a one-standard-deviation lower equity ratio would pay 15 basis points more for an unsecured contract with maturity of 90 days (versus secured contract of the same maturity) compared to contracts of maturity of one week (0.77*8.1311*(log(7)-log(90))). In column (6), we show that this result holds when we include bank *maturity*day fixed effects, thereby controlling for any time-varying bank characteristics that could affect the forward premium, such as daily varying demand for hedging FX risk or time-varying bank risk.

V. CONCLUSION

In this paper, we empirically study the cost of banks' dollar hedging using a novel and unique contract-level data on German banks' USD/EUR forward sales for the period 2014–2016. Contrary to the standard international finance textbook view, we find economically large cross-sectional variation in the cost of dollar hedging for contracts with the same counterparty, of the same maturity initiated on the same day. We show that this demand-driven price dispersion relates positively to banks' dollar funding gaps, i.e., a measure for how much of banks' on balance sheet dollar assets are funded by on balance sheet direct dollar liabilities. Because banks with unhedged balance sheet positions on regulatory reporting days face additional capital charges, our results suggest that the heterogeneous effect of banks' positive dollar funding gaps on banks' abilities to negotiate favourable terms reflects heterogeneous shadow cost of capital. That is, banks' abilities to bargain better terms depends on the fundamental alternative to immediate trade, i.e., leaving the FX risk exposure unhedged. We also show that bargaining frictions are the key mechanism through which heterogeneous demand generates price dispersion.

Our findings have broad implications. The mechanisms we identify are directly relevant for the current policy debate regarding global funding markets and the importance of the U.S. dollar for broader financial markets and the real economy (Shin 2016). At a high level, 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. More specifically, our findings imply that good capitalization renders a bank more resilient against funding liquidity shocks. In this regard, our findings suggest that a bank's shadow cost of capital is closely linked to its shadow cost of funding. Moreover, our results show that when running a large U.S. dollar book, a solid on-shore dollar funding base and internal capital markets are key to avoid being caught wrong-footed when dollar funding liquidity dries up in off-shore markets. Another key take-away from our study is that supervisory point-in time reporting policy of regulatory measures induces further price variation through banks that engage in window-dressing behavior.

Last but not least, 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 using the FX derivatives market. We leave these interesting topics open for future research.

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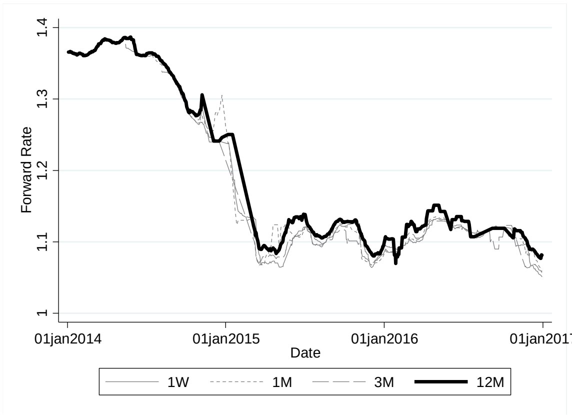
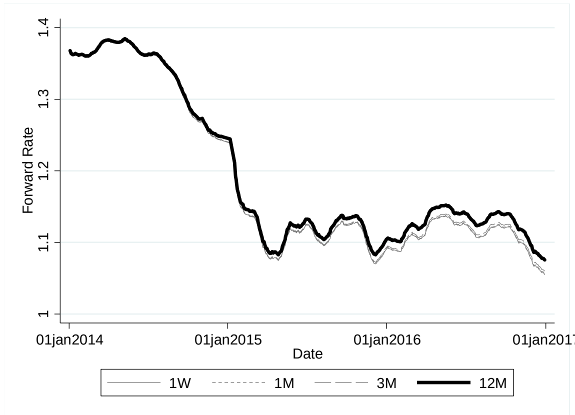
Figure 1 — Forward Rate (EMIR Data and Bloomberg)

(A) USD/EUR FORWARD RATES (EMIR)

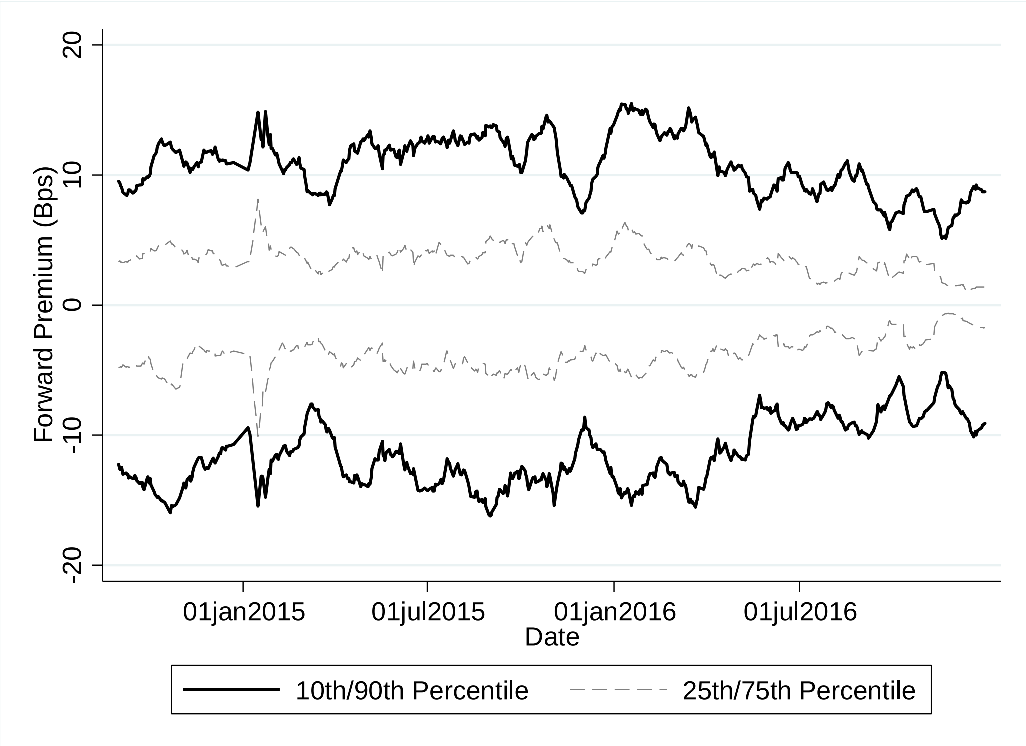


(B) USD/EUR FORWARD RATES (BLOOMBERG)



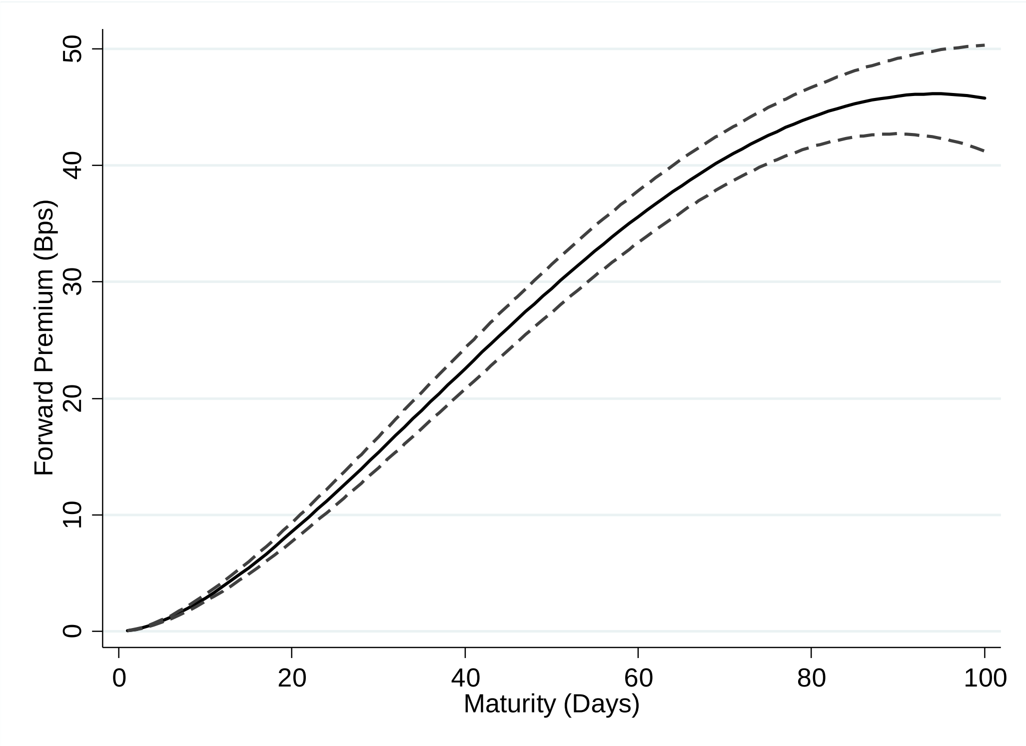
Note: This figure presents the daily time series (30-day moving average) of the USD/EUR forward rates different maturities from January 1, 2014, through December 31, 2016. The gray solid line refers to one week forwards, the gray dotted line to one-month forwards, the gray dashed line to three-month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

Figure 2 — Cross-Sectional Dispersion of Forward Premium



Note: This figure presents the daily time series (30-day moving average) of cross-sectional percentiles of the cleaned forward premium (in basis points) of USD/EUR forward contracts initiated in the period from January 1, 2014, through December 31, 2016. Cleaned forward premium is obtained as the residuals from a regression of the forward premium on counterparty*maturity*day fixed effects (i.e., where time-varying maturity and supply effects are removed). The black solid lines refer to the 10th and 90th percentile and the gray dashed lines represent the 25th and 75th percentile, respectively.

Figure 3 — Forward Premium Term Structure



Note: This figure shows the estimated term structure of the forward premium (in basis points). The solid line represents the point estimate for the term structure of the forward premium from a (fractional) polynomial regression with the forward premium as the dependent variable and a polynomial in contract maturity on the right-hand side (optimal polynomial structure selected according to minimum deviation criterion). The polynomial regression includes, in addition to the polynomial in contract maturity, also bank, counterparty, and day fixed effects. Dashed lines correspond to 10 percent significance bounds.

Table 1: Contract Collateralization

	Type of Collateralization			
	Uncollateralized	Collateralized	Unknown	Total
# Client Trades	295,727	246,971	69,542	612,240
% All Client Trades	48.30%	40.40%	11.40%	100.00%
# Inter-Dealer Trades	50,270	79,242	14,441	143,953
% All Inter-Dealer Trades	34.90%	55.00%	10.00%	100.00%
# Total Trades	345,997	326,213	83,983	756,193
% All Trades	45.80%	43.10%	11.10%	100.00%

Note: The table shows the decomposition of our data on dollar forward sales initiated in the period from January 1, 2014, through December 31, 2016 depending on the type of collateralization. 'Uncollateralized' refers to a contract where neither the selling bank nor the buying counterparty pledges any collateral, whereas 'Collateralized' represents contracts where any collateral is involved (initial margin, variation margin, for either one or both counterparties). 'Unknown' refers to a contract for which no information on collateralization is available. 'Client Trades' defines any contract, where one party is not a dealer. 'Inter-Dealer Trades' represents trades among two dealers. We define dealer as any institution that it is on the list of global FX dealers that are reporting institutions in the 2016 BIS Triennial Central Bank Survey of Foreign Exchange and Derivatives Market Activity. This comprehensive list comprises 1,283 FX dealers globally, of which 37 institutions are Germany-based (including German banks and German offices of foreign banks).

Table 2: Contract-Level Summary Statistics

	Mean	P10	P25	P50	P75	P90	SD	Obs.
Forward Premium (Bps)	51.04	-21.92	-2.97	14.87	44.35	102.36	203.00	261,467
Forward Premium (Bps, Cleaned)	0.00	-18.77	-4.98	0.00	4.26	17.03	74.27	110,066
Forward Premium (Bps, Annualized)	578.07	-653.95	-33.28	116.50	474.50	2,557.09	2,369.78	261,467
Forward Premium (Bps, Annualized, Cleaned)	0.00	-799.32	-104.59	0.00	86.62	715.01	1,282.15	110,066
Contract Value (USD Million)	8.98	0.02	0.07	0.30	1.93	13.60	35.70	261,467
Maturity (Days)	81.43	3.00	5.00	32.00	97.00	225.00	134.50	261,467
Assets (EUR Billion)	635.05	21.36	303.02	842.28	898.39	961.01	365.07	261,467
Equity (% Assets)	5.31	4.64	4.96	5.18	5.62	6.20	0.77	261,467
Dollar Assets (% Assets)	14.51	3.91	9.57	16.93	18.75	20.31	6.61	261,467
Dollar Assets (% Equity)	283.72	69.83	150.43	330.68	368.22	391.01	151.13	261,467
Dollar Funding Gap (% Assets)	46.43	2.07	36.07	59.75	63.89	64.10	27.00	261,467
Dollar Funding Gap (% Equity)	159.22	0.10	31.91	198.61	233.57	250.61	130.45	261,467
Dollar Intragroup Liabilities (% Dollar Liabilities)	8.20	0.00	0.00	8.85	11.56	16.13	5.80	261,432

Note: This table presents summary statistics on our main variables at the forward contract level for the period from January 1, 2014, through December 31, 2016. ‘Forward Premium’ refers to the relative difference (in basis points) between the dollar forward and spot exchange rate. Cleaned ‘Forward Premium’ is obtained as the residual from a regression of the forward premium on counterparty*maturity*day fixed effects (i.e., where time-varying maturity and supply effects are removed). Annualized ‘Forward Premium’ is obtained by multiplying the forward premia by 360/Maturity. ‘Dollar Funding Gap’ is defined as the difference between total dollar assets and total dollar liabilities, and normalized with total dollar assets*100 (and equity*100, respectively). ‘Dollar Intragroup Liabilities’ refers to the intragroup dollar liabilities relative to total dollar liabilities (in percentages). There are only 13 banks with non-zero dollar intragroup liabilities. Among these banks, the average (median) share amounts to 11.31% (9.85%). One bank has not positive dollar liabilities in each month in which case ‘Dollar Intragroup Liabilities’ is not defined. The sample includes only uncollateralized contracts.

Table 3: Bank-Level Summary Statistics

	Mean	P10	P25	P50	P75	P90	SD	Obs.
Assets (EUR Billion)	26.51	1.27	2.34	4.16	8,01	24.58	96.69	145
Equity (% Assets)	5.84	4.01	4.90	5.57	6.44	7.51	2.30	145
Dollar Assets (% Assets)	2.93	0.08	0.14	0.29	0.78	8.98	7.94	145
Dollar Assets (% Equity)	53.50	1.39	2.46	4.95	14.21	152.08	156.46	145
Dollar Funding Gap (% Assets)	4.84	-21.33	-1.04	0.38	6.37	59.84	32.89	145
Dollar Funding Gap (% Equity)	20.36	-0.59	-0.03	0.02	0.27	41.86	139.40	145
Dollar Intragroup Liabilities (% Dollar Liabilities)	0.58	0.00	0.00	0.00	0.00	0.00	3.67	145

Note: This table presents summary statistics on our main variables at the bank level. For each bank, there is one observation, which is the average of each balance sheet statistics throughout our sample period from January 1, 2014, through December 31, 2016. 'Dollar Funding Gap' is defined as the difference between total dollar assets and total dollar liabilities, and normalized with total dollar assets*100 (and equity*100, respectively). 'Dollar Intragroup Liabilities' refers to the intragroup dollar liabilities relative to total dollar liabilities (in percentages). There are only 13 banks with non-zero dollar intragroup liabilities. Among these banks, the average (median) share amounts to 10.34% (9.17%).

Table 4: Cross-Quarter Effect

	Forward Premium			
	(1)	(2)	(3)	(4)
Cross-Quarter	18.4400***	9.5646***	9.5059***	12.4963**
	(4.80)	(3.19)	(5.02)	(2.00)
Log(Maturity)	23.3232***	18.4338***	--	--
	(10.19)	(8.09)		
Cross-Quarter * Log(Maturity)	--	--	--	-0.9018
				(-0.46)
Contract Value Control	No	Yes	Yes	Yes
Bank Fixed Effects	No	Yes	Yes	Yes
Counterparty Fixed Effects	No	Yes	Yes	Yes
Maturity Fixed Effects	No	No	Yes	Yes
Observations	261,481	256,911	256,653	256,653
R-squared	0.050	0.366	0.382	0.382

Note: The estimations report the differential effect of forward premium depending on cross-quarter and maturity. The dependent variable is the forward premium implicit in USD/EUR forward contracts between bank ‘i’ and counterparty ‘j’ of maturity ‘m’ initiated during 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 basis points). ‘Cross-Quarter’ is a dummy variable that equals one for any contract that crosses the upcoming quarter-end day, and zero otherwise. ‘Log(Maturity)’ is the logarithm of the maturity of the forward contract (in days). Fixed effects are either included (‘Yes’) or not included (‘No’). The sample includes only uncollateralized contracts. All regressions are estimated using ordinary least squares. Standard errors are clustered at the bank-maturity level and presented in parentheses. Statistical significance at the 10 percent, (5 percent), and [1 percent] levels is indicated by *, (**), and [***], respectively.

Table 5: Dollar Funding Gap

	Forward Premium					
				Short-Term		
	(1)	(2)	(3)	(4)	(5)	(6)
Dollar Funding Gap	0.5028***	0.1898**	0.0871	-0.0436	-0.8476	-0.0251
	(5.10)	(2.26)	(0.17)	(-0.40)	(-1.21)	(-0.05)
Cross-Quarter * Dollar Funding Gap	0.1868***	0.2509***	-0.0912	0.2030**	1.4524**	-0.2087
	(2.94)	(5.15)	(-0.34)	(2.15)	(2.07)	(-0.26)
Cross-Quarter * Dollar Funding Gap * Log(Maturity)	--	--	--	--	-0.4992**	0.1658
					(-2.28)	(0.80)
Cross-Quarter * Dollar Funding Gap * Log(Maturity) * High Leverage	--	--	--	--	--	-1.2744**
						(-2.01)
Lower-Order Interaction Terms Controlled	Yes	Yes	Yes	Yes	Yes	Yes
Contract Value Control	Yes	Yes	Yes	Yes	Yes	Yes
Bank Size Control	Yes	Yes	Yes	Yes	Yes	Yes
Bank Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Counterparty Fixed Effects	Yes	Yes	--	--	--	--
Maturity Fixed Effects	Yes	--	--	--	--	--
Maturity*Day Fixed Effects	No	Yes	--	--	--	--
Counterparty*Maturity*Day Fixed Effects	No	No	Yes	Yes	Yes	Yes
Observations	256,639	234,738	110,060	64,211	110,060	110,060
R-squared	0.383	0.615	0.822	0.717	0.822	0.822

Note: The estimations report the differential pricing of cross-quarter forward contracts depending on dollar funding gap. The dependent variable is the forward premium implicit in USD/EUR forward contracts between bank 'i' and counterparty 'j' of maturity 'm' initiated during 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 basis points). 'Cross-Quarter' is a dummy variable that equals one for any contract that crosses the upcoming quarter-end day, and zero otherwise. 'Dollar Funding Gap' denotes the difference between total dollar assets and total dollar liabilities, and normalized with total dollar assets*100. 'Log(Maturity)' is the logarithm of the maturity of the forward contract (in days). 'High Leverage' is a binary variable that takes the value of one for all banks whose equity-to-asset ratio is lower than the 50^{th} percentile of the cross-sectional distribution according to the last balance sheet statements before day 't'. In column 4, we restrict the sample to contracts with maturity smaller than one month, i.e., 'Short-Term'. Time-varying controls (lagged logarithm of bank size, contemporaneous logarithm of contract value) and fixed effects are either included ("Yes"), not included ("No"), or spanned by another set of fixed effects ("-"). Lower-order interaction terms are included where possible, but coefficients are left unreported for clarity. The sample includes only uncollateralized contracts. All regressions are estimated using ordinary least squares. Standard errors are clustered at the bank-maturity level and presented in parentheses. Statistical significance at the 10 percent, (5 percent), and [1 percent] levels is indicated by *, (**), and [***], respectively.

Table 6: Internal Dollar Capital Markets

	Forward Premium					
				Only Banks with IDL		
	(1)	(2)	(3)	(4)	(5)	(6)
Cross-Quarter * Dollar Funding Gap * Intragroup Share	-0.0855*	--	0.3115*	-0.3852	2.2318*	-7.5855
	(-1.65)		(1.93)	(-1.44)	(1.82)	(-0.91)
Cross-Quarter * Dollar Funding Gap * Net Intragroup Share	--	-0.0668*	--	--	--	--
		(1.91)				
Cross-Quarter * Dollar Funding Gap * Intragroup Share * Log(Maturity)	--	--	-0.1313***	--	--	2.0994
			(-2.62)			(1.19
Cross-Quarter * Dollar Funding Gap * Intragroup Share * Short-Term Intragroup Share	--	--	--	--	-0.0479*	0.2589
					(-1.76)	(1.27)
Cross-Quarter * Dollar Funding Gap * Intragroup Share * Short-Term Intragroup Share * Log(Maturity)	--	--	--	--	--	-0.0645
						(-1.52)
Lower-Order Interaction Terms Controlled	Yes	Yes	Yes	Yes	Yes	Yes
Contract Value Control	Yes	Yes	Yes	Yes	Yes	Yes
Bank Size Control	Yes	Yes	Yes	Yes	Yes	Yes
Bank Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Counterparty*Maturity*Day Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	109,068	109,068	109,068	53,634	53,634	53,634
R-squared	0.822	0.822	0.822	0.806	0.806	0.807

Note: The estimations report the differential pricing of cross-quarter forward contracts depending on dollar funding gap and intragroup dollar liabilities (IDL). The dependent variable is the forward premium implicit in USD/EUR forward contracts between bank 'i' and counterparty 'j' of maturity 'm' initiated during 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 basis points). 'Cross-Quarter' is a dummy variable that equals one for any contract that crosses the upcoming quarter-end day, and zero otherwise. 'Dollar Funding Gap' denotes the difference between total dollar assets and total dollar liabilities, and normalized with total dollar assets*100. 'Dollar Intragroup Liabilities' refers to the intragroup dollar liabilities relative to total dollar liabilities (in percentages). 'Net Intragroup Liabilities' refers to the intragroup dollar liabilities minus intragroup dollar assets relative to total dollar liabilities (in percentages). 'Log(Maturity)' is the logarithm of the maturity of the forward contract (in days). In columns 4-6, we restrict the sample to banks with non-zero intragroup liabilities, i.e., 'Only Banks with IDL'. Time-varying controls (lagged logarithm of bank size, contemporaneous logarithm of contract value) and fixed effects are either included ("Yes") or not included ("No"). Lower-order interaction terms are included where possible, but coefficients are left unreported for clarity. The sample includes only uncollateralized contracts. All regressions are estimated using ordinary least squares. Standard errors are clustered at the bank-maturity level and presented in parentheses. Statistical significance at the 10 percent, (5 percent), and [1 percent] levels is indicated by *, (**), and [***], respectively.

Table 7: Bargaining Power

	Client-to-Dealer vs. Dealer-to-Dealer			Client-to-Dealer vs. Client-to-Client		
	(1)	(2)	(3)	(4)	(5)	(6)
Cross-Quarter * Dollar Funding Gap * Bank is Dealer	-5.8799***	-0.4107	0.1998	--	--	--
	(-13.43)	(-0.88)	(0.42)			
Cross-Quarter * Dollar Funding Gap * Bank is Dealer * Log(# Counterparties)	--	-6.3717***	--	--	--	--
		(-24.11)				
Cross-Quarter * Dollar Funding Gap * Bank is Dealer * Log(Maturity)	--	--	-2.9662***	--	--	--
			(-12.98)			
Cross-Quarter * Dollar Funding Gap * Counterparty is Client	--	--	--	-0.2699***	0.4173**	0.0680
				(-3.92)	(2.13)	-0.22
Cross-Quarter * Dollar Funding Gap * Counterparty is Client * Log(# Counterparties)	--	--	--	--	-0.2707***	--
					(-3.48)	
Cross-Quarter * Dollar Funding Gap * Counterparty is Client * Log(Maturity)	--	--	--	--	--	-0.0670
						(-0.81
Lower-Order Interaction Terms Controlled	Yes	Yes	Yes	Yes	Yes	Yes
Amount Controls	Yes	Yes	Yes	Yes	Yes	Yes
Size Controls	Yes	Yes	Yes	Yes	Yes	Yes
Bank*Maturity*Day FE	No	No	No	Yes	Yes	Yes
Counterparty*Maturity*Day FE	Yes	Yes	Yes	No	No	No
Observations	36,060	36,060	36,060	7,619	7,619	7,619
R-squared	0.581	0.581	0.581	0.816	0.816	0.816

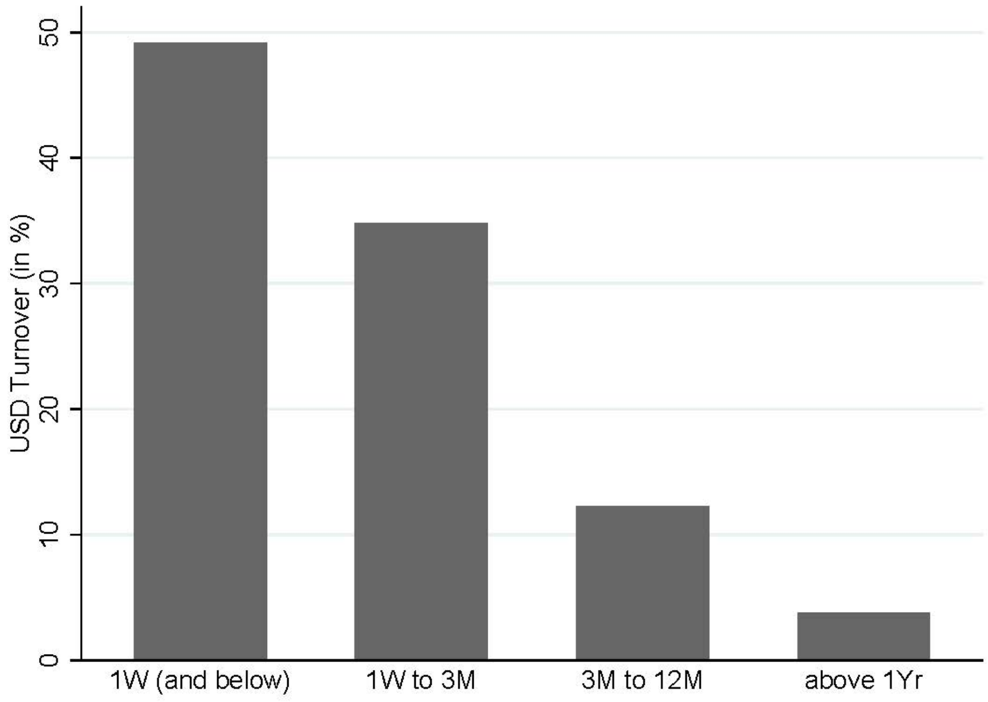
Note: The estimations report the differential pricing of cross-quarter forward contracts depending on bargaining power. The dependent variable is the forward premium implicit in USD/EUR forward contracts between bank 'i' and counterparty 'j' of maturity 'm' initiated during the period January 1, 2014, 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 basis points). In columns 1-3, we restrict the sample to contracts where the counterparty is a dealer. In columns 4-6, we restrict the sample to contracts where the bank is a client. 'Cross-Quarter' is a dummy variable that equals one for any contract that crosses the upcoming quarter-end day, and zero otherwise. 'Dollar Funding Gap' denotes the difference between total dollar assets and total dollar liabilities, and normalized with total dollar assets*100. 'Bank is Dealer' is a binary variable that equals the value of one when the bank is a dealer, and zero otherwise. 'Counterparty is Client' is a binary variable that equals the value of one when the counterparty is a client, and zero otherwise. 'Log(#Counterparties)' refers to the logarithm of the number of trading partners in the last year prior to the contract. 'Log(Maturity)' is the logarithm of the maturity of the forward contract (in days). Time-varying controls (lagged logarithm of bank size, contemporaneous logarithm of contract value) and fixed effects are either included ("Yes"), not included ("No"), or spanned by another set of fixed effects ("-"). Lower-order interaction terms are included where possible, but coefficients are left unreported for clarity. The sample includes only uncollateralized contracts. All regressions are estimated using ordinary least squares. Standard errors are clustered at the bank-maturity level and presented in parentheses. Statistical significance at the 10 percent, (5 percent), and [1 percent] levels is indicated by *, (**), and [***], respectively.

Table 8: Collateralized versus Uncollateralized Contracts

	Forward Premium					
	(1)	(2)	(3)	(4)	(5)	(6)
Initial Margin	-1.8842	5.6956	-7.3005	-5.6613	43.5199**	43.1724**
	(-0.95)	(1.39)	(-1.14)	(-0.66)	(2.09)	(2.08)
Initial Margin * Cross-Quarter	-12.3490***	-3.3072	-15.7411	11.9566	254.3152	1,323.7133
	(-3.15)	(-0.34)	(-1.04)	(0.14)	(1.44)	(1.37)
Initial Margin * Log (Maturity)	--	-3.5007**	-4.7020**	-9.1486*	-36.8824**	-36.7001**
		(-2.10)	(-2.41)	(-1.67)	(-2.23)	(-2.23)
Initial Margin* Cross-Quarter * Log (Maturity)	--	-1.4578	-3.2195	-11.7983	-121.4024	-379.1978
		(-0.48)	(-0.73)	(-1.12)	(-1.17)	(-1.21)
Initial Margin * Equity	--	--	3.9331**	7.1141*	-10.2660*	-10.1473*
			(2.37)	(1.80)	(-1.86)	(-1.86)
Initial Margin * Cross-Quarter * Equity	--	--	4.1921	7.1666	-29.8876	-234.6849
			(0.86)	(0.39)	(-0.93)	(-1.29)
Initial Margin * Equity * Log(Maturity)	--	--	--	--	8.1298**	8.0799**
					(2.27)	(2.27)
Initial Margin * Cross-Quarter * Log(Maturity) * Equity	--	--	--	--	17.8800	67.2053
					(0.95)	(1.13)
Lower-Order Interaction Terms Controlled	--	--	--	--	Yes	Yes
Amount Controls	Yes	Yes	Yes	Yes	Yes	Yes
Size Controls	Yes	Yes	Yes	Yes	Yes	Yes
Bank Fixed Effects	Yes	Yes	Yes	--	--	--
Counterparty Fixed Effects	Yes	Yes	Yes	Yes	Yes	--
Maturity*Day Fixed Effects	Yes	Yes	Yes	--	--	--
Bank*Maturity*Day Fixed Effects	No	No	No	No	No	Yes
Counterparty*Maturity*Day Fixed Effects	No	No	No	Yes	Yes	Yes
Observations	280,438	280,438	280,438	151,655	151,655	149,916
R-squared	0.615	0.615	0.615	0.822	0.822	0.822

Note: The estimations report the differential pricing of cross-quarter forward contracts depending on initial margin. The sample is extended to include not only uncollateralized but also collateralized contracts, which are one-way collateralized by the seller; that is, the selling bank must post collateral (initial margin) while the counterparty does not provide any form of margin. The dependent variable is the forward premium implicit in USD/EUR forward contracts between bank 'i' and counterparty 'j' of maturity 'm' initiated during 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 basis points). In this table, we extend the sample to contracts where the counterparty. 'Cross-Quarter' is a dummy variable that equals one for any contract that crosses the upcoming quarter-end day, and zero otherwise. 'Log(Maturity)' is the logarithm of the maturity of the forward contract (in days). Time-varying controls (lagged logarithm of bank size, contemporaneous logarithm of contract value) and fixed effects are either included ("Yes"), not included ("No"), or spanned by another set of fixed effects ("-"). Lower-order interaction terms are included where possible, but coefficients are left unreported for clarity. All regressions are estimated using ordinary least squares. Standard errors are clustered at the bank-maturity level and presented in parentheses. Statistical significance at the 10 percent, (5 percent), and [1 percent] levels is indicated by *, (**), and [***], respectively.

Appendix Figure A.1 — Market Turnover by Maturity Segment



Note: The figure presents the maturity breakdown of USD notional amounts of USD/EUR forward contracts initiated in the period from January 1, 2014, through December 31, 2016. The maturity bucket '1W (and below)' refers to contracts of up to 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 above 12 months (exclusive).

Appendix Table A.1: Conditional Contract-Level Summary Statistics

	Cross-Quarter				Non-Cross-Quarter			
	Mean	IQR	SD	Obs.	Mean	IQR	SD	Obs.
Forward Premium (Bps)	94.59	70.80	281.43	112,352	18.23	32.94	100.38	149,115
Forward Premium (Bps, Cleaned)	0.00	6.03	107.22	36,313	0.00	10.33	50.71	73,753
Contract Value (USD Million)	5.35	0.98	25.70	112,352	11.70	2.94	41.50	149,115
Maturity (Days)	166.84	144.00	169.81	112,352	17.08	22.00	18.82	149,115
	Inter-Dealer				Client			
	Mean	IQR	SD	Obs.	Mean	IQR	SD	Obs.
Forward Premium (Bps)	19.50	31.19	88.63	40,385	56.80	51.03	216.99	221,082
Forward Premium (Bps, Cleaned)	0.00	11.16	56.46	31,913	0.00	8.52	80.42	78,140
Contract Value (USD Million)	16.00	1.94	52.30	40,385	7.70	1.82	31.60	221,082
Maturity (Days)	102.22	135.00	157.00	40,385	77.64	88.00	129.60	221,082
	Large Banks				Small Banks			
	Mean	IQR	SD	Obs.	Mean	IQR	SD	Obs.
Forward Premium (Bps)	51.17	46.29	205.16	248,925	48.43	76.25	153.81	12,542
Forward Premium (Bps, Cleaned)	0.00	8.66	75.98	104,672	0.00	19.79	22.42	5,278
Contract Value (USD Million)	9.36	1.93	36.50	248,925	1.43	0.19	12.20	12,542
Maturity (Days)	80.63	91.00	134.32	248,925	97.39	139.00	137.02	12,542
	High Dollar-Funding-Gap Banks				Low Dollar-Funding-Gap Banks			
	Mean	IQR	SD	Obs.	Mean	IQR	SD	Obs.
Forward Premium (Bps)	50.90	46.01	205.54	231,578	52.14	60.44	182.13	29,889
Forward Premium (Bps, Cleaned)	0.00	8.36	76.15	97,389	0.00	15.67	52.36	12,055
Contract Value (USD Million)	9.76	2.14	37.20	231,578	2.93	0.41	19.60	29,889
Maturity (Days)	80.72	90.00	132.64	231,578	86.98	114.00	147.99	29,889

Note: This table presents summary statistics on our main variables at the forward contract level for the period from January 1, 2014, through December 31, 2016. 'Forward Premium' refers to the relative difference (in basis points) between the dollar forward and spot exchange rate. Cleaned 'Forward Premium' is obtained as the residuals from a regression of the forward premium on counterparty*maturity*day fixed effects (i.e., where time-varying maturity and supply effects are removed). In the panel 'Cross-Quarter' ('Non-Cross-Quarter'), we restrict the sample to all cross-quarter (non-cross-quarter) forward contracts. In panel 'Inter-Dealer' ('Client'), we restrict the sample to all inter-dealer (client) contracts. In panel 'Large Banks' ('Small Banks'), we restrict the sample to the top-25th (bottom-75th) percentile largest (smallest) banks. In panel 'High Dollar-Funding-Gap Banks' ('Low Dollar-Funding-Gap Banks'), we restrict the sample to banks with the top-25th (bottom-75th) percentile highest (lowest) dollar funding gap. The sample includes only uncollateralized contracts.

Appendix Table A.2: Correlation Table

	Assets (EUR Billion)	Equity (% Assets)	Dollar Assets (% Assets)	Dollar Assets (% Equity)	Dollar Funding Gap (% Assets)	Dollar Funding Gap (% Equity)	Dollar Intragroup Liabilities (% Dollar Liabilities)
Assets (EUR Billion)	1.00						
Equity (% Assets)	-0.16	1.00					
Dollar Assets (% Assets)	0.24	-0.02	1.00				
Dollar Assets (% Equity)	0.17	-0.11	0.51	1.00			
Dollar Funding Gap (% Assets)	0.22	0.41	0.36	0.50	1.00		
Dollar Funding Gap (% Equity)	0.30	-0.08	0.42	0.81	0.76	1.00	
Dollar Intragroup Liabilities (% Dollar Liabilities)	0.47	-0.13	0.01	0.00	0.13	0.17	1.00

Note: The table presents a correlation matrix of our main variables at the bank-level. For each of the 145 bank in the sample, there is one observation, which is the average of each balance sheet statistics throughout our sample period from January 1, 2014, through December 31, 2016. 'Dollar Funding Gap' is defined as the difference between total dollar assets and total dollar liabilities, expressed as a percentage to total dollar assets (and total equity, respectively) 'Dollar Intragroup Liabilities' refers to the intragroup dollar liabilities relative to total dollar liabilities (in percentages).

Appendix Table A.3: Bank-Level Number of Contracts and Volume at Quarter End

	Log(#Contracts)			Log(Volume)		
	(1)	(2)	(3)	(4)	(5)	(6)
End-of-Quarter	0.0268**	0.1505***	--	0.0893**	0.3784***	--
	(2.34)	(3.47)		(2.54)	(3.01)	
End-of-Quarter * Log(Maturity)	--	-0.0283***	-0.0281***	--	-0.0661**	-0.0642**
		(-3.19)	(-2.74)		(-2.50)	(-2.15)
Bank Fixed Effects	No	No	No	No	No	No
Maturity Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Day Fixed Effects	No	No	Yes	No	No	Yes
Observations	82,880	82,880	82,871	82,880	82,880	82,871
R-squared	0.363	0.363	0.376	0.291	0.291	0.304

Note: The estimations report the differential effect of bank-level number of contracts and contract value depending on end-of-quarter. In columns 1-3, the dependent variable is the logarithm of the number of USD/EUR forward contracts by bank 'i' of maturity 'm' initiated on any given day 't' during the period January 1, 2014, through December 31, 2016. In columns 4-6, the dependent variable is the logarithm of the notional value of USD/EUR forward contracts by 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 one for the last five days of any given quarter, and zero otherwise. 'Log(Maturity)' is the logarithm of the maturity of the forward contract (in days). Fixed effects are either included ("Yes"), or not included ("No"). Results are based on uncollateralized contracts. All regressions are estimated using ordinary least squares. Standard errors are clustered at the bank-maturity level and presented in parentheses. Statistical significance at the 10 percent, (5 percent), and [1 percent] levels is indicated by *, (**), and [***], respectively.

Appendix Table A.4: Bank-Level Volume-Weighted Hedging Cost at Quarter End

	Volume-Weighted Forward Premium		
	(1)	(2)	(3)
End-Of-Quarter	10.7605	4.5612	--
	(1.36)	(0.57	
Dollar Funding Gap	--	0.1007	-0.0580
		(0.61)	(-0.29)
End-Of-Quarter * Dollar Funding Gap	--	0.4575**	0.4922**
		(2.48)	(2.35)
Bank Fixed Effects	Yes	Yes	Yes
Day Fixed Effects	No	No	Yes
Observations	11,025	11,012	10,910
R-squared	0.074	0.071	0.176

Note: The estimations report the differential effect of bank-level volume-weighted forward premium depending on end-of-quarter. The dependent variable is the volume-weighted forward premium implicit in USD/EUR forward contracts by bank 'i' of maturity 'm' initiated on any given day 't' during the period January 1, 2014, through December 31, 2016. 'End-of-Quarter' is a dummy variable that equals one for the last five days of any given quarter, and zero otherwise. 'Dollar Funding Gap' denotes the difference between total dollar assets and total dollar liabilities, and normalized with total dollar assets*100. Fixed effects are either included ("Yes"), or not included ("No"). Results are based on uncollateralized contracts. All regressions are estimated using ordinary least squares. Standard errors are clustered at the bank-maturity level and presented in parentheses. Statistical significance at the 10 percent, (5 percent), and [1 percent] levels is indicated by *, (**), and [***], respectively.

Appendix Table A.5 – Market Liquidity by Maturity Segment

	Maturity Segment	
	1 Week and Below	1 Month to 3 Month
# Banks	45.14	49.63
# Counterparties	2254.43	606.13
# Dealer Banks	11.57	7.72
# Dealer Counterparties	98.29	16.50
Std. of Forward Premium	34.64	201.12
Relative Std. of Forward Premia	5.89	10.24
Cross-Quarter Forward Premium of High-Funding-Gap Banks with IDL	16.36	52.95
Cross-Quarter Forward Premium of High-Funding-Gap Banks without IDL	17.73	72.26

Note: This table presents mean values of main variables of our data on dollar forward sales initiated in the period from January 1, 2014, through December 31, 2016 for two different maturity buckets. '1 Week and Below' refers to forward contracts with maturity less than one week (inclusive), while '1 Month to 3 Month' represent contracts with maturity between one and three month (inclusive). Values represent means across maturities within each maturity bucket. That is, we first compute the statistic for each individual maturity (e.g., 10 days, 11 days, 12 days, etc) and then take the average within each maturity bucket. 'Relative Std.' is the mean (within each maturity bucket) of the standard deviation of the forward premium (by maturity) divided by the median standard deviation (by maturity). The last two rows report the cross-quarter premium for high-funding-gap banks with versus without intragroup dollar liabilities (IDL). 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 basis points). The sample includes only uncollateralized contracts.