The Dark Side of FX Volume: Evidence from Large Dealer Banks

Mario Cerrato *[1], Shengfeng Mei †[2], Alex Saunders ‡[3], and Tongtong Wang §[1]

[1]Adam Smith Business School, University of Glasgow
[2]Institute of Inner City Learning, University of Wales Trinity Saint David
[3]
[1]Adam Smith Business School, University of Glasgow

(Dated: May 5, 2025)

Abstract:
We employ two new proprietary FX volume and order flow datasets and provide evidence on the informative role of volume before and after 2008. Our empirical evidence suggests that US$ (spot) trading post-2008 can become impaired when dealers' balance frictions are tighter. This result holds after controlling for larger FX spot volumes. We focus on debt overhang costs (Myres, 1974) related to the equity holder of the bank when supplying (extra) fx dollar liquidity in times of negative shocks. We study the financial crisis and the COVID-19 shocks. We also consider shifts in the demand side of the dollar following a negative shock. In short, FX dealers, following a negative shock on capital, reduce the intermediation (supply) of the US dollar (relatively to times when they are unconstrained) when debt overhang cost is stringent. Therefore, they do not provide sufficient dollar liquidity to clear the market demand. We present a model explaining the possible mechanism behind this. We show that debt overhang cost introduces a shadow cost on the capital for the dealer. This explains why she has little incentive to increase the intermediation of dollar liquidity in bad times and accommodate the market.
Keywords: JEL Financial Crises(G01); Asset Pricing, Trading Volume, Bond Interest Rates(G12); International Financial Markets(G15); Foreign Exchange(F31)

*E-mail: mario.cerrato@glasgow.ac.uk
†E-mail: s.mei@uwtsd.ac.uk
‡E-mail:
§E-mail: tongtong.wang@glasgow.ac.uk

1 Introduction

Does forex volume contain relevant information? What type of information? In this paper, we address these important questions. Market participants observe the volume of trade to infer information about the predictability of price returns. Why volume is informative depends on what type of information it contains, and this depends on the reasons investors trade (hedging, speculation or other purposes).

Using fx bilater volumes, from two of the largest fx dealers, over a very long period, we show that the predictability information of the fx spot volume is related to dealers' balance sheet constraints post 2008. The information contained in the fx volume is related to the steeper US dollar supply curve post 2008. In this paper we focus on debt overhang (Myres...) as the empirical literature studying balance sheet constraints has largerly focused on different constraints. This paper fills this gap.

We find no evidence of predictability for the fx volume before 2008. In fact, we show that this predictability manifests itself in periods when the fx dealer is constrained (debt overhang is higher). In this case, we see that forex volumes can predict appreciation of the US dollar. We present a model that formalises our empirical results.

There is substantial literature in the equity arena suggesting that volume contains information. Campbell et al (1993) suggest that trading volume occurs when a shift in liquidity demand is accommodated by risk-averse market makers. Therefore, their theoretical model and empirical results point towards the liquidity information role of trading volume. Liorente et al (2002) propose a model for the equity return-volume relationship suggesting that returns driven by fundamental information tend to continue while those from hedging tend to reverse. They test this hypothesis using stocks and show that there is indeed some information in the volume about future price movements.

The ones discused earlier are only a few examples of the large literature on volume and returns in the equity arena, but One interesting aspect consensus on whether volume is informative is still far from converging. In many seminal papers, equity volume is still viewed as a measure of liquidity shocks (i.e. it does not convey fundamental information) with no persistent impact on equity prices.

The forex market is very large with an average of almost $7 trillion traded each day (BIS 2019). The literature on FX volume is still at a nascent stage as large-volume datasets have only been available recently. But this literature has already produced important research advancing our understanding of fx volume (Cespa et al, 2022), Huang et al (2021), Klocks et al (2023), Ranaldo et al (2019), Czech et al (2021)). However, although this literature, has helped us to better understand the informative role of the fx volume, both in spot and derivatives markets, it is still short from providing robust evidence of the type of information contained in it. Furthermore, most of the recent literature on fx volume rests mainly on the interdealer market and does not cover periods before the 2008 financial crisis.

In this paper, we fill this gap as we use (bilateral) fx volume and order flows from two of the largest fx dealers and covering a very long time period. We conjecture that dealers' debt overhang cost (Myres, 1974) poses stringent frictions on the fx dealer's balance sheet, affecting her capacity to supply sufficient dollar liquidity to clear the market. For example, following a surge in dollar demand, and conditionally on higher debt overhang cost, the dollar appreciates sharperly. The increase in FX dollar volume, is related to a surge in demand of dollars. As we have detailed order flows data from the dealers, we show that the surge arises from price sensitive customers (financial customers). But constrained dealers are unable to provide sufficent dollar liquidity and therefore the dollar supply curve becomes inelastic. We show that this is only true after 2008. Therefore, the predicability power of the fx volume seems to be a feature manifesting only post 2008 and when larger dealers' equity and funding costs increase significantly. This is a novel and important contribution of this paper.

What is debt overhang ? (Myres, 1974; Anderson et al, 2019). Debt overhang was first noted in Myres (1974). He noted that highly leveraged firms do not invest in projects with positive net present value (NPV), as debt (equity) financing would lead to a transfer of wealth from equity holders to creditors. Andersen et al (2019) discuss debt overhang costs related to funding value adjustments (FVA) for swap pricing, while Burnside and Cerrato (2024) discuss debt overhang cost for large dealers when arbitraging CIP deviations in different markets.

In times of a surge in the demand of US dollar, if the dealer equity capital is lower (dollar funding costs higher), the dollar appreciates. This result is also in line with Jiang et al(2021). They show that CIP fails when the demand of dollar assets increase and banks financial constraints in supplying dollars also increase. Thus, following a demand and supply shock in the spot market, fx volume increase and the dollar appreciates significantly.

In sum, the predicability power of the fx volume is related to the supply shock. This is a new and significant results which also shed further light on recent papers such as Bianchi et al (2021). Our model suggests that, following a dollar demand shock, as the one oserved during the financial crisis of recently the COVID-19, and due to dealers' balance sheet constraints, the shadow cost for the equity holders of the bank to provide sufficient immediacy in dollars increases, leading to an appreciation of the dollar and a significant predictability power of the fx volume.

As we mentioned, we also study two shocks. The Financial crisis and the COVID-19 shock. We provide evidence that the financial crisis shock, and the COVID-19 shock, are associated with significant higher leverage, followed by quick deleveraging. That is, debt overhang is likely to be highly relevant during the two periods we study. Our measure of dealers' leverage is from He et al (2017) and it is defined as total debt of the dealer to total market equity. Therefore, our measure of leverage reflects directly debt overhang cost for the equity holders.

Higher leverage (or lower capital), makes the provision of US$ spot liquidity highly expensive for the dealers. This becomes even more important when the dealer fx books of the dealer is flooded by dollar demand, leading to higher inventory costs. This happens when the dealer cannot offset the dollar demand internally (via matched book). In this circumstance, the higher shadow cost of capital (higher debt overhag), makes "inconvenient" for the dealer to supply sufficient dollar liquidity to clear the market. This supply side effect increases significantly the predictability of the fx volume.

Who is the intermediary in our paper? Differently from the recent literature, our intermediaries are two large banks, providing liquidity to their clients (financial and non-financial). This is a significant departure with respect to the recent fx literature where the intermediary is an "arbitrageur". When facing large inventory and higher balance sheet costs, she skews prices of foreign currency to attract clients to purchase it. In line with current evidence (Barzykin et al 2022; Butz et al 2019; Chaboud et al 2023), she holds the client's position on her balance sheet until another client comes to offset it (Internalisation).

The externalisation, via the interdealer market, would allow the dealer to reduce balance sheet costs but this comes at a price. For example, the dealer will have to quote cross bid-ask spreads or accept a greater market impact as the trade will be visible to others (Barzykin et al 2022, Butz et al 2019). Therefore, the dealer will generally prefer to skew prices to attract flows on the book internally (Barzykin, 2022).

Furthermore, as discussed in Butz and Roel(2018), internationalisation advantages the large FX dealers (with respect to smaller banks) as they benefit from economies of scale and large FX trading volumes and therefore they need to skew their prices less.

In this paper, we do not aim to provide a systematic analysis of FX liquidity (see, for example, Ranaldo et al (2022), Klocks et al(2023)), but rather to study FX volume predictability, controlling for balance sheet costs. We aim to shed further lights on the type of information (if any) embedded in fx volume (Cespa et al (2022)) and relate it to the scramble for dollars[1]

Cespa et al (2022) made a significant contribution on the informative role of FX volume. They propose a theoretical model to motivate asymmetric information via FX volume. The authors use FX volume data for spot, forward and swap positions from CLS Group over a period of six years,

[1] Du et al.(2023) show, in the context of covered interest parity (CIP), that larger CIP deviations are associated with quarter-end effects. Given that the sample period of the first dealer is not affected by Leverage Ratio Requirements (LLR), our results may imply that quarter-end effects are only the tip of the iceberg. Burnside and Cerrato, 2024 make a similar point.

and suggest that FX (spot and derivatives) volume is informative to predict currency excess returns. The paper goes further, suggesting that informed dealers can exploit the volume information to predict currency excess returns the next day.

We do not focus on using the information in fx volume (if any) to exploit trading behaviour. Our paper is related to Cespa et al (2022) in other distinct ways. While we also use fx volume data, our dataset originates from two large dealers, but for a smaller set of currencies (only 11 currencies for the first dealer and G10 for the second). Crucially, our dataset covers a much longer time period, spanning before and after the 2008 financial crisis (2002 to 2012 for our first dealer, and 2014-2023 for the second dealer, although we only focus on the period related to the COVID-19 shock, 2018-2021.). Our volume dataset only refers to spot fx transactions at weekly and daily frequencies. We match this data with two novel order flows data from the same dealers.

As in Cespa et al (2022), we confirm that fx volume is informative after 2008. This is true when we use the volume data from the first dealer spanning the period 2008-2013 as well as the volume data from the second dealer, spanning the period 2018-2021. Given that, for the first dealer, we use weekly frequency, the evidence of persistent reversal is already important in itself, as one would expect that the informational content in FX volume would dissipate very quickly. We provide a plausible explanation for the persistent reversal.

However, when using data (from the first dealer) covering a long period before 2008, we cannot find any predictive ability in the fx volume. We reconcile this conflicting evidence suggesting that, post 2008 balance sheet frictions (in our case debt overhang costs) have changed the slope of the supply curve for dollars.

It is important important to point out that, debt overhang is unrelated to the dealer's risk aversion. However, while in this paper we focus on debt overhang, we also acknowledge that one alternative explanation for our results could be endogenous risk as in Kondor and Vayanos (2019). Endogenous risk aversion arises, for example, when funding costs (and funding spreads) increase and speculators depend on dealers' liquidity to roll over their short-term liabilities (see He et al.(2017)) [2]. We do not study or model this interesting feature and leave it on the agenda for future work.

As we mentioned, there are two papers related to ours, Czech et al (2021) and Ranaldo et al (2019). The former studies the informational content of the FX option volume using a six-year daily dataset, CLS Group, and suggests that option volume can explain exchange rate predictability in bad times, that is when the convenience yield of the US Treasury is high or when the demand for the US$is high. They propose a model to rationalise these features. Results in Czech et al (2021) are consistent with ours as they suggest that in bad times, the marginal utility of dealers' wealth is high (in our case the capital is lower), and dealers' balance sheet constraints bind. In this case, dealers are scrambling for dollars (Bianchi et al, 2023). They use data from the interdealer market and therefore they also cover large dealers.

Ranaldo et al (2019) propose a unified FX model which links exchange rates, volume and volatility. They show that disagreement amongst market participants, given the difference between market price and reservation price, generates trading and volatility. Results in our paper are also in line with this literature as we show that larger US$ volumes are also correlated with periods of larger reservation prices (proxied by larger bid-ask spreads). Differently from that paper, we explicitly focus on debt overhang cost and study two shocks (financial crisis and COVID-19 shocks).

An important part of the literature on post-2008 financial intermediation has studied the dynamics leading to illiquidity in periods of stress across different asset classes (for example US Treasury during the 2020 COVID-19 shock, credit lines in the US and Europe (Copeland et al (2021)) or reluctance of arbitrageurs (banks' dealers but also nonbanks) to arbitrage covered interest rate (CIP) violations, or bond-CDS spread violations (Copeland et al (2021)). This line of research points towards post-2008 financial regulations, particularly leverage ratio requirements (LRR) as an explanation for that.

[2] endogenous risk aversion introduces general wrong way risk from the dealer's side as leveraged clients in the fx market also rely on dealers' funding via the collateralised REPO market. In times of market turmoil, both the markets-fx and funding markets (REPO)- are impaired.

Our paper speaks to this part of the literature, suggesting that, although regulatory effects on financial intermediation are relevant, dollar funding (equity) cost has become an important friction, which is not only relevant at quarter ends. Debt overhang cost (Andersen et al, 2019) has introduced frictions in the fx market (spot and derivatives markets) associated with persistent (US dollar) returns.

Huang et al (2021) study FX dealers' liquidity provision when their intermediary capacity is constrained. They consider regulatory and firms' constraints and show that dealers reduce intermediation in the currency market when constraints bind and as a consequence, bid-ask spreads widen. We mainly focus on debt overhang costs, although we do not claim that regulatory costs are irrelevant. For example, leverage ratio requirements (LLR) are also debt overhang cost for equity holders as this (regulatory) cost is to be financed by new equity, making creditors of the bank better off (see also discussion in Andersen et al (2019), Burnside and Cerrato (2024)). While we do not dispute the relevance of the LLR and its effect on financial intermediation, our results suggest that additional relevant frictions are also in place and they have not been well understood yet.

2 Literature Review

Our paper is related to three strands of the literature. First, it is related to the literature on financial intermediation and dealers' balance sheet frictions post-2008 (Du et al. (2018), Rime et al. (2022), Huang et al. (2021), Cenedese et al.(2021), Burnside et al (2024)). We extend this literature by focusing on fx spot intermediation and fx spot volume and its association with dealers' debt overhang costs.

This strand of the literature is still in its infancy and has mainly focused on regulatory frictions (apart from Burnside et al (2019), who study debt overhang cost and funding value adjustments when arbitraging CIP). Since one of our fx volume data also spans a period when the leverage ratio requirement (LRR) was not binding, we use this sample to study whether alternative frictions were in place and how they relate to fx volume. We provide evidence suggesting that debt overhang cost was at work during the 2008 financial crisis and that, probably, it has been very relevant following the discussion and the signature of the Dodd-Frank Act in the US. This is also well documented in Berndt et al (2024). Our evidence would suggest that higher US dollar trading volume is associated with this new friction.

Secondly, we contribute to the strand of the FX microstructure literature highlighting the importance of the FX volume (Cespa et al, 2022), Czech et al.(2021), Ranaldo et al (2022)). This strand of the literature has provided evidence that FX volume (spot and forward) contains valuable information which can be used for trading strategy or associated with FX returns. However, this important strand is limited in that their volume data mainly refers to the interdealer segment and spans a period (in many cases rather short) covering only the post-2008 financial crisis. We extend this part of the literature by providing evidence that, following negative shocks on dealers' capital, the large fx volume observed is associated with the flight to a safe US dollar and also to restore dollar capital (Bianchi et al, 2024).

In sum, we complement the two strands of the literature above in several ways. First, we use customer fx volume data from two of the largest fx dealers. Using the new data, we are able to shed light on the informative role of FX volume before and after the 2008 financial crisis. In this respect, we can extend the empirical study in Cespa et al (2022) reporting new and interesting results and, more importantly, we relate their model of asymmetric information to the new strand of literature cited above but focusing on dealers' balance sheet constraints.

Finally, although the main objective of our paper is not to undertake a systematic study on fx liquidity, but only to study why large fx volume occurs and when they occur, our empirical results also speak to Ranaldo et al (2022) as we show that fx liquidity can be largely impaired by dealers' debt overhang costs.

3 Data and Summary Statistics

Summary statistics of the data.

3.1 *Forex Volume*

We use two confidential (bilateral) datasets from two large FX dealers. The first dataset uses 11 currencies against the US dollar (USD). The currencies include Euro(EUR), Japanese yen (JPY), British pound (GBP), Swiss franc (CHF), Australian dollar (AUD), New Zealand dollar (NZD), Canadian dollar (CAD), Mexican peso (MXN), South African rand (ZAR), Singapore dollar (SGD), Hong Kong dollar (HKD). This dataset contains only seven G10 currencies (EUR, JPY, GBP, CHF, AUD, NZD, and CAD). For each currency pair, we have fx US$ trading volume for almost twelve years (2001-2012), at a weekly frequency. Data is reported in Table 1 (A). We also have matching order flows for the same currencies, which have been kindly provided by Burnside et al (2024).

The second dataset consists of daily US$ volume across the G9 currencies. We have volume data for Australian dollar (AUD), Canadian dollar (CAD), Euro (EUR), Japanese yen (JPY), New Zealand dollar (NZD), Norwegian krone (NOK), Britsh Pound (GBP), Swedish krona (SEK), and Swiss franc (CHF). This FX Volume Indicator measures the average daily volume based on client trades. It is calculated as the average daily volume over the past 20 days, normalised by the 6-month median volume of a currency and investor client type. A value greater than one (1) means that more recent daily volume is above its longer-term median, and less than one, means that it is below its median. The Volume Indicators are based on the total buy and sell trades of a currency by client type that are aggregated in USD equivalent terms regardless of the cross they are transacted in. Indicators are calculated separately for Leveraged Accounts, Real Money and Investors. The data spans the period 2014 to 2023, daily frequency, although in this paper we only focus on the period 2018 to 2021 and the COVID-19 period. Data is reported in Table 1 (B). We alsohae. for the same dealer, order flows (in US dolar billions) for the same currencies spanning the same period.

For our first dealer, the sample consists of 493 observations for each currency from the first week of November 2002 to the fourth week of March 2012. Trading volume is expressed in billion US$. Table 1 (Panel A) shows the average weekly volume for our currencies. The Euro is the currency with the largest volume while the Hong Kong dollar is the currency with the smallest weekly volume. It is worth noting that low-interest-rate currencies are, in general, the ones with the largest volume, much larger than high-interest-rate currencies. For a description of the statistics of order flow data from the first dealer, refer to Burnside et al (2024).

Table 1 (Panel B) shows the volume data of the second dealer. As we mentioned, this is an index which relates the volume of US$ and spanning Jan 2018 to Dec 2021. Trading volume is expressed relative to the median volume.

Table 2 shows the order flow data from the second dealer covering the period 2018-2021.

3.2 *Return and Excess Return*

We use the weekly spot exchange rate from WM/Refinitiv (via Datastream). WM/Refinitiv weekly exchange rates are simultaneously recorded on Friday at 4 pm in London. We calculate the weekly exchange rate return as the log difference between the spot exchange rate:

$$\Delta s_{i,t} = s_{i,t} - s_{i,t-1} \tag{1}$$

where $\Delta s_{i,t}$is the exchange rates log return of each currency pair $i$at time t. And $s_{i,t}$is the log of the exchange rate price of currency pair i at time t.

We then compute the excess return for each currency pair:

$$r_{i,t} = \Delta s_{i,t} - (ir^{i}_{i,t-1} - ir^{\$}_{i,t-1}) \tag{2}$$

Where $r_{i,t}$ is the excess return for each currency i, $ir^{\$}_{i,t-1}$ is the short-term interest rate of USD and the $ir^{i}_{i,t-1}$ is the short-term interest rate of quoted currency i at observed time $t-1$. We replace short-term interest rates with forward rates under the assumption that ($ir^{i}_{i,t-1} - ir^{\$}_{i,t-1} \approx f_{i,t-1} - s_{i,t-1}$), and express the excess return as:

$$r_{i,t} = \Delta s_{i,t} - (ir^{i}_{i,t-1} - ir^{\$}_{i,t-1}) = (s_{i,t} - s_{i,t-1}) - (f_{i,t-1} - s_{i,t-1}) = s_{i,t} - f_{i,t-1} \quad (3)$$

where $f_{i,t-1}$ is the log of 3 month forward rate of currency i at time $t-1$. To be able to use all our currencies, we use the 3-month forward rate of all currencies from Barclays Bank PLC (via Datastream) as shorter maturity is not available for non-G7 currencies. However, for robustness, in the online Appendix (A), we also show the results when using the one-month and the one-week maturity. Note that we use excess returns in the first part of the paper to be consistent with Cespa et al (2022), but we could use returns, as we do in the second part of the paper, given that our main focus is to explain the predictability of the fx volume.

4 The Empirical Model

When start addressing some of the key questions of this paper: does fx volume contain information? If yes, what type of information does it contain? This has been investigated in some recent and important papers, Czech et al (2021), Klocks et al (2023) and Cespa et al (2022). Cespa et al (2022), for example, use data on FX spot volume and make a case for asymmetric information driving the fx volume. This is a plausible explanation. For example, if the fx volume moves with fx volatility, then one can assume that higher volatility increases the demand for dollar liquidity, and this affects fx volume and the dollar exchange rate. Therefore, one would observe a predictability power of the volume on returns (or excess returns). In this context, models based on asymmetric information could provide a possible explanation (for example Cespa et al, 2022).

The data used in the literature, included Cespa et al (2022), originate in a settlement specific platform, CLS Group. In this paper we use bilateral flow data, therefore it makes sense to re-do their analysis using our data and test the predictability of the fx volume. However, in doing so, crucially, we divide our sample into two parts, before and after 2008. We shall discuss the reason in the next section. As in Cespa et al (2022), we also control for GARCH volatility, bid-ask spread and more.

For the bid-ask spread, we collect the bid and ask price from Refinitiv (via Datastream). The larger the bid-ask spread, the larger fx illiquidity[3] To mitigate heteroskedasticity and trends in the time series of volume, we follow Cespa et al (2022) and calculate the normalized volume as:

$$nv_{i,t} = log(vlm_{i,t}) - log(\frac{\sum_{s=1}^{N} vlm_{i,t-s}}{N}) \quad (4)$$

where $nv_{i,t}$ is the normalized volume, $vlm_{i,t}$is the original volume. We set N equals 12.

$$r_t = A + Br_{t-1} + C(r_{t-1} \times nv_{t-1}) + Dnv_{t-1} + \lambda x_{t-1} + \phi + E_{t-1} \quad (5)$$

where $x_{i,t-1}$ controls for currency-pair-specific measures of liquidity and volatility. The coefficients A and ϕ denote currency pair and time fixed-effects. In this model, we add the ($r_{i,t-1} \times nv_{i,t-1}$) interaction term.

5 Preliminary Results

Table 3 shows the results. We include time and currency fixed effects and use double-clustered standard errors.

[3] Bid-ask spread is also a measure of asymmetric information. (Ranaldo et al.(2022)) Larger bid-ask spreads are proxies for larger asymmetric information.

In columns 1-3 we use all the 11 currencies. We focus on the interaction coefficient which, following the model in Cespa et al (2022), we expect to be highly significant.

In columns 2 and 3, the interaction coefficient is indeed highly significant. Based on similar results, Cespa et al (2022) conclude that asymmetric information in the FX market is relevant and that FX trading volume is informative. Our results confirm this.[4]

Table 3 shows some novel and interesting results on top of what we have learned in the literature. For example, our estimated interaction coefficients are much larger than the ones reported in many recent papers, included Cespa et al (2022). This may suggest that customers' volumes are more informative than the ones used in most papers (Cespa et al, 2022), Huang et al (2021)). Czech et al (2021) makes a similar remark.

More important, the degree of persistence in currency returns that we document is surprisingly higher given that we use weekly data. Also, volume on its own, is always highly significant while in most recent FX empirical papers (and in the model in Cespa et al (2022)), the latter is insignificant and, generally, the significance is reached by the interaction of volume with other variables (for example volume and exchange rate or volume and proxies for dealers' balance sheet constraints).

In columns 4-9, we control for large and small volume, bid-ask spread and volatility. We divide groups into high (low) bid-ask spread, volume and volatility based on the median. Overall, the results are reasonably consistent with Cespa et al (2022) and one could interpret this evidence as supportive of asymmetric information[5]

Given that our data-set also spans a long period before the 2008 financial crisis, and it is the only fx volume covering such a long time span, we now focus on that period. If fx volume has some predictability power, this should also be the case before 2008.

Table 4 shows the results. There is no evidence of predictability of the FX volume on dollar returns before 2008. This result also contrasts with the FX microstructure literature suggesting an informational role for the order flow, unless volume and order flow capture different types of information. [6]

Summing up the evidence in Table 3 and Table 4, we can conclude that there is indeed an informative role in the fx volume for the post-2008 period, but not for the period before 2008. We think that this different role of fx volume can be rationalised after considering supply side factors and how they have affected the slope of the supply curve of US dollars post 2008.

A recent paper (Huang et al 2025) shows that the supply curve for fx liquidity has become steeper. This could reasonably be attributed to higher US$ funding costs (or equity capital costs), especially for large dealers after 2008. In the next sections we study if supply side constrains can help to understand the informative role of fx dollar volume after 2008.

Note that the FX data used in this paper comes from two of the largest FX dealers. Their balance sheets are the primary source of US$ liquidity as they intermediate significant fx volume every day. It is plausible to assume that any pressure on their balance sheets would affect the intermediation service in the US$ market. For example Duffie et al, (2023) make a similar case for the US Treasury market.

To gain a deeper sense of this, consider again the example on FX volatility discussed earlier. A rise in FX volatility can drive up the demand for US$ for any given supply. For example, a surge in demand for dollars can be related to the increase in convenience yield (Du et al, 2018), or macroeconomic factors, or dash for cash as during the COVID-19. The inelastic supply of US$ can instead be related to different factors, for example dollar funding costs (Du et al, 2018). Therefore, the demand for US$ liquidity (in bilateral and also interdealer market) is expected to increase with volatility. When volatility increases, higher demands for dollar, in combination with a lower level of dollar intermediation from the dealer, can drive up fx volumes but can also have a bigger impact

[4] We have done the same using the daily volume data for the second dealer and for the period 2018-2021 and confirm that the interaction coefficient is also highly significant and results are, in general, supportive of the Cespa et al (2022) argument. See online Appendix C

[5] Results in Table 3 are robust to different measures of volatility. See online Appendix

[6] Cespa et al (2022) suggest that the informational role of volume and order flow are different.

on dollar returns. Therefore, the predictive information of the fx volume arises by the higher costs for dollar intermediation post 2008. We shall discuss this in greater details in the next sections.

When the FX dealer balance sheet is significantly loaded by the demand of dollar (i.e. fx volume is significantly larger) from price sensitive clients, and, the dealer's dollar funding costs are higher (or capital lower), the impact on the dollar returns is expected to be significantly larger.

Therefore, we are not suggesting that asymmetric information does not play a role. We have already explained it earlier. Asymmetric information is also consistent with the (demand-side) theory that we shall discuss in the next sections, where dealers and clients trade in the bilateral FX market.

Balance sheet costs, post-2008, have increased, and, as a consequence, the renting cost to provide US$ liquidity, especially during negative shocks, has also increased. There is a large and recent literature in different markets supporting this argument. After 2008 debt overhang (Myers, S. C. 1977; Andersen et al, 2019) has become important. This cost, for large banks, can arise from many different sources. For example, higher funding costs post-2008, Berndt et al (2024), and Funding Valuation Adjustments (FVA). Lower level of equity capital following negative shocks, or even regulatory costs (Leverage Ratio Requirements). In this paper, we focus on funding costs, however, we also acknowledge that regulatory costs are important.

Why is debt overhang important for banks? One possibility is that the Dodd-Frank Act in the US, has exacerbated it [7]. We shall come back on this issue briefly in the next sections. In this paper, we suggest that this friction is also having a significant effect on the intermediation US$ spot fx liquidity, (Du et al, 2023), Anderson et al (2019)). Similar argument is also discussed in a recent important paper (Huang et al, 2025). The difference with Huang et al (2025) is that we do not study fx liquidity in this paper but provide plausible explanation for the informative role of the fx volume which has been discussed recently in the literature.

In a spot fx bilateral market, from the fx dealer's side, the intermediation of spot OTC liquidity is very similar to the intermediation of a derivative position (for example a swap), but with two important differences. Balance sheet imbalance (inventory) is generally financed from the bank's treasury (internal capital markets), at the bank's own credit spread, and not at the risk-free rate as it used to be the case before 2008. Fx spot transactions involve very large sums settled two business days after the trade, T+2 settlement, Chaboud et al (2023). Funding costs in the case of FX spot can be significantly larger than the FX swap market, as the dealer will have to employ a significant amount of capital unless she can run a matching book (or use the interdealer market). Therefore, balance sheet cost is likely to be very relevant.

5.1 *Balance Sheet Constraints and Debt Overhang*

To understand how debt overhang relates to the balance sheet of an fx dealer trading bilaterally with a client, consider the simplified balance sheet in Figure 10. We assume that the fx dealer will have US$ lending on one side of the balance sheet, and US$ borrowing on the other side. This can be seen as customers demanding and offering US$. Generally, the liability side will consist of liabilities financed externally (via US$ REPO market for example or even commercial paper), or internally (generally uncollateralised borrowing via the Treasury).

There is strong evidence (Lu et al, 2023) that dealers' desks use internal capital markets, especially in times of shocks, to search for the necessary liquidity to meet clients' demand. However, given the stiffness of (internal and external) capital at times of market turmoil, dealers will try to run as much as possible a matching book with clients as a way to reduce the consumption of capital. [8]

Suppose that following a shock, the equity capital of the dealer falls and, at the same time, the demand of US$ from clients surges (additional demand). The balance sheet of the dealer will show an imbalance, between US$ demand from clients and the financing resources available. To

[7] This is explained and studied in Berndt et al (2024).

[8] Generally dealers' desks are allocated capital daily and it is very expensive for them to borrow extra capital from the treasury or even externally.

accommodate the demand, dealers will need to commit their own capital. Generally, they are reluctant to do so to support the liquidity, particularly when their capital is already hit following negative shocks. For example, for the Treasury market, Duffie et al (2023) show that dealers post large bid and ask prices to recover these costs, or as a way of not being hit by customers flows. Boyarchenko et al. (2017) make a similar case but related to higher regulatory capital post 2008.

This situation introduces higher debt overhang cost and it does affect the slope of the US dollar supply curve (see Figure 10 (b)). The supply curve for the US dollar becomes steeper. This is also consistent with Ferreira et al (2024), who show that when USD liquidity is limited, the central bank conducts USD sale operations, anticipating stronger spot price effects due to the inelastic USD supply. The intervention in the FX market by the central bank has a stronger impact when fx dealers' balance sheets are constrained.

Huang et al (2025) show that when the capacity of intermediation of the fx dealer is limited, the fx liquidity supply curve is steeper. A steeper supply curve for US dollar, combined with a surge in the demand for dollars, can explain what we observe in Figure 10.

Based on the earlier empirical results and discussion, in this paper we conjecture that it is the change in the supply curve of dollars post 2008, and its larger impact on the dollar exchange rate, that is driving the informative content of the fx volume. Of course, this was not the case before 2008. The steeper slope reflects the shadow cost (debt overhang) that banks' shareholders face when providing additional dollar liquidity post 2008. The empirical results in recent papers (for example Huang et al, 2025) point towards this direction.

5.2 *Motivating Evidence*

Is debt overhang relevant during the period we study in this paper? In this section we present and discuss evidence supporting the case that debt overhang is indeed relevant. In Figure 1 we plot the intermediary leverage from He et al (2017), at a monthly frequency over the period 2002 to 2012 (Panel a) and 2018-2021 (Panel b). These are the two periods we study in this paper. The leverage is the ratio of total debt to market equity. This measure of leverage is directly linked to the dealer's equity capital and therefore to debt overhang (see discussion in the previous sections).

Intermediary leverage as a proxy for intermediary's financial frictions is also supported empirically and theoretically in Adrian et al. (2015), He et al (2017), only to cite a few. As discussed in the previous section, this friction is also related to debt overhang, as large leverage will correspond to times when equity capital is lower and therefore the marginal utility of wealth of the dealer is higher (balance sheet constraints). See also the discussion in Burnside et al (2024) and He et al (2017). In He et al (2017), primary dealers' leverage expands in states when equity is declining and it increases in states when the intermediary equity is increasing.

In Panel (a), the red vertical bar is the start of our empirical analysis (i.e the end of 2007) while the green bar corresponds to the middle of 2009 to capture the effect of the Dodd-Frank Act which was proposed and discussed in 2009 and signed in 2010. For Panel (b), the vertical bar corresponds to the start of the COVID-19 shock (March 2020).

Figure 1 (Panel a) is suggestive at least for two reasons: first, intermediaries' leverage peaked in 2009, when the Dodd-Frank Act started to be discussed but not during the 2007-2008 financial crisis. Leverage started to decline sharply in late 2009. The discussion of the Dodd-Frank Act coincides with a significant deleveraging.

The leverage adjustment in 2009 is consistent, amongst other things, with dealers starting to be concerned with the effect of the Dodd-Frank Act and the extra costs on their balance sheets and being more cautious about balance sheet usage [9]. Figure 1 is consistent with a scenario where debt overhang to the dealers increased sharply in 2008 and early 2009 and fell in late 2009, remaining sticky after that period.

We now turn to the COVID-19 shock. In Panel B we plot the dealer's leverage before and after the COVID-19 shock in 2020. We observe a very similar picture. Leverage peaked sharply

[9] Leverage may also be affected by the equity injection in banks starting in 2009. However, relating the Dobb-Frank act to the observed large swings in leverage during the period is not the scope of this paper

during the COVID-19 period and reverted back to previous levels only in 2021. As before, the large increase (decrease) in leverage is consistent with a situation where dealers are largely constrained and debt overhang is relevant.

Andersen et al (2019) discuss debt overhang costs related to funding costs and funding value adjustment (FVA), for the swap market. They show that dealers' FVA can be viewed as wealth transfers from equity holders to creditors (i.e. debt overhang). As we mentioned, this cost can be proxied by the dealer's credit spread. Cerrato and Mei (2025) use a balance sheet model to motivate it.

Burnside et al (2024) proxy debt overhang cost related to FVA, when studying Covered Interest Rate Parity (CIP), using the 5-year CDS spreads of the 12 largest dealers' banks.[10]

To dive deeper into our discussion above, we follow Burnside and Cerrato (2024), and Cerrato and Mei (2025), and use the CDS spread of large US and European dealers to proxy for debt overhang arising from higher funding costs. We complement our results by using market measures like the 3-month Libor minus the OIS spread. Figure 2 (Panel a) plots the average cross-sectional CDS spread of the largest six US and six European banks, as well as the three-month LIBOR minus OIS spread, as an alternative marked-based proxy.

The picture emerging from Figure 2 is consistent with Figure 1. Debt overhang cost is significantly higher during the period we study in this paper. Debt overhang cost related to funding costs (same for equity financing), was very small before 2008, it has increased sharply starting from 2008, and again in 2009 and has remained higher since then. As documented in Burnside et al (2024), and Andersen et al (2019), the increase in dealers' debt overhang has had a significant impact on arbitraging Covered Interest Rate Parity (CIP) deviations. Taking Figure 1 and Figure 2 together, we can reasonably conjecture that debt overhang was significantly higher during the period we study in this paper.

Since we have granular data on the fx volume from the first dealer, we dive deeper into her balance sheet and in Figure 3 and Figure 4, we plot the (monthly) fx volume and the volatility of the fx volume over the sample period. Fx volume increased consistently between 2003 and 2008. The dealer supply dollar liquidity at any given level of dollar demand. This suggests that (unconstrained) dealers were able to accommodate the dollar demand with only modest increase on dollar liquidity and exchange rate. However, volume has fluctuated around its mean between 2009 and 2012. After the 2008 financial crisis, we observe large swings in fx liquidity intermediation. This large fluctuation of the FX volume is consistent with higher balance sheets' frictions constraining the supply of dollar post-2008.

In Figure 4, we plot the (monthly) volume volatility over the same period. Volatility increased sharply in 2008 and decreased thereafter, but it has never gone back to the 2003-2008 level. This higher volatility is also consistent with significant balance sheet frictions. For example, Badrinath (2019) makes this case to explain the presence of arbitrage opportunities due to supply side constraints.

Figure 5 shows (the cross-sectional average) of the bid-ask spread of our currencies (median quarterly). Bid-ask prices fell until the end of 2007 and then started to increase. The dynamics in bid-ask spread in Figure 5 is also consistent with higher balance sheet frictions. As explained in Anderson et al (2019) and Cerrato and Mei (2025), in the presence of debt overhang, dealers will need to extract some "donation" from the clients to compensate equity holders. In the OTC market, this donation takes the form of larger spreads.

Finally, in Figure 6, we computed the median, within each quarter, of the aggregate US$ fx volume relative to the dealers' total assets in that quarter. The trend we observe is also consistent, amongst the other things, with balance sheets' frictions and it suggests that after 2008 there is less space on the dealer's balance sheet for any additional unit of fx spot intermediation.

Finally, the evidence in this section would suggest that debt overhang was persistent during the

[10] The CDS is an index containing an equal-weighted average of the largest 12 US and European Dealers. This index is highly liquid and difficult to be manipulated by a single dealer. The index reflects funding costs for receivable derivatives that the dealer charges to clients to provide liquidity in the OTC market.

period we study in this paper, and it could be a plausible (additional) explanation for the dynamics observed in our data. We conjecture that this supply side constrain can help us to rationalise the different results we report in Table 3 and Table 4 and understand why fx volumes (post 2008) contain predictive information. In the next sections, we study it empirically and finally motivate it theoretically.

5.3 *Debt Overhang and the FX Volume*

We start with simple panel regressions using (weekly) data between the end of 2007 and 2012 (first dealer). These regressions will be useful to establish a useful benchmark. We use the same empirical model as before, but focusing on the lagged volume coefficient as opposed to the Cespa et al (2022) whose focus is mainly on the interaction coefficient to motivate asymmetric information. We study the predictability content of the fx volume on dollar returns.

The lagged volume used will also help us to mitigate endogeneity while focusing on the predictability of the FX volume. We control for the demand of US dollars. We employ a set of fixed effects and control for variables which generally correlated with the demand for US dollars (see discussion in the previous section). We focus on returns instead of excess returns as in Cespa et al (2022)[11]

The bank's CDS spread is a direct and relevant proxy measure of debt overhang cost arising from funding (equity) financing (see also Andersen et al, 2019 and Cerrato and Mei (2024)). We complement it by using a market-based proxy, that is the Libor-OIS spread (Cooperman, et al, 2023). When the spread is larger, debt overhang cost for the dealer increases. We also include leverage for the reasons explained earlier.

In Table 5, we sort the data using the median of CDS (Leverage) and form two groups, larger (smaller) CDS spreads (leverage). We associate this with higher (lower) debt overhang cost for the dealer. We then regress returns on lagged returns and lagged fx volume. We use robust standard errors, and the same econometric design, as well as controls we have used in Table 3 and Table 4.

We note that lagged fx volumes are all significant when debt overhang cost bites, while they are insignificant otherwise. Finally, large FX dollar volume is associated with large US$ returns (i.e US$ appreciation). Therefore, fx volume appears to contain predictive information but only conditionally to higher debt overhang. This would suggest that the predictive content of the fx volume steams from the supply side. Recently, Huang et al (2025) make a similar case for the fx spot liquidity. Our results appear in line with theirs although our paper is mainly focusing on the what drives the informative content of the fx volume. These results are also in line with Kloks et al (2023), although that paper studies the effect of dealer's constraint on fx swap market, while we focus on the spot market and the predictability information of the fx spot volume. Finally, we report in column 7 unconditional estimates of the beta coefficient and it is clearly insignificant and much smaller than the conditional ones.

In the Appendix A, we report results using the first dealer fx volume (weekly) and the period before 2008. Clearly, debt overhang cost was not an issue during that period, and indeed the evidence is much weaker over that period.

To further control for demand side shocks, in the Appendix D, we also control for the dealer order flow. We do not report the estimated coefficient on the order flow, but they are all statistically insignificant. The overall results remain unchanged.

The results in this section suggest that the dollar volume can predict dollar returns but only when debt overhang is significant. This evidence is consistent with the motivation discussed in Figure 9 and Figure 10, as well as with Czech et al (2021), Huang et al, (2025). Debt overhang has

[11] While the focus in Cespa et al (2022) is on the interaction coefficient term as their model suggests that asymmetric information directly affects it, the focus of our paper is on predictability of fx volume and dealer's balance sheet frictions. Therefore, the interaction coefficient does not play any role in our model. However, our online appendix shows the results when using excess returns and the interaction coefficient and they are in line with what already reported in Table 5.

affected the slope of the supply curve for dollar lending [12]. The dollar market is still functioning during these times too but dealers charge higher costs for the additional dollar liquidity and, as a consequence the dollar appreciates.

Our results add further evidence to the literature on the financial channel for US dollar appreciation, with the critical difference that we focus on primary G-SIBs dealers, (Bruno & Shin (2015), Jiang et al. (2021a), Kekre & Lenel (2021)) [13]

Given that, the intermediaries in this paper are also the largest players in the interdealer market, our results might suggest that, in periods of negative shocks, the fx flows in customer and interdealer markets are correlated, increasing substantially the liquidity costs in both markets. We leave this topic for future research.

Given that the leverage ratio requirement (LRR) was not binding over the sample period we study, our results cannot be related to regulatory frictions, leverage ratio requirements (LLR), for example. This also suggests that LLR is not the only explanation for what is observed in some papers, for example, Klocks et al (2023), as it is likely that other and more persistent (i.e. not just quarter-end effects) forces are at work.

6 The COVID-19 Shock

We now turn to our second dealer, and focus on the COVID-19 shock. We use the period 2018 to 2021. Our dataset is daily.

As before, we divide the sample into two bins, higher and lower balance sheet frictions as proxied by the dealers' 5-year CDS spread, LIBOR-OIS spread and also Leverage, according to their median value. We do a similar analysis as before. Table 6, Panel A shows the results for leverage investors, while Panel B shows the results for Real Money, and Panel C the total of the two. Note that volume data from the second dealer is calculated as the average daily volume over the past 20 days, normalised by the 6-month median volume of a currency and investor client type. A value greater than one (1) means that more recent daily volume is significantly above its longer-term median, and less than one, means the opposite.

The results in Table 6 are in line with the ones reported earlier. Although coefficients are generally significant in both the case of higher (lower) debt overhang cost, the estimated coefficients, in the former scenario, are larger, and the R-squared in the case of lower debt overhang costs are negative. In sum, larger FX volumes can predict US dollar appreciation but only conditionally to higher debt overhang cost (i.e. higher balance sheet frictions).

7 Demand for US Dollars

In the previous sections, we have mainly focused on supply side effects. Our results suggest that fx volume can predict dollar returns, but only conditionally to a steeper supply curve (post 2008) for US dollars.

In this section we dive deeper on the way the dealer and clients trade in a bilateral market, We conjecture that debt overhang will also affect the trading and the demand-supply of dollars. We have observed that fx spot volumes are positively related to dollar appreciation during periods when debt overhang bites. We now present evidence suggesting that during the period we study in this paper, the demand of US dollars has also increased. We focus on two large shocks (2008 financial crisis and the COVID-19).

In Figure 7 (a,b) and Figure 8 (a,b) we plot the cumulative (aggregate and disaggregate) order flows of the two dealers. Negative flows suggest larger demand for dollar liquidity. Clearly, there

[12] See discussion in Czech et al.(2021) for the role of US dollars in a period of market turmoil, reaching similar conclusions

[13] Note that large part of the US$ liquidity, which is the focus of the financial channel argument of exchange rates, it is intermediated by a few large dealers and these can be viewed as marginal price setting. This is indeed the case for the spot market. (Ingomar Krohn and Vlady Sushko (2022)).

was a significant demand for dollars. The increase of demand for dollar arise mainly from financials, while non-financials (especially during the COVID-19) take the opposite side. Given that the dealer is balance sheet constrained, she will have to trade with clients in a way to attract foreign flows and reduce dollars ones.

Du et al(2017), and other recent papers (see, for example, Ingomar Krohn, Vladyslav Sushko, (2022)) show an increasing trading competition amongst G-SIB dealers in the spot market after 2008. This evidence is in line with other markets, for example, the Treasury market (Duffie, 2010). Clients prefer to trade with dealers with lower debt overhang cost (i.e. lower funding costs and/or higher capital), as they can obtain better quotes.

Based on recent empirical evidence (for example Du et al, 2019), we conjecture that the dealer's capital plays also an important role (amongst the other things) for running a matching book. Dealers with higher level of capital (or lower leverage) are better posed to meet their clients' dollar liquidity. We do not have data for a large panel of dealers and therefore cannot study how (in the cross section), capital is related to the demand of dollars from clients. But we can still study the time series effect of dollar flows from clients and the dealer leverage (or capital). We do this in Table 7. we study if changes of the capital of the dealer can predict change of dollar flows. We focus on the second dealer as it is only with Basel III that banks have started optimising capital across trading desks and business competition amongst fx dealers has become tighter. We use monthly data as we do not have daily balance sheet data for the dealer. [14]

Table 7 shows the empirical results. Results in (1)-(3) refer to the flows of the second dealer (aggregate, Financial, Non-Financial). Leverage refers to the leverage of the second dealer. Therefore, we match capital and flows of the dealer. In line with our model, we focus on lagged leverage (predictability). We run a time series regression of changes in flows (we sum up flows across all the G-9 currencies), on changes in lagged leverage. We include an intercept. Results in Table 7 suggest that if leverage increases (or capital decreases) this month, dollar flows will first increase next month, and revert thereafter. Therefore, we provide evidence that the dealer's capital is an important factor to understand trading in the bilateral spot fx market and. To additionally support our results, note that the predictability of the leverage arises from financial, while it is insignificant for non-financials. This suggests that price sensitive customers are important as it is the demand for dollars arising from them to have a significant price impact, We believe that our evidence is consistent with our earlier discussion and our model in the next section will shed further light on this. [15]

8 Fx Spot Intermediation Under Capital Frictions

In this section, we present a model which explains our empirical results. We consider a model of FX spot intermediation with a dealer facing leverage constraints (supply side) but also market frictions (demand side). Consistently with our empirical results, we assume inelastic supply of US$ dollars (leverage constraint), and higher demand of US$ liquidity to accommodate clients. This is consistent with Figure 7 and Figure 8.

Following a negative shock on her capital, and given the exogeneous increase in demand of US$, to accommodate the excess demand, the dealer cannot raise new debt (or equity), which is expensive, but runs a fx book internally (i.e. by matching the US$ asset and liability side of the balance sheet). The dealer may have different incentives for doing this. For example, higher funding costs but also scarce US$ reserves as in Bianchi et al (2023). This is plausible and supported empirically in recent papers, for example, Bianchi et al (2023). Furthermore, US$ preference for the dealer is also consistent with theoretical and empirical evidence suggesting that dollar reserves serve as a leading funding currency, Ivashina et al (2015), Du (2022).

[14] We focus on the period 2018-2021 for this analysis as this corresponds to the stringent regulatory period for large dealers.

[15] We leave on the agenda further analysis on how FX dealers manage their inventories when trading with clients in the spot bilateral market.

We build on Koijen et al. (2015), Koijen et al. (2016), and Ellu et al. (2011) but focus on the implication of leverage constraints and market frictions on fx spot dollar intermediation. We show that, in the presence of balance sheet constraints, the dealer is facing a shadow cost on her capital when providing dollar immediacy, and this is a debt overhang cost for the equity holder of the bank. In such a situation, the dealer's incentive to clear the market might be significantly reduced.

Suppose that following a negative shock, the demand for US$ increases and the dealer's equity capital falls. This assumption is consistent with the results we have reported earlier. Let's first consider the (US$) asset side of the balance sheet after the shock. The dealer will have FX $ lend (FX dollar Borrow) as in Figure 9. Assume that the dealer runs an internal book by selling foreign currencies (euro, yen, etc...) $i = 1, 2, ..., N$ to her clients to match the demand for the US dollar from her (financial) clients. Let $X_{i,t}$ in period t be the flow of foreign currency vis a vis US dollar, and the price (exchange rate) is $P_{i,t}$. Let A_{t-1} be the dealer's assets in $t-1$, and R_t is the exogenous return on the assets in period t. The dealer's assets in t is:

$$A_t = R_t A_{t-1} + \sum_{i=1}^{N} P_{i,t} X_{i,t} \tag{6}$$

Let L_{t-1} define the dealer's existing (US$) liability and R_t defines the growth on the liabilities in period t. Suppose that R_t^* is an exogenous financing rate. Assuming the flow of funds identity of assets and liabilities, the dealer's liability in period t is

$$L_t = R_t L_{t-1} + \sum_{i=1}^{N} R_t^* X_{i,t} \tag{7}$$

We define the dealer's capital as:

$$K_t = A_t - \rho L_t \tag{8}$$

where ρ is non-negative. Given Equations 6 and 7, and using the law of motion for capital, we obtain:

$$K_t = R_t K_{t-1} + \sum_{i=1}^{N} (P_{i,t} - \rho R_t^*) X_{i,t} \tag{9}$$

where K_{t-1} denotes the capital in period t_{t-1}. $P_{i,t} - \rho R_t^*$ is the dollar intermediation revenue of the dealer.

Andersen et al (2019), Cerrato and Mei (2024) show that borrowing introduces debt overhang. Therefore we relate debt overhang cost to the dealer's higher leverage (or lower equity capital). We assume that given a leverage constraint, higher levels of leverage would be "inconvenient" for the equity holder, in the sense that higher leverage would impact the equity value (and, therefore, increases debt overhang). [16] It follows that, clearing the imbalance between demand and supply of US$ via additional borrowing (or increasing inventories which require additional capital) would be expensive for the equity holder. We define

$$\rho = \rho_0 \mathbf{1}_{\{L_t > R_t L_{t-1}\}}, \tag{10}$$

where ρ_0 is a constant satisfying

$$\rho_0 \leq \frac{A_t}{L_t}.$$

The indicator $\mathbf{1}_{\{L_t > R_t L_{t-1}\}}$ suggests that leverage is the consequence of an excessive expansion of liabilities.

[16] We do not consider any asset substitution effects which could create incentives for shareholders to increase leverage.

We now move on to the US$ demand side. Following the negative shock and the demand for the US$, we assume that customers ready to purchase foreign currency are active in the market, but they search for the dealers' best quote. We assume that for each foreign currency i in period t, there are $m_{i,t}(K_{t-1})$ clients ready to absorb the supply of this currency. These investors match with dealers whose capital is K_{t-1} at the end of period $t-1$. This implies that $\partial m_{i,t}/\partial K_{t-1} > 0$, suggesting that clients are searching for the best quotes and this can be offered by the dealers with higher capital (or lower debt overhang).

This assumption follows from the simple observation that business competition amongst dealers in OTC markets is very tight (Duffie, 2010), and that dealers with higher levels of equity capital have lower funding costs and therefore can boost future business (Ingomar Krohn, Vladyslav Sushko, 2022). This assumption is also consistent with what is observed in OTC markets and closely related to the concept of slow motion of capital as in Duffie (2010). Du et al(2017), and other papers show increasing trading competition amongst G-SIB dealers in the spot market after 2008 (see for example, Ingomar Krohn, Vladyslav Sushko, (2022)).

The dealer will be able to match the demand $d_{i,t}(P_{i,t})$ for currency i at the exchange rate $P_{i,t}$, if she can quote a price, such that $\partial d_{i,t}/\partial P_{i,t} < 0$. Thus, the demand function of the dealer is of the following type:

$$D_{i,t}(P_{i,t}, K_{t-1}) = m_{i,t}(K_{t-1})d_{i,t}(P_{i,t}) \tag{11}$$

in which $\partial D_{i,t}/\partial K_{t-1} > 0$ and $\partial D_{i,t}/\partial P_{i,t} < 0$. This suggests that demand increases with the dealer's level of capital and also that demand is price sensitive and downward sloping. This is also consistent with Gromb and Vayanos (2002).

Define the profit function in period t as

$$\pi_t = \sum_{i=1}^{N}(P_{i,t} - R_t^*)X_{i,t} \tag{12}$$

The dealer chooses a price $P_{i,t}$ for the foreign currency i to maximize equity holder's value

$$J_t = \pi_t + \mathbb{E}_t[M_{t+1}J_{t+1}] \tag{13}$$

where M_{t+1} is a stochastic discount factor. The above equation is important as it suggests that to maximise equity value, the dealer will have to consider not only current profit but also ways to boost the profit in the future.

Following Equation 9, Equation 10, and Equation 13, we can set the Lagrangian

$$\mathcal{L}_t = J_t + \lambda_t K_t, \tag{14}$$

where $\lambda_t \geq 0$ is the Lagrange multiplier. Solving the first-order condition of the Lagrangian with respect to the exchange rate yields

$$\frac{\partial \mathcal{L}_t}{\partial P_{i,t}} = \frac{\partial \pi_t}{\partial P_{i,t}} + \frac{\partial}{\partial P_{i,t}}\mathbb{E}_t[M_{t+1}J_{t+1}] + \lambda_t \frac{\partial K_t}{\partial P_{i,t}} = 0 \tag{15}$$

And applying the chain rule and the Leibniz integral rule,

$$\frac{\partial \mathbb{E}_t[M_{t+1}J_{t+1}]}{\partial P_{i,t}} = \mathbb{E}_t\left[M_{t+1}\frac{\partial J_{t+1}}{\partial K_{i,t}}\right]\frac{\partial K_t}{\partial P_{i,t}} \tag{16}$$

This suggests that a change in the dealer's quote can affect the dealer's capital in the future and boost future profits. We can now re-write Equation 15 to get

$$\frac{\partial \mathcal{L}_t}{\partial P_{i,t}} = \frac{\partial \pi_t}{\partial P_{i,t}} + \left(\lambda_t + \mathbb{E}_t\left[M_{t+1}\frac{\partial J_{t+1}}{\partial K_t}\right]\right)\frac{\partial K_t}{\partial P_{i,t}} = 0 \tag{17}$$

Assuming that $\overline{\lambda}_t$ satisfies

$$\overline{\lambda}_t = \lambda_t + \mathbb{E}_t\left[M_{t+1}\frac{\partial J_{t+1}}{\partial K_t}\right]. \tag{18}$$

Rearranging Equation 17 gives the expression of $\overline{\lambda}_t$ as

$$\overline{\lambda}_t = -\frac{\partial \pi_t}{\partial P_{i,t}} \left(\frac{\partial K_t}{\partial P_{i,t}} \right)^{-1} \tag{19}$$

We can now rewrite the Lagrangian in Equation 14 as

$$\mathcal{L}_t = \pi_t + \overline{\lambda}_t K_t \tag{20}$$

We define, $\overline{\lambda}_t$ as the "shadow cost of capital". Equation (18) suggests that this is related to leverage constraint, and market frictions. Suppose, for example, that there is no leverage constraint. In this case, the dealer could boost future profitability (and US$ capital) via higher leverage. Consider now the case where market frictions are absent. In this case, the dealer will increase the intermediation of US$ as long as it can charge a break even price, given its funding costs.

The shadow cost of capital reflects not only debt overhang cost today (leverage constraint) but also how the dealer can boost profitability in the future [17] This is also consistent with Du et al (2022).

Our model suggests that the forex spot market may become impaired because of debt overhang cost. Therefore, fx spot volumes reflect this supply side friction, particularly when there is a significant large demand of US$ (dash for cash).

9 Discussion on the Model

Our model incorporates some of the key features of our empirical results. For example, during the financial crisis (and the COVID-19 shock), banks were hit by large capital shocks (see Figure 1 and Figure 2). Furthermore, this seems to coincide with the discussion on the Dobb-Frank Act in 2009. Dealers became more conservative about the (future) cost of their balance sheets. Figure 5 and Figure 6 are consistent with this assumption.

Our model suggests that higher debt overhang cost introduces a shadow cost on the capital of the dealer. This shadown cost is related to her funding (equity) cost. Therefore, given the higher (dollar) funding costs, there might be a reduced incentive for the dealer to provide sufficient immediacy in the dollar market. Of course, the dealer could provide (additional) dollar liquidity (internally) by draining dollar reserves. But this is also highly expensive due to the precautionary role of the dollar reserves.

Bianchi et al (2023) propose a model where funding frictions for dealers are related to the liquidity supply of US$. When funding constraints bind (in our case debt overhang cost increases), warehouse financing freezes and banks are exposed to funding risk. To mitigate this risk, banks maintain a buffer of liquid assets, especially dollars, increasing their dollar reserves [18]

Our model also considers a US$ demand side and market frictions. We conjecture that clients are price sensitive and prefer trading with dealers with lower leverage (lower debt overhang or higher capital); Our flows data suggest, in both the shocks we study, that demand of dollars arise manly from financials, while non-financials are supplying dollars. However, this trading process work slowly as in-flow only arrives slowly, leading to higher persistence in fx returns, especially in times of significant shocks (see also discussion in Duffie, 2010). This is consistent with the persistence observed in our data.

We use the dealers' order flows and exploit the two shocks (financial crisis and COVID-19 shocks) to shed light on this issue. For example, Figure 7 (a and b) show the cumulative aggregate

[17] The expression for the shadow cost of capital is interesting as it is consistent with the trading behavioural at quarter end of large European banks. Indeed, our model suggests that, to boost future profit and capital, there is an incentive for the dealer to novate their trades to less constrained dealers (or non-banks), even at a loss, if this serves to boost future profit. However, this would require a complete market model and it is not the scope of this paper. We leave it on the agenda for future research.

[18] Reserves in Bianchi et al (2023) are not only dollar funding but also liquid assets such as treasury securities. Therefore, dollar reserves can be viewed as insurance against running out of dollar flows.

order flows (Panel a 2008 January to 2009 March; Panel b 2020 February to September). Negative flows suggest US$ purchase. Following the shocks, there is indeed a significant increase in demand for US$ and this lasts for several weeks.

To dive deeper into the demand, Figure 8 (a,b) split the flows into non-financials and financials. Following the financial crisis, the demand for US$ liquidity both from financial and non-financial increased sharply. The dealer book is likely to be impaired due to larger inventory.

Figure 8 (b) shows disaggregate flows over the COVID-19 shock. During this shock, the demand for US$ liquidity is mainly driven by financials, while non-financials are (in part) providing liquidity. The dealer can match the flows internally (i.e. via her own book, see our model). This trend of warehousing inventory risk imbalances, whereby dealers match customers' flows on their balance sheet is well documented (Mathias and Vladyslav (2022), Alain et al.(2023). By matching customers' flows, the dealer relies less on her own capital. This may suggest that leverage constraint frictions, for our second dealer, have been less stringent, as most of the demand of dollars was matched internally.

Two conclusions emerge from Figure 8. First, consistent with our previous empirical results and model, we observe a large demand of dollars during the financial crisis as well as during the COVID-19 shock. Dealers face leverage constraint (debt overhang costs) during large shocks. Consistently with our model, the demand for U$ is only accommodated slowly.

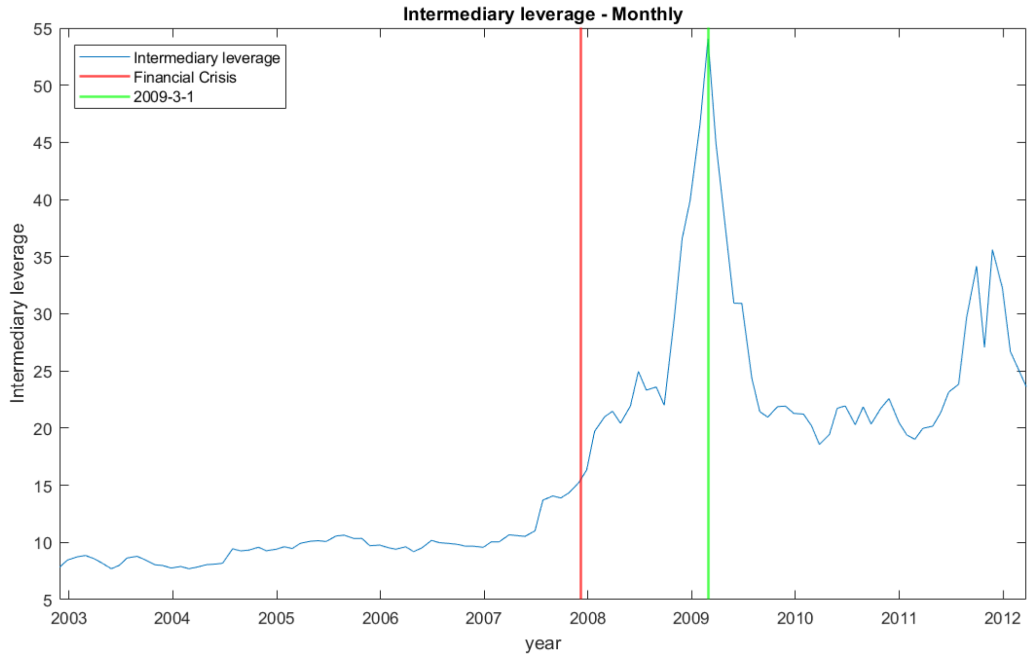
10 Conclusion

We provide evidence that FX trading volume after the 2008 financial crisis is associated with the large dealers' balance sheet constraints. Our results suggest that larger dollar FX volume is consistent with higher debt overhang cost (Myres(1977), Andersen et al (2019)) for equity holders when supplying dollar liquidity. The dealer is facing a shadow cost, that is, will have an incentive to skew the quote of foreign currency to attract more dollar flows to increase its dollar reserves.

We do not fully exclude leverage ratio requirements (LRR) as an additional explanation, but we point out that, probably, LLR is only the tip of an iceberg as additional and more persistent forces may be at work. The scope of this paper is to study this novel aspect in greater detail using novel proprietary data. Finally, we complement and extend the results in Cespa et al (2022) by showing that their persistent returns are also highly associated with dealers' balance sheet constraints and flight to dollar liquidity.

Figure 1: Intermediary Leverage

(a) Intermediary Leverage - Monthly for Financial Crisis



(b) Intermediary Leverage - Monthly for Covid-19

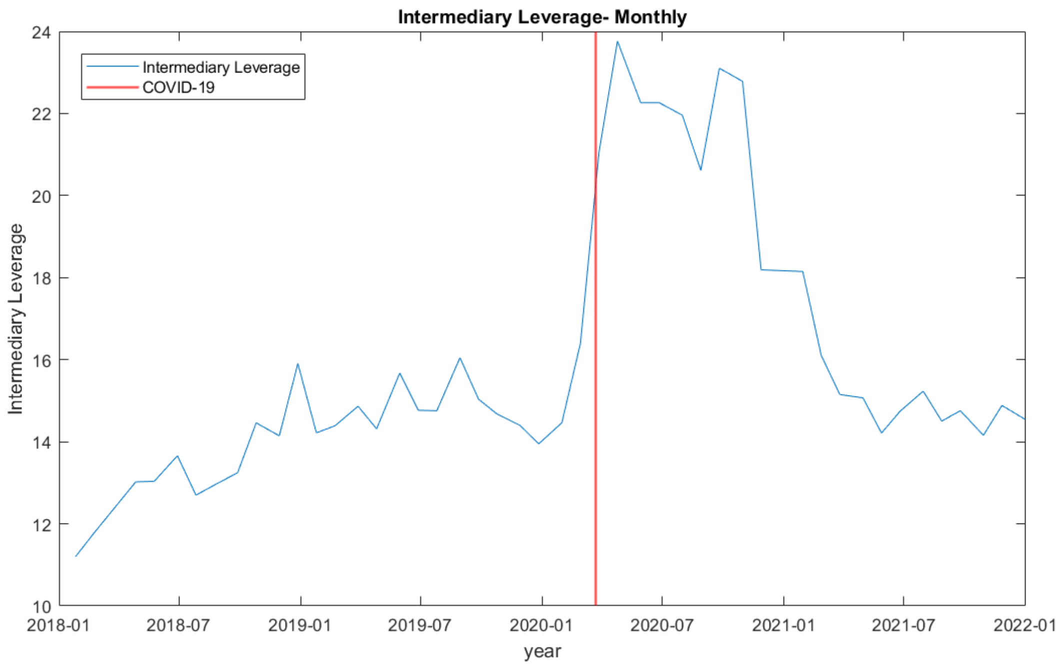
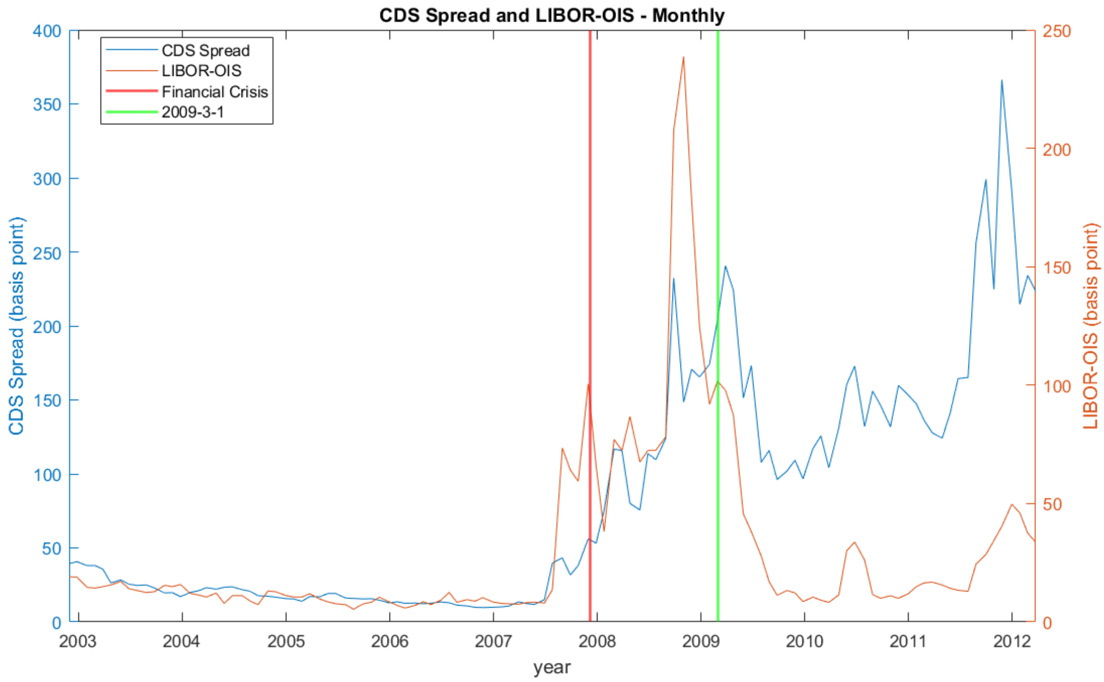


Figure 2: CDS Spread and LIBOR-OIS

(a) CDS Spread and LIBOR-OIS - Monthly for Financial Crisis



(b) CDS Spread and LIBOR-OIS - Monthly for Covid-19

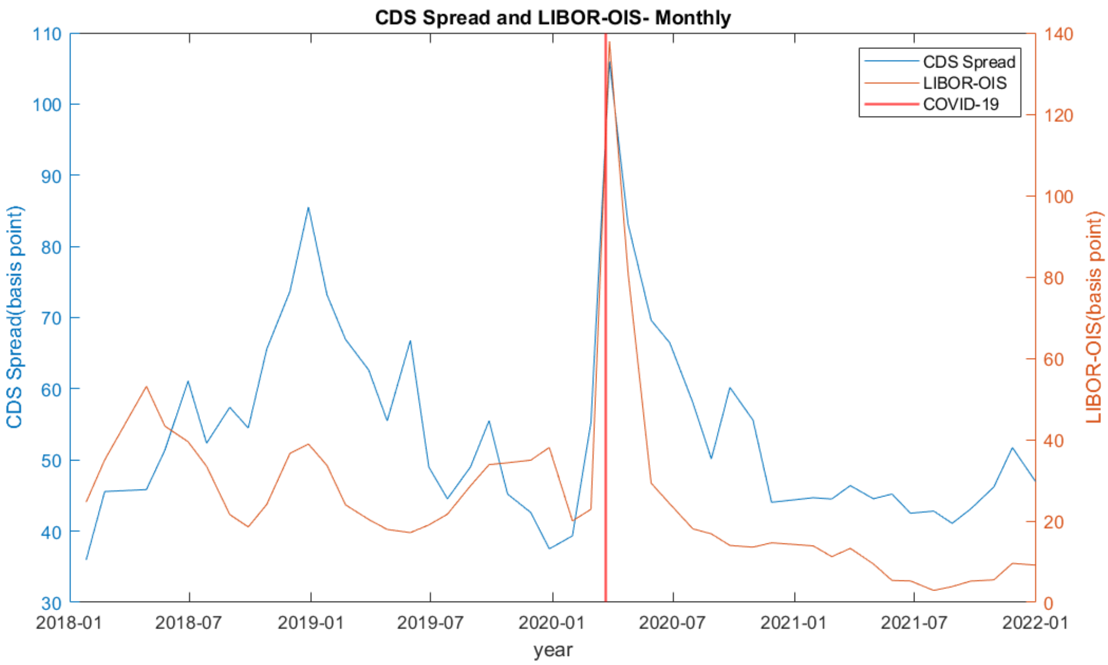


Figure 3: Volume

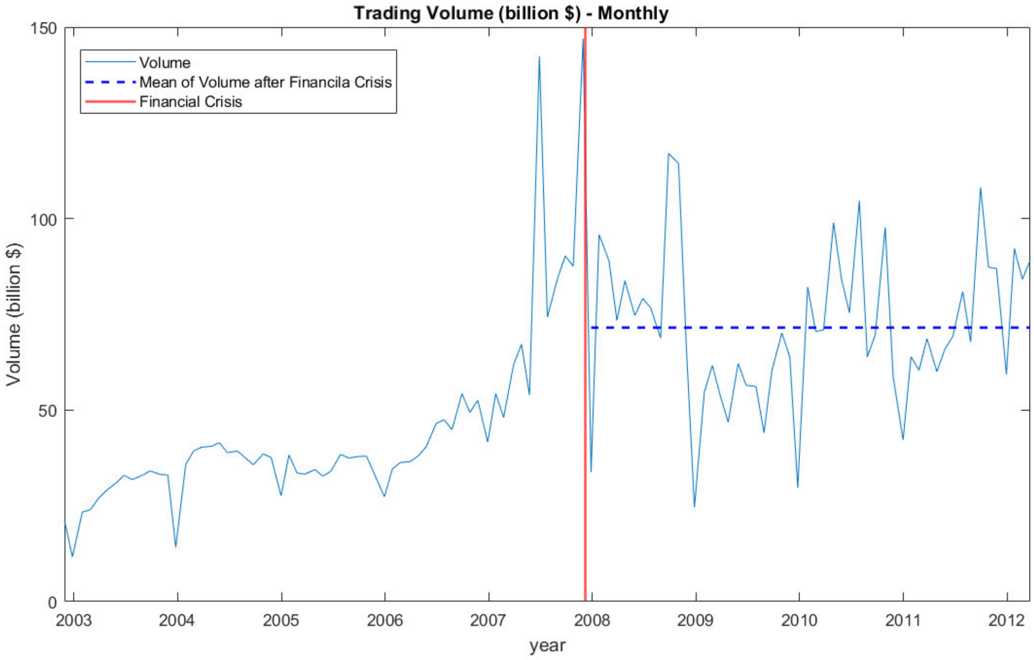


Figure 4: Volatility of Volume

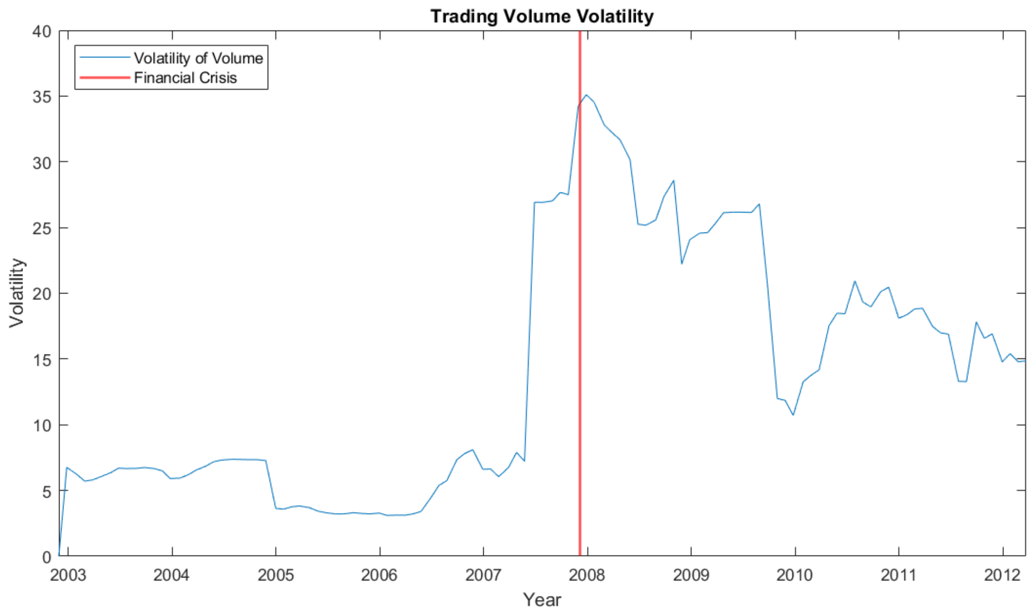


Figure 5: Bid-Ask Spread

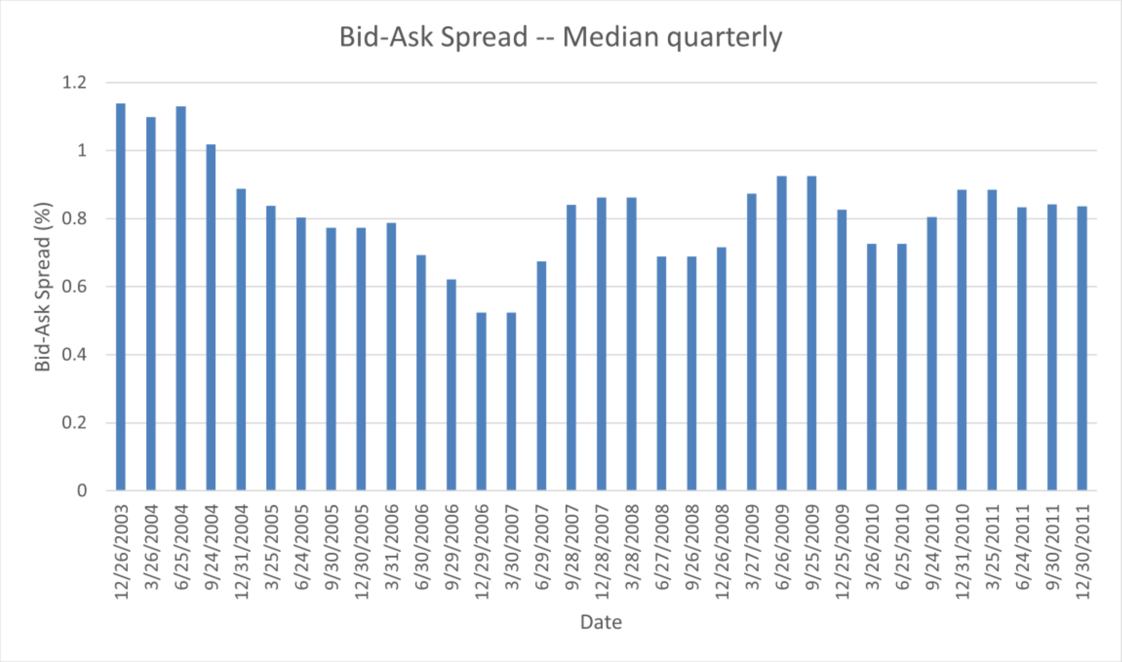


Figure 6: Ratio of Total Volume/ Dealer's Total Asset

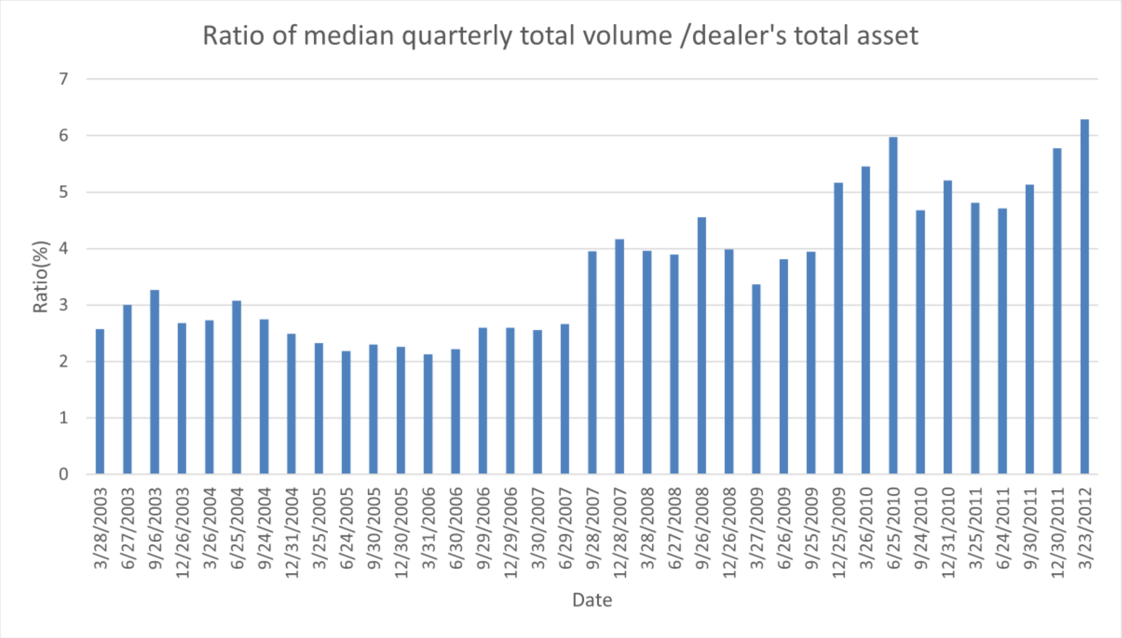
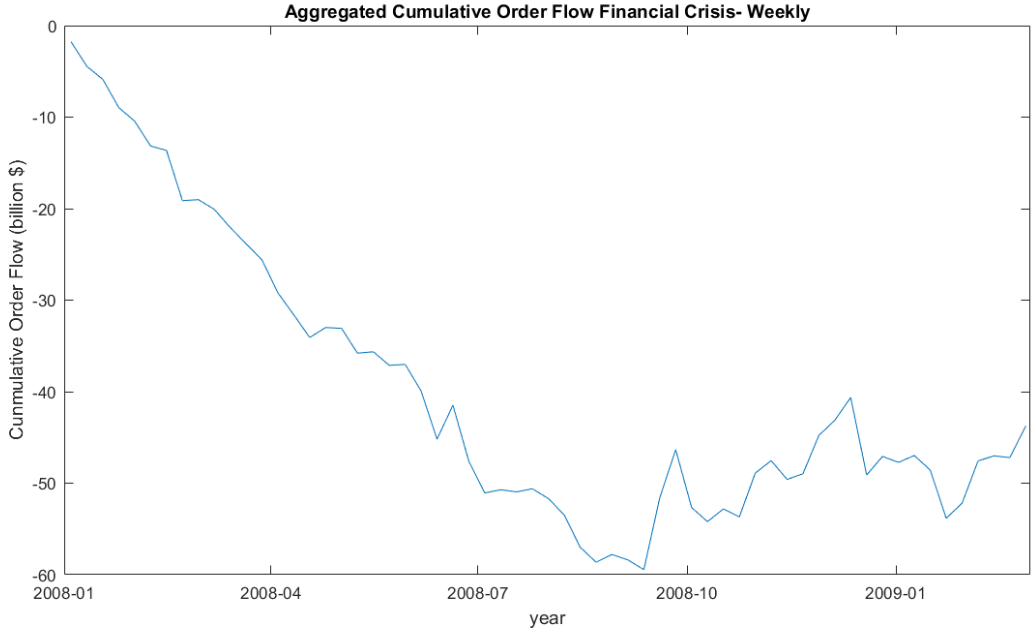


Figure 7: Aggregated Cumulative Order Flow

(a) Financial Crisis - Weekly



(b) Covid 19 - Daily

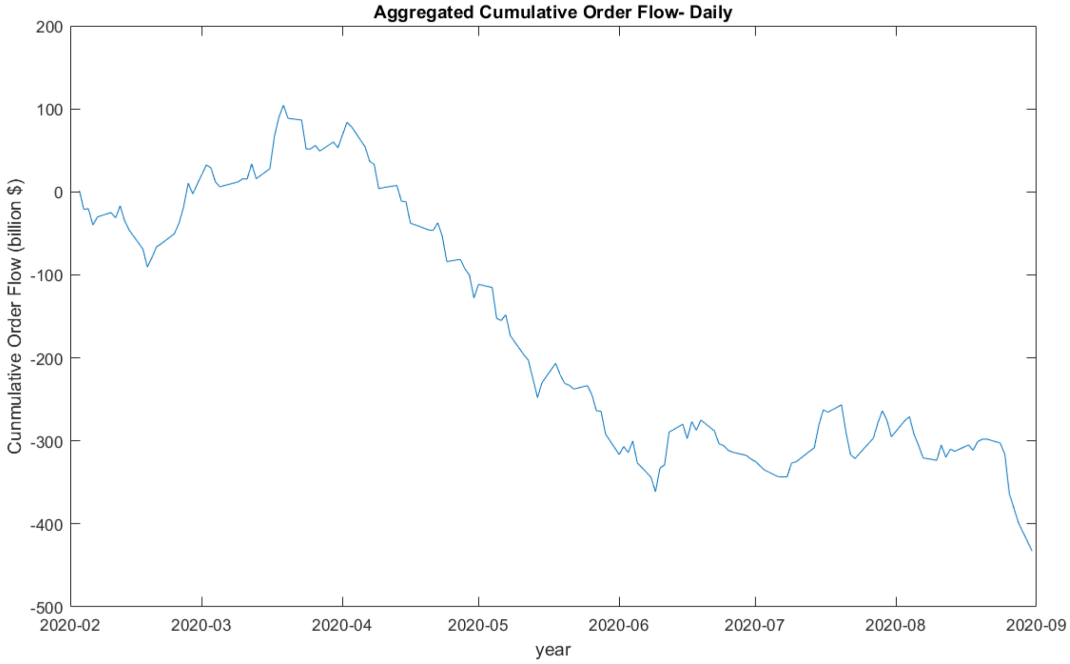
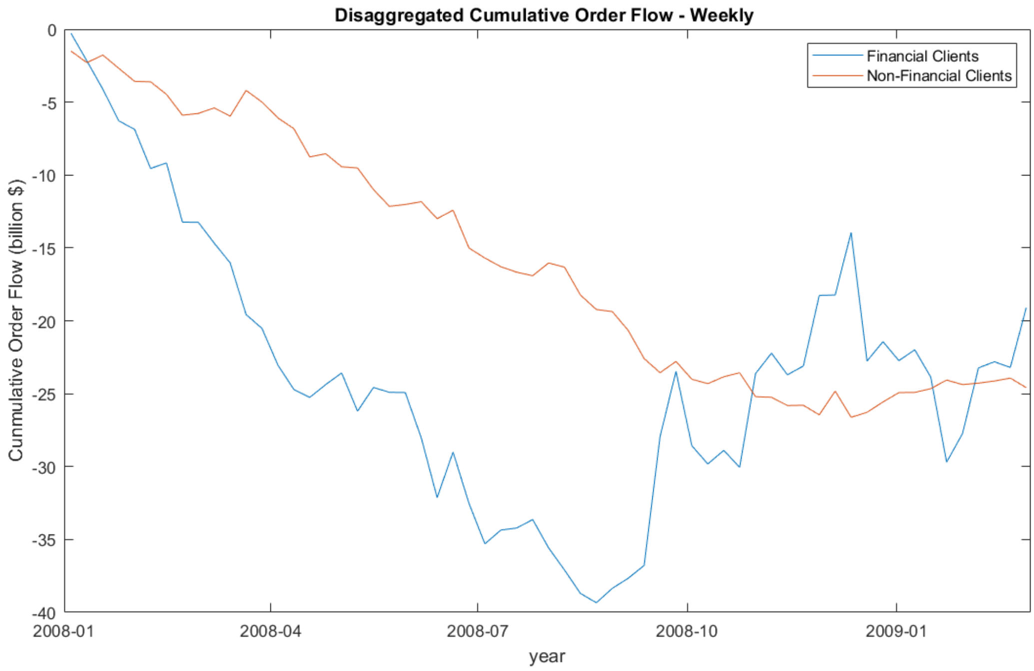


Figure 7 shows the aggregated cumulative order flow. We calculate it from 2008 January to 2009 March in (a). We show the cumulative flow from 2020 February to September. For our order flow data, negative means buying USD and positive shows selling.

Figure 8: Dis-aggregated Cumulative Order Flow

(a) Financial Crisis - Weekly



(b) Covid 19 - Daily

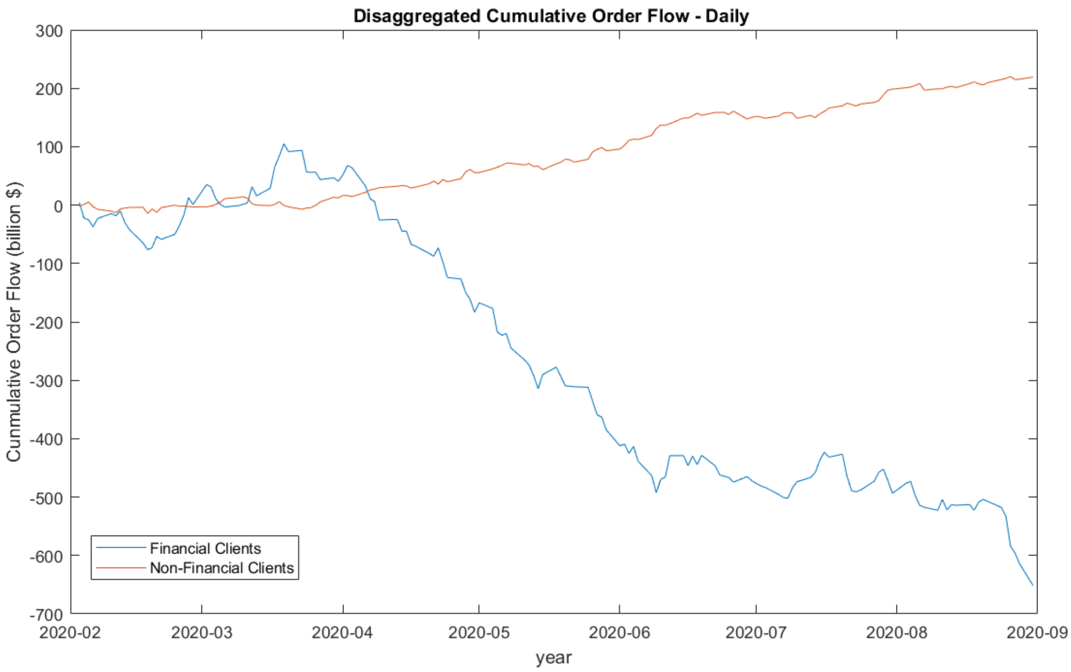
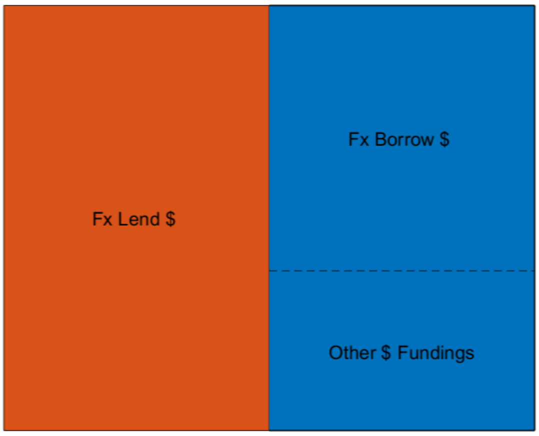


Figure 8 shows the dis-aggregated cumulative order flow. We use the same period as in Figure 7.

Figure 9: Balance Sheet

(a) Normal Period



(b) During Shocks

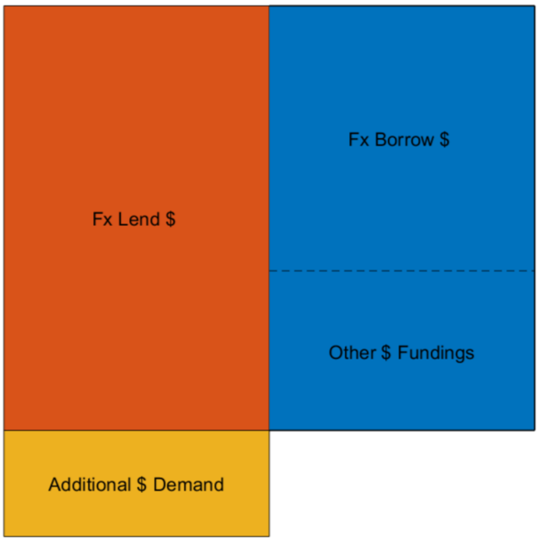
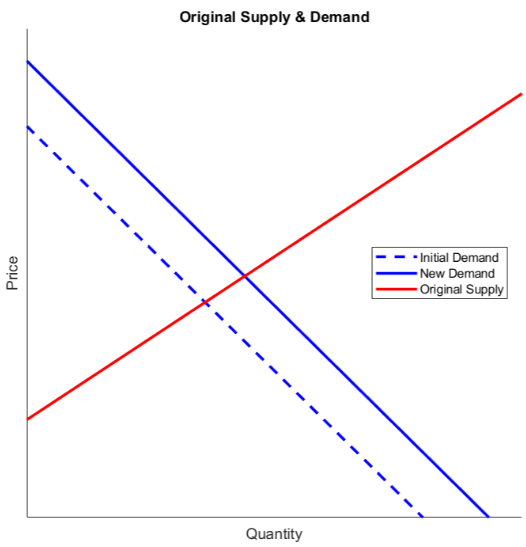


Figure 10: Supply Demand Curve

(a) Normal Period



(b) During Shocks

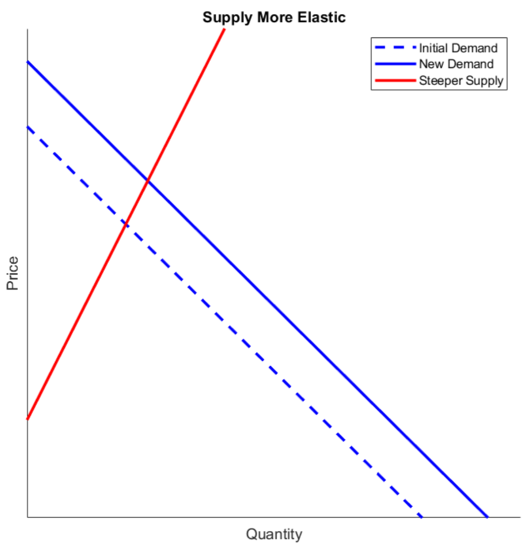


Table 1: Summary of Volume

Panel A: First Dealer- Volume (billion$)					
Variables	N	Mean	S.D.	Min	Max
EUR	493	23.738	11.553	4.805	84.437
JPY	493	9.434	3.764	1.787	25.915
GBP	493	8.228	5.026	1.299	50.699
CHF	493	7.030	3.309	1.898	24.790
AUD	493	3.888	2.518	0.135	11.691
CAD	493	2.717	1.592	0.283	12.303
NZD	493	0.834	0.592	0.066	3.171
HKD	493	0.629	0.485	0.028	2.539
MXN	493	0.505	0.386	0.012	2.217
ZAR	493	0.491	0.424	0.010	2.395
SGD	493	0.455	0.333	0.015	1.790

Panel B: Second Dealer - Volume					
Variables	N	Mean	S.D.	Min	Max
Leverage Volume	204	1.047	0.165	0.631	1.607
Real Money	204	1.111	0.133	0.777	1.623

Table 1 shows the summary of currencies. This table shows the number of observations, mean, standard deviation, minimum value and maximum value of the volume. All the currencies in Table 1 use USD as the base currency. Panel A shows our first dealer and Panel B shows our second dealer.

Table 2: Summary of Order Flow

Order Flow -Second Dealer (billion$)											
Variables	N	Mean	S.D.	Min	25%	50%	75%	Max	Skew	Kurt	AR1
EUR	204	-0.214	3.350	-10.334	-2.543	-0.245	1.971	7.930	-0.058	-0.014	0.033
AUD	204	-0.855	4.839	-14.151	-3.719	-0.647	2.180	11.683	-0.029	0.150	-0.020
CAD	204	0.450	5.985	-17.325	-3.745	0.390	4.404	16.890	0.170	-0.178	0.068
CHF	204	1.864	6.454	-18.446	-1.583	1.843	6.364	19.777	-0.196	0.099	-0.018
GBP	204	0.227	3.931	-14.333	-2.372	0.708	2.849	9.276	-0.463	0.386	-0.036
JPY	204	0.527	3.759	-9.882	-2.057	0.512	3.019	10.726	0.136	-0.162	-0.013
NOK	204	-0.073	9.856	-26.695	-5.395	0.281	5.353	31.487	-0.064	0.872	-0.119
NZD	204	-1.002	6.348	-19.212	-5.238	-0.160	3.380	14.515	-0.158	-0.193	0.125
SEK	204	0.782	8.399	-18.929	-4.568	0.375	5.966	28.748	0.298	0.581	-0.049

Table 2 shows the summary of order flow. This table shows the number of observations, mean, standard deviation, minimum value to maximum value, skew, and kurtosis of the volume. All the currencies in Table 2 use USD as the base currency.

Table 3: Excess Return and Normalized Volume - during and after financial crisis

start from Dec 2007	$ExcessReturn_t$								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
				Volume		Bid-Ask Spread		Volatility	
		All Currencies		High	Low	High	Low	High	Low
$Return_{t-1}$	-0.1119**	-0.1028**	-0.1025**	-0.0411	-0.1310*	-0.1071*	-0.1017**	-0.1580***	0.0309
	0.0361	*0.0332*	*0.0340*	*0.0511*	*0.0630*	*0.0554*	*0.0298*	*0.0407*	*0.0474*
$Volume_{t-1}$	0.0018*	0.0027**	0.0027***	0.0018	0.0021	0.0030*	0.0011	0.0046***	-0.0004
	0.0009	*0.0009*	*0.0008*	*0.0015*	*0.0012*	*0.0015*	*0.0015*	*0.0012*	*0.0014*
$Return_{t-1} * Volume_{t-1}$		0.3738**	0.3694**	0.0944	0.4926**	0.3805*	0.5260	0.2566**	0.0564
		0.1411	*0.1465*	*0.2478*	*0.2131*	*0.1686*	*0.4110*	*0.1055*	*0.2339*
Controls	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
$adj - R^2$	0.4337	0.4365	0.4361	0.4400	0.4563	0.3439	0.5544	0.4808	0.4141
Nobs	2,464	2,464	2,464	1,214	1,223	1,226	1,238	1,230	1,232

*** indicates statistical significance at 10 % level

** indicates statistical significance at 5 % level

* indicates statistical significance at 1 % level

Table 3 shows the coefficient results of equation (6). This table uses double-clustered standard error and double fixed effect. We use the sample from December 2007 to March 2012. Columns (1) to (3) show the results when using all 11 currencies. Columns (4) - (9) split currencies according to median volume (4 and 5), median liquidity (6 and 7), and median volatility (8 and 9).

Table 4: Excess Return and Normalized Volume - before financial crisis

before financial crisis	$ExcessReturn_t$								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
				Volume		Bid-Ask Spread		Volatility	
		All Currencies		High	Low	High	Low	High	Low
$Return_{t-1}$	0.0259	0.0229	0.0187	0.0101	0.0198	0.0259	0.0027	0.0003	0.1405
	0.0299	*0.0312*	*0.0322*	*0.0486*	*0.0372*	*0.0447*	*0.0391*	*0.0409*	*0.0448*
$Volume_{t-1}$	-0.0008	-0.0007	-0.0007	-0.0015	0.0000	-0.0009	-0.0003	-0.0011	-0.0005
	0.0007	*0.0008*	*0.0008*	*0.0014*	*0.0010*	*0.0009*	*0.0011*	*0.0016*	*0.0010*
$Return_{t-1} * Volume_{t-1}$		0.0869	0.0734	0.2243	-0.1710	0.1589	-0.4422	0.1211	-0.0182
		0.2659	*0.2569*	*0.3037*	*0.2417*	*0.2665*	*0.2751*	*0.3102*	*0.2007*
Controls	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
$adj - R^2$	0.4531	0.453	0.4545	0.4133	0.5372	0.3593	0.5776	0.5016	0.4523
Nobs	2,904	2,904	2,904	1,438	1,442	1,444	1,460	1,451	1,453

*** indicates statistical significance at 10 % level

** indicates statistical significance at 5 % level

* indicates statistical significance at 1 % level

Table 4 shows the coefficient results of equation (6). This table uses the sample from November 2002 to November 2007. Columns (1) to (3) show the results when using all 11 currencies. Columns (4) - (9) split currencies according to median volume (4 and 5), median liquidity (6 and 7), and median volatility (8 and 9).

Table 5: Return and Normalized Volume - high and low groups

2007-2012

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	CDS		LIBOR-OIS		Leverage		Full
	High	Low	High	Low	High	Low	Period
Return_t-1	-15.9905**	-7.3658**	-14.2596**	-9.5726**	-12.9708**	-12.5521**	-12.8688***
	5.4126	*2.6876*	*4.9351*	*3.4235*	*4.7985*	*3.9437*	*3.6044*
Volume_t-1	0.3420**	0.0042	0.3828**	-0.0763	0.2814	0.0507	0.1624
	0.1315	*0.1327*	*0.1356*	*0.1220*	*0.1637*	*0.1178*	*0.1082*
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
$adj - R^2$	0.414	0.329	0.3948	0.3704	0.4014	0.3369	0.3879
Nobs	1,232	1,232	1,221	1,243	1,232	1,232	2,464

*** indicates statistical significance at 10 % level

** indicates statistical significance at 5 % level

* indicates statistical significance at 1 % level

Table 5 shows results when logarithmic return is the dependent variable and logarithmic return delay and normalized volume are independent variables. We still control GARCH volatility and bid-ask spread. This table uses the sample from 2007 December to 2012 March to run the double fixed effect and double cluster standard error regression. We split the sample into two parts according to the median of CDS Spread/ LIBOR-OIS Spread/ Leverage. The coefficient and standard error in this table are all multiplied by 100.

Table 6: Return and Normalized Volume - high and low groups - Covid 19

2018-2021

Panel A : Leverage Volme

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	CDS		LIBOR-OIS		Leverage		Full
	High	Low	High	Low	High	Low	Period
$Return_{t-1}$	8.6534**	1.24531	9.8800**	0.26106	7.4340**	2.32	6.0901***
	2.8939	*0.9082*	*2.9979*	*0.8195*	*2.8174*	*1.3138*	*1.7436*
$Volume_{t-1}$	0.1377***	0.0373***	0.1250***	0.0266**	0.1532***	0.0413**	0.0897***
	0.0243	*0.0089*	*0.0302*	*0.0096*	*0.0229*	*0.0160*	*0.0185*
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
$adj-R^2$	0.0144	-0.0005	0.0166	-0.0014	0.0149	-0.0002	0.007
Nobs	3,771	3,744	3,744	3,771	3,753	3,762	7,515

Panel B : Real Money

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	CDS		LIBOR-OIS		Leverage		Full
	High	Low	High	Low	High	Low	Period
$Return_{t-1}$	8.9229**	1.27788	10.2742**	0.25809	7.9755**	2.33847	6.2557***
	2.9888	*0.8752*	*3.0955*	*0.8178*	*2.9222*	*1.3114*	*1.8222*
$Volume_{t-1}$	0.1294***	0.0293**	0.1104**	0.02368	0.1111***	0.0437**	0.0738***
	0.0307	*0.0126*	*0.0356*	*0.0265*	*0.0195*	*0.0149*	*0.0115*
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
$adj-R^2$	0.0104	-0.0009	0.0121	-0.0015	0.0078	-0.0002	0.0048
Nobs	3,771	3,744	3,744	3,771	3,753	3,762	7,515

Panel C : Total Volume

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	CDS		LIBOR-OIS		Leverage		Full
	High	Low	High	Low	High	Low	Period
$Return_{t-1}$	8.6722**	1.24755	9.9310**	0.25976	7.5523**	2.31891	6.1145***
	2.9268	*0.8902*	*3.0243*	*0.8186*	*2.8701*	*1.3143*	*1.7762*
$Volume_{t-1}$	0.0850***	0.0195***	0.0743***	0.01547	0.0855***	0.0257***	0.0515***
	0.0161	*0.0035*	*0.0193*	*0.0093*	*0.0130*	*0.0065*	*0.0090*
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
$adj-R^2$	0.0139	-0.0006	0.0157	-0.0014	0.0129	-0.0001	0.0065
Nobs	3,771	3,744	3,744	3,771	3,753	3,762	7,515

*** indicates statistical significance at 10 % level

** indicates statistical significance at 5 % level

* indicates statistical significance at 1 % level

Table 6 uses the panel regression with currency fixed effect and currency cluster standard error. We split the sample into two parts according to the median of CDS Spread/ LIBOR-OIS Spread/ Leverage. This time still uses the regression which is similar to Table 6, however, this table uses the daily sample during the COVID-19 period which is from January 20189 to the end of 2021. The coefficient and standard error in this table are all multiplied by 100.

Table 7: Order Flow and Market Leverage - Covid

2018-2021

	(1) Aggregrated	(2) Financial	(3) Non-Financial
$DealerLeverage_{t-1}$	7.7329**	7.9322**	-0.1992
	3.1624	3.0950	2.0620
$DealerLeverage_{t-2}$	-8.2468**	-8.4427***	*0.1959*
	3.3092	*2.9311*	*1.8509*
$adj - R^2$	0.065	0.0689	0.0004
Nobs	46	46	46

*** indicates statistical significance at 10 % level

** indicates statistical significance at 5 % level

* indicates statistical significance at 1 % level

Table 7 shows the results between order flow and market leverage. For the market leverage, we use a similar way as He et al (2017). We generate the market leverage equals to

$$DealerLeverage_t = (MarketEquity_t + BookDebt_t)/MarketEquity_t \tag{21}$$

This table uses monthly data to do this regression. Because Bloomberg can only get the quarterly data of total book debt, we use quarterly data for each month as our monthly data. This regression uses robust standard error to do the time series regression. Column (1) shows the results of aggregated order flow and columns (2) and (3) show the order flow of financial clients and non-financial clients.

References

[1] Acharya, C. and Du, W. "Bank Balance Sheet Constraints at the Center of Liquidity Problems". In: (2022).

[2] Adrian, T. et al. "Market liquidity after the financial crisis". In: *Annual Review of Financial Economics* 9 (2017), pp. 43–83.

[3] Adrian, T. et al. *What's Driving Dealer Balance Sheet Stagnation?* Tech. rep. Federal Reserve Bank of New York, 2015.

[4] Andersen, L., Duffie, D., and Song, Y. "Funding value adjustments". In: *The Journal of Finance* 74.1 (2019), pp. 145–192.

[5] Barzykin, A., Bergault, P., and Guéant, O. "Market-making by a foreign exchange dealer". In: *Risk (Cutting Edge)* (2022).

[6] Berndt, A., Duffie, D., and Zhu, Y. "The decline of too big to fail". In: *American Economic Review (forthcoming)* (2024).

[7] Bianchi, J., Bigio, S., and Engel, C. *Scrambling for dollars: International liquidity, banks and exchange rates*. Tech. rep. National Bureau of Economic Research, 2021.

[8] Burnside, C., Cerrato, M., and Zhang, Z. *Foreign exchange order flow as a risk factor*. Tech. rep. National Bureau of Economic Research, 2020.

[9] Butz, M. and Oomen, R. "Internalisation by electronic FX spot dealers". In: *Quantitative Finance* 19.1 (2019), pp. 35–56.

[10] Campbell, J. Y., Grossman, S. J., and Wang, J. "Trading volume and serial correlation in stock returns". In: *The Quarterly Journal of Economics* 108.4 (1993), pp. 905–939. ISSN: 1531-4650.

[11] Cenedese, G., Della Corte, P., and Wang, T. "Currency mispricing and dealer balance sheets". In: *The Journal of Finance* 76.6 (2021), pp. 2763–2803.

[12] Cerrato, M. and Mei, S. "Quantitative Easing, Banks' Funding Costs, and Credit Line Prices". In: *Banks' Funding Costs, and Credit Line Prices (May 3, 2024)* (2024).

[13] Cespa, G. et al. "Foreign Exchange Volume". In: *The Review of Financial Studies* 35.5 (2022), pp. 2386–2427. ISSN: 0893-9454 1465-7368. DOI: 10.1093/rfs/hhab095.

[14] Chaboud, A., Rime, D., and Sushko, V. "Monetary and Economic Department". In: (2023).

[15] Cooperman, H. et al. "Bank funding risk, reference rates, and credit supply". In: *The Journal of Finance* 80.1 (2025), pp. 5–56.

[16] Copeland, A., Duffie, D., and Yang, Y. *Reserves were not so ample after all*. Tech. rep. National Bureau of Economic Research, 2021.

[17] Czech, R. et al. "FX option volume". In: (2021).

[18] Di Maggio, M., Kermani, A., and Song, Z. "The value of trading relations in turbulent times". In: *Journal of Financial Economics* 124.2 (2017), pp. 266–284.

[19] Drehmann, M. and Sushko, V. "The global foreign exchange market in a higher-volatility environment". In: *BIS Quarterly Review* 12 (2022), pp. 33–48.

[20] Du, W., Hébert, B., and Huber, A. W. "Are intermediary constraints priced?" In: *The Review of Financial Studies* 36.4 (2023), pp. 1464–1507.

[21] Du, W., Im, J., and Schreger, J. "The U.S. Treasury Premium". In: *Journal of International Economics* 112 (2018), pp. 167–181. ISSN: 0022-1996. DOI: https://doi.org/10.1016/j.jinteco.2018.01.001. URL: https://www.sciencedirect.com/science/article/pii/S0022199618300011.

[22] Du, W., Tepper, A., and Verdelhan, A. “Deviations from covered interest rate parity”. In: *The Journal of Finance* 73.3 (2018), pp. 915–957.

[23] Duffie, D. “Asset price dynamics with slow-moving capital,(American Finance Association Presidential Address)”. In: *Journal of Finance* 65 (2010), pp. 1238–68.

[24] Ellul, A., Jotikasthira, C., and Lundblad, C. T. “Regulatory pressure and fire sales in the corporate bond market”. In: *Journal of Financial Economics* 101.3 (2011), pp. 596–620.

[25] Ferreira, A. et al. “Foreign exchange interventions and intermediary constraints”. In: (2024).

[26] Gargano, A., Riddiough, S. J., and Sarno, L. “The value of volume in foreign exchange”. In: *SSRN Electronic Journal* (2018).

[27] Gromb, D. and Vayanos, D. “Equilibrium and welfare in markets with financially constrained arbitrageurs”. In: *Journal of financial Economics* 66.2-3 (2002), pp. 361–407.

[28] He, Z., Kelly, B., and Manela, A. “Intermediary asset pricing: New evidence from many asset classes”. In: *Journal of Financial Economics* 126.1 (2017), pp. 1–35. ISSN: 0304-405X. DOI: `https://doi.org/10.1016/j.jfineco.2017.08.002`. URL: `https://www.sciencedirect.com/science/article/pii/S0304405X1730212X`.

[29] Huang, W. et al. “Constrained liquidity provision in currency markets”. In: *Journal of Financial Economics* 167 (2025), p. 104028.

[30] Ivashina, V., Scharfstein, D. S., and Stein, J. C. “Dollar funding and the lending behavior of global banks”. In: *The Quarterly Journal of Economics* 130.3 (2015), pp. 1241–1281.

[31] Jiang, Z., Krishnamurthy, A., and Lustig, H. “Foreign safe asset demand and the dollar exchange rate”. In: *The Journal of Finance* 76.3 (2021), pp. 1049–1089.

[32] Kloks, P., Mattille, E., and Ranaldo, A. “Foreign Exchange Swap Liquidity”. In: *Swiss Finance Institute Research Paper* 23-22 (2023).

[33] Koijen, R. S. and Yogo, M. “Shadow insurance”. In: *Econometrica* 84.3 (2016), pp. 1265–1287.

[34] Koijen, R. S. and Yogo, M. “The cost of financial frictions for life insurers”. In: *American Economic Review* 105.1 (2015), pp. 445–475.

[35] Kondor, P. and Vayanos, D. “Liquidity risk and the dynamics of arbitrage capital”. In: *The Journal of Finance* 74.3 (2019), pp. 1139–1173. ISSN: 0022-1082.

[36] Kottimukkalur, B. “Variation in Liquidity and Costly Arbitrage”. In: *Available at SSRN 3427668* (2019).

[37] Krohn, I. and Sushko, V. “FX spot and swap market liquidity spillovers”. In: *Journal of International Money and Finance* 120 (2022), p. 102476.

[38] Levich, R. M. “FX counterparty risk and trading activity in currency forward and futures markets”. In: *Review of Financial Economics* 21.3 (2012), pp. 102–110. ISSN: 1058-3300 1873-5924. DOI: `10.1016/j.rfe.2012.06.004`.

[39] Llorente, G. et al. “Dynamic volume-return relation of individual stocks”. In: *The Review of financial studies* 15.4 (2002), pp. 1005–1047. ISSN: 1465-7368.

[40] Lu, L., Macchiavelli, M., and Wallen, J. “Internal and External Capital Markets of Large Banks”. In: *Available at SSRN* (2023).

[41] Myers, S. C. “Determinants of corporate borrowing”. In: *Journal of financial economics* 5.2 (1977), pp. 147–175.

[42] Of the Press Secretary, O. *Remarks of the President on Regulatory Reform.* 2009. URL: `https://obamawhitehouse.archives.gov/the-press-office/remarks-president-regulatory-reform/`.

[43] Ranaldo, A. and de Magistris, P. S. "Liquidity in the global currency market". In: *Journal of Financial Economics* 146.3 (2022), pp. 859–883.

[44] Ranaldo, A. and Santucci de Magistris, P. "Trading volume, illiquidity and commonalities in FX markets". In: *Research Paper, University of St. Gallen* (2019).

[45] Reform, D.-F. W. S. and Act, C. P. "Dodd-Frank Wall Street Reform and Consumer Protection Act". In: *On the Horizon* (2010).

[46] Rime, D., Schrimpf, A., and Syrstad, O. "Covered interest parity arbitrage". In: *The Review of Financial Studies* 35.11 (2022), pp. 5185–5227.

[47] Schwert, G. W. "Stock volatility and the crash of'87". In: *The review of financial studies* 3.1 (1990), pp. 77–102.

Appendices

A Before Financial Crisis

The coefficient and standard error in this part are all multiplied by 100.

Table 8: Return and Normalized Volume - before financial crisis

2002-2007

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	CDS		LIBOR-OIS		Leverage		Full
	High	Low	High	Low	High	Low	Period
$Return_{t-1}$	0.9810	-8.5468**	-1.7251	-5.5484*	-8.7362	1.7896	-2.7975
	4.4919	3.3376	4.5911	2.8992	5.5450	3.2769	*2.7864*
$Volume_{t-1}$	-0.1258	0.0578	-0.1061	0.0502	0.0497	-0.1135	-0.0495
	0.0857	0.0607	0.0931	0.0708	0.0831	0.0874	*0.0610*
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
$adj-R^2$	0.323	0.3802	0.3244	0.3719	0.296	0.3886	0.347
Nobs	1,441	1,463	1,430	1,474	1,452	1,452	2,904

*** indicates statistical significance at 10 % level

** indicates statistical significance at 5 % level

* indicates statistical significance at 1 % level

B Different Volume Windows

The coefficient and standard error in this part are all multiplied by 100.

B.1 window equals 8

Table 9: Return and Normalized Volume - during and after financial crisis

2007-2012

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	CDS		LIBOR-OIS		Leverage		Full
	High	Low	High	Low	High	Low	Period
$Return_{t-1}$	-16.0239**	-7.3718**	-14.2294**	-9.5778**	-12.9678**	-12.5239**	-12.8698***
	5.4228	*2.6946*	*4.9530*	*3.4252*	*4.8063*	*3.9735*	*3.6132*
$Volume_{t-1}$	0.4264**	-0.0031	0.4392**	-0.0687	0.3748*	0.0339	0.1982*
	0.1499	*0.1261*	*0.1511*	*0.1110*	*0.1705*	*0.1081*	*0.1091*
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
$adj-R^2$	0.4147	0.329	0.3953	0.3704	0.4022	0.3368	0.3881
Nobs	1,232	1,232	1221	1,243	1,232	1,232	2,464

*** indicates statistical significance at 10 % level

** indicates statistical significance at 5 % level

* indicates statistical significance at 1 % level

Table 10: Return and Normalized Volume - before financial crisis

2002-2007

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	CDS		LIBOR-OIS		Leverage		Full
	High	Low	High	Low	High	Low	Period
$Return_{t-1}$	0.9817	-8.5620**	-1.7369	-5.5657*	-8.7374	1.7844	-2.7921
	4.49287	3.34669	4.5907	2.90414	5.55344	3.28404	*2.7860*
$Volume_{t-1}$	-0.1534*	0.0720	-0.1290	0.0571	0.0393	-0.1224	-0.0625
	0.0834	0.0494	0.0885	0.0558	0.0894	0.0776	*0.0567*
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
$adj - R^2$	0.3233	0.3803	0.3246	0.3719	0.2959	0.3886	0.3471
Nobs	1,441	1,463	1,430	1,474	1,452	1,452	2,904

*** indicates statistical significance at 10 % level

** indicates statistical significance at 5 % level

* indicates statistical significance at 1 % level

B.2 window equals 16

Table 11: Return and Normalized Volume - during and after financial crisis

2007-2012

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	CDS		LIBOR-OIS		Leverage		Full
	High	Low	High	Low	High	Low	Period
$Return_{t-1}$	-15.9450**	-7.4169**	-14.2227**	-9.5607**	-12.9704**	-12.4750**	-12.8357***
	5.4150	*2.7032*	*4.9467*	*3.4253*	*4.7983*	*3.9815*	*3.6104*
$Volume_{t-1}$	0.3010**	-0.0458	0.3203**	-0.1180	0.25051	-0.0086	0.1157
	0.1304	*0.1198*	*0.1318*	*0.1061*	*0.1591*	*0.1097*	*0.1001*
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
$adj - R^2$	0.4137	0.3291	0.3942	0.3707	0.4013	0.3368	0.3877
Nobs	1,232	1,232	1221	1,243	1,232	1,232	2,464

*** indicates statistical significance at 10 % level

** indicates statistical significance at 5 % level

* indicates statistical significance at 1 % level

Table 12: Return and Normalized Volume - before financial crisis

2002-2007

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	CDS		LIBOR-OIS		Leverage		Full
	High	Low	High	Low	High	Low	Period
$Return_{t-1}$	0.9561	-8.5538**	-1.7442	-5.5513*	-8.7533	1.7585	-2.8042
	4.4884	3.3379	4.5886	2.8959	5.5451	3.2629	*2.7875*
$Volume_{t-1}$	-0.1158	0.0677	-0.1007	0.0619	0.0739	-0.1123	-0.0389
	0.0883	0.0674	0.0953	0.0723	0.0845	0.0828	*0.0653*
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
$adj - R^2$	0.3229	0.3803	0.3244	0.372	0.2962	0.3886	0.347
Nobs	1,441	1,463	1,430	1,474	1,452	1,452	2,904

*** indicates statistical significance at 10 % level

** indicates statistical significance at 5 % level

* indicates statistical significance at 1 % level

Online Appendix

Online Appendix Not For Publication

A Different Maturity for Forward Rates

Table 13: Excess Return and Normalized Volume - using 1-month forward rate

start from Dec 2007

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
				Volume		Bid-Ask Spread		Volatility	
	All Currencies			High	Low	High	Low	High	Low
$Return_{t-1}$	-0.1086**	-0.0971**	-0.1005**	-0.0169	-0.1312*	-0.0947	-0.1123**	-0.1661***	0.0019
	0.0415	*0.0373*	*0.0381*	*0.0772*	*0.0657*	*0.0539*	*0.0360*	*0.0400*	*0.0513*
$Volume_{t-1}$	0.0013	0.0018	0.0019	-0.0004	0.0020	0.0022	0.0003	0.0050**	-0.0010
	0.0014	*0.0013*	*0.0012*	*0.0019*	*0.0021*	*0.0021*	*0.0016*	*0.0018*	*0.0014*
$Return_{t-1} * Volume_{t-1}$		0.5376***	0.5448***	-0.0242	0.6465***	0.5945**	0.6944	0.4102**	0.0997
		0.1456	*0.1497*	*0.3830*	*0.1720*	*0.1710*	*0.4876*	*0.1245*	*0.2988*
Controls	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
$adj - R^2$	0.3753	0.3809	0.3807	0.3873	0.4027	0.2225	0.5472	0.4493	0.3521
Nobs	2,016	2,016	2,016	984	995	1,002	1,014	1,002	1,008

*** indicates statistical significance at 10 % level

** indicates statistical significance at 5 % level

* indicates statistical significance at 1 % level

Table 13 uses the 1-month forward rate to calculate excess return. In this table, we use Euro(EUR), Japanese yen (JPY), Swiss franc (CHF), Australian dollar (AUD), New Zealand dollar (NZD), Canadian dollar (CAD), South African rand (ZAR), Singapore dollar (SGD), Hong Kong dollar (HKD) as our sample.

Table 14: Excess Return and Normalized Volume - using 1-week forward rate

start from Dec 2007

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
				Volume		Bid-Ask Spread		Volatility	
	All Currencies			High	Low	High	Low	High	Low
$Return_{t-1}$	-0.0948*	-0.0841	-0.0861*	0.0280	-0.1565*	-0.0847	-0.0834	-0.1193*	-0.0275
	0.0473	*0.0443*	*0.0433*	*0.0810*	*0.0788*	*0.0757*	*0.0510*	*0.0504*	*0.0622*
$Volume_{t-1}$	-0.0008	-0.0010	-0.0011	-0.0014	0.0003	0.0006	-0.0005	-0.0015	0.0009
	0.0012	*0.0011*	*0.0011*	*0.0024*	*0.0016*	*0.0018*	*0.0018*	*0.0019*	*0.0018*
$Return_{t-1} * Volume_{t-1}$		0.5054**	0.5056**	0.0024	0.6445**	0.3447	0.7892	0.4261**	0.2195
		0.1662	*0.1700*	*0.5412*	*0.1985*	*0.2689*	*0.3982*	*0.1582*	*0.2241*
Controls	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
$adj - R^2$	0.2305	0.236	0.2357	0.2271	0.2057	0.0009	0.439	0.2204	0.2793
Nobs	1,568	1,568	1,568	755	765	764	804	783	784

*** indicates statistical significance at 10 % level

** indicates statistical significance at 5 % level

* indicates statistical significance at 1 % level

Table 14 uses the 1-week forward rate to calculate excess return. In this table, we use the Japanese yen (JPY), British pound (GBP), Swiss franc (CHF), Canadian dollar (CAD), South African rand (ZAR), Singapore dollar (SGD), Hong Kong dollar (HKD) as our sample.

B Realized Volatility

This section uses the realized volatility instead of the GARCH volatility.

Table 15: Excess Return and Normalized Volume - during and after financial crisis

start from Dec 2007 $ExcessReturn_t$

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
				Volume		Bid-Ask Spread		Volatility	
		All Currencies		High	Low	High	Low	High	Low
$Return_{t-1}$	-0.1119**	-0.1028**	-0.1186***	-0.0610	-0.1442**	-0.1394**	-0.097**	-0.1770***	-0.0291
	0.0361	*0.0332*	*0.0323*	*0.0436*	*0.0603*	*0.0503*	*0.0329*	*0.0390*	*0.0192*
$Volume_{t-1}$	-0.0018*	-0.0027**	-0.0029**	-0.0019	-0.0019	-0.0028*	-0.0009	-0.0039**	-0.0005
	0.0009	*0.0009*	*0.0010*	*0.0015*	*0.0012*	*0.0013*	*0.0014*	*0.0014*	*0.0007*
$Return_{t-1} * Volume_{t-1}$		0.3738**	0.3865**	0.1188	0.4622*	0.3604*	0.4737	0.3199	-0.0196
		0.1411	*0.1606*	*0.2397*	*0.2385*	*0.1674*	*0.3762*	*0.1940*	*0.1098*
Controls	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
$adj - R^2$	0.4337	0.4365	0.4579	0.4494	0.4767	0.3754	0.5634	0.5478	0.572
Nobs	2,464	2,464	2,464	1,214	1,223	1,226	1,238	1,227	1,221

*** indicates statistical significance at 10 % level

** indicates statistical significance at 5 % level

* indicates statistical significance at 1 % level

Table 15 uses the realized volatility to redo Table 2.

Table 16: Excess Return and Normalized Volume - before financial crisis

before financial crisis

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
				Volume		Bid-Ask Spread		Volatility	
	All Currencies			High	Low	High	Low	High	Low
$Return_{t-1}$	0.0259	0.0229	0.0120	0.0004	0.0275	0.0128	0.0038	-0.0111	0.0264
	0.0299	*0.0312*	*0.0326*	*0.0456*	*0.0338*	*0.0434*	*0.0402*	*0.0439*	*0.0277*
$Volume_{t-1}$	0.0008	0.0007	0.0007	0.0014	0.0000	0.0009	0.0003	0.0034	0.0001
	0.0007	*0.0008*	*0.0008*	*0.0013*	*0.0010*	*0.0011*	*0.0011*	*0.0016*	*0.0009*
$Return_{t-1} * Volume_{t-1}$		0.0869	0.0510	0.1600	-0.1672	0.1201	-0.4336	0.1731	-0.1006
		0.2659	*0.2498*	*0.2806*	*0.2539*	*0.2506*	*0.2724*	*0.3238*	*0.0944*
Controls	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
$adj-R^2$	0.4531	0.453	0.4600	0.4365	0.5412	0.3743	0.5777	0.5539	0.6662
Nobs	2,904	2,904	2,904	1,438	1,442	1,444	1,460	1,442	1,449

*** indicates statistical significance at 10 % level

** indicates statistical significance at 5 % level

* indicates statistical significance at 1 % level

Table 16 uses the realized volatility to redo Table 3.

C Second Dealer Results

Table 17: Excess Return and Normalized Volume - Covid

2018-2021

Panel A : Leverage Volume									
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
		All Currencies		Volume		Bid-Ask Spread		Volatility	
				High	Low	High	Low	High	Low
$Return_{t-1}$	0.5092	1.4592***	1.3561***	1.3720***	1.1483***	1.4788***	0.4089*	1.5268***	0.0048
	0.2953	*0.1108*	*0.1062*	*0.2954*	*0.0929*	*0.1480*	*0.1730*	*0.0653*	*0.4184*
$Volume_{t-1}$	0.0020***	0.0046***	0.0047***	0.0100***	-0.0011	0.0052**	0.0041***	0.0057**	0.0029**
	0.0006	*0.0012*	*0.0012*	*0.0029*	*0.0014*	*0.0019*	*0.0007*	*0.0021*	*0.0010*
$Return_{t-1} * Volume_{t-1}$		-0.8509***	-0.7696***	-0.8045***	-0.5344**	-0.7775*	-0.4377**	-0.8719**	-0.0200
		0.2350	*0.1766*	*0.1055*	*0.1881*	*0.3416*	*0.1410*	*0.2617*	*0.4049*
Controls	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
$adj-R^2$	0.3132	0.3508	0.3612	0.2279	0.5218	0.4818	0.0548	0.4334	0.0348
Nobs	1,827	1,827	1,827	918	909	890	937	913	914

Panel B : Real Money									
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
		All Currencies		Volume		Bid-Ask Spread		Volatility	
				High	Low	High	Low	High	Low
$Return_{t-1}$	0.5096	1.3303***	1.1635***	1.2313***	0.3144	1.3529***	0.6393**	1.4209***	-0.0065
	0.2949	*0.1752*	*0.1462*	*0.2739*	*0.2387*	*0.2010*	*0.2182*	*0.1118*	*0.4497*
$Volume_{t-1}$	0.0016**	0.0034*	0.0044**	0.0077**	0.0059***	0.0051*	0.0051***	0.0045	0.0034***
	0.0006	*0.0016*	*0.0016*	*0.0030*	*0.0012*	*0.0024*	*0.0007*	*0.0032*	*0.0007*
$Return_{t-1} * Volume_{t-1}$		-0.6796**	-0.5542**	-0.6172**	0.2765***	-0.6119	-0.6145**	-0.7171**	-0.0086
		0.2785	*0.2213*	*0.2253*	*0.0662*	*0.3492*	*0.1712*	*0.2685*	*0.4070*
Controls	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
$adj-R^2$	0.3125	0.3295	0.3424	0.2628	0.4614	0.4648	0.0589	0.4116	0.0339
Nobs	1,827	1,827	1,827	918	909	890	937	913	914

*** indicates statistical significance at 10 % level

** indicates statistical significance at 5 % level

* indicates statistical significance at 1 % level

Table 17 shows the results of Table 3 when using the Covid period (2018-2021).

D Order Flow as Control

The coefficient and standard error in this part are all multiplied by 100.

Table 18: Order Flow as Control - during and after financial crisis

2007-2012

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	CDS		LIBOR-OIS		Leverage		Full
	High	Low	High	Low	High	Low	Period
$Return_{t-1}$	-15.9928**	-7.3278**	-14.2252**	-9.5856**	-12.9614**	-12.7063***	-12.8442***
	5.3878	*3.1307*	*4.9040*	*3.3965*	*4.7251*	*3.8601*	*3.5799*
$Volume_{t-1}$	0.3419**	-0.0053	0.3823**	-0.0788	0.2816	0.0413	0.1611
	0.1288	*0.1362*	*0.1375*	*0.1224*	*0.1595*	*0.1175*	*0.0011*
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Order Flow Control	Yes	Yes	Yes	Yes	Yes	Yes	Yes
$adj-R^2$	0.4135	0.3307	0.3944	0.3703	0.4009	0.3379	0.3879
Nobs	1,232	1,232	1,221	1,243	1,232	1,232	2,464

*** indicates statistical significance at 10 % level

** indicates statistical significance at 5 % level

* indicates statistical significance at 1 % level

Table 18 adds order flow as a control to redo Table 5, and the main results do not change.

Table 19: Order Flow as Control - Covid 19

2018-2021

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Panel A : Leverage Volme							
	CDS		LIBOR-OIS		Leverage		Full
	High	Low	High	Low	High	Low	Period
$Return_{t-1}$	8.9029**	1.4604	10.2347***	0.3892	7.5747**	2.7209*	6.3365***
	2.8520	*0.9885*	*2.8947*	*0.8575*	*2.8508*	*1.4422*	*1.7435*
$Volume_{t-1}$	0.1375***	0.0372***	0.1256***	0.0258**	0.1527***	0.0414**	0.0895***
	0.0248	*0.0088*	*0.0303*	*0.0095*	*0.0230*	*0.0154*	*0.0185*
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Order Flow Control	Yes	Yes	Yes	Yes	Yes	Yes	Yes
$adj-R^2$	0.0179	0.0005	0.0203	-0.0004	0.0173	0.0018	0.0094
Nobs	3,771	3,744	3,744	3,771	3,753	3,762	7,515
Panel B : Real Money							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	CDS		LIBOR-OIS		Leverage		Full
	High	Low	High	Low	High	Low	Period
$Return_{t-1}$	9.1725**	1.4932	10.6287***	0.3863	8.1119**	2.7426*	6.5023***
	2.9431	*0.9593*	*2.9938*	*0.8568*	*2.9566*	*1.4378*	*1.8215*
$Volume_{t-1}$	0.1288**	0.0289*	0.1110**	0.0225	0.1098***	0.0439**	0.0732***
	0.0318	*0.0132*	*0.0360*	*0.0273*	*0.0200*	*0.0150*	*0.0117*
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Order Flow Control	Yes	Yes	Yes	Yes	Yes	Yes	Yes
$adj-R^2$	0.0138	0.0002	0.0158	-0.0005	0.0103	0.0018	0.0087
Nobs	3,771	3,744	3,744	3,771	3,753	3,762	7,515
Panel C : Total Volume							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	CDS		LIBOR-OIS		Leverage		Full
	High	Low	High	Low	High	Low	Period
$Return_{t-1}$	8.9217**	1.4627	10.2855***	0.3877	7.6884**	2.7230*	6.3610***
	2.8833	*0.9725*	*2.9216*	*0.8570*	*2.9031*	*1.4417*	*1.7757*
$Volume_{t-1}$	0.0848***	0.0194***	0.0747***	0.0149	0.0850***	0.0257***	0.0513***
	0.0166	*0.0036*	*0.0194*	*0.0096*	*0.0131*	*0.0063*	*0.0090*
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Order Flow Control	Yes	Yes	Yes	Yes	Yes	Yes	Yes
$adj-R^2$	0.0174	0.0004	0.0194	-0.0004	0.0153	0.002	0.009
Nobs	3,771	3,744	3,744	3,771	3,753	3,762	7,515

*** indicates statistical significance at 10 % level

** indicates statistical significance at 5 % level

* indicates statistical significance at 1 % level

Table 19 adds order flow as a control to redo Table 6, and the main results do not change.

E Volume and CDS

Table 20: Change of Volume and Change of CDS - Financial Crisis

2008-2012	$\Delta Volume_t$
	(1)
$\Delta Volume_{t-1}$	-0.3735*** *0.0181*
ΔCDS_{t-1}	0.0315*** *0.0071*
ΔCDS_{t-2}	-0.0525*** *0.0129*
$adj - R^2$	0.1429
Nobs	2,442

Table 20 shows the weekly results when Y is change of Volume and X are lag change of volume and some lags of Δ cds. This table use currency fixed effects and currency standard error to do the panel regression.

Table 21: Change of Volume and Change of CDS - COVID 19

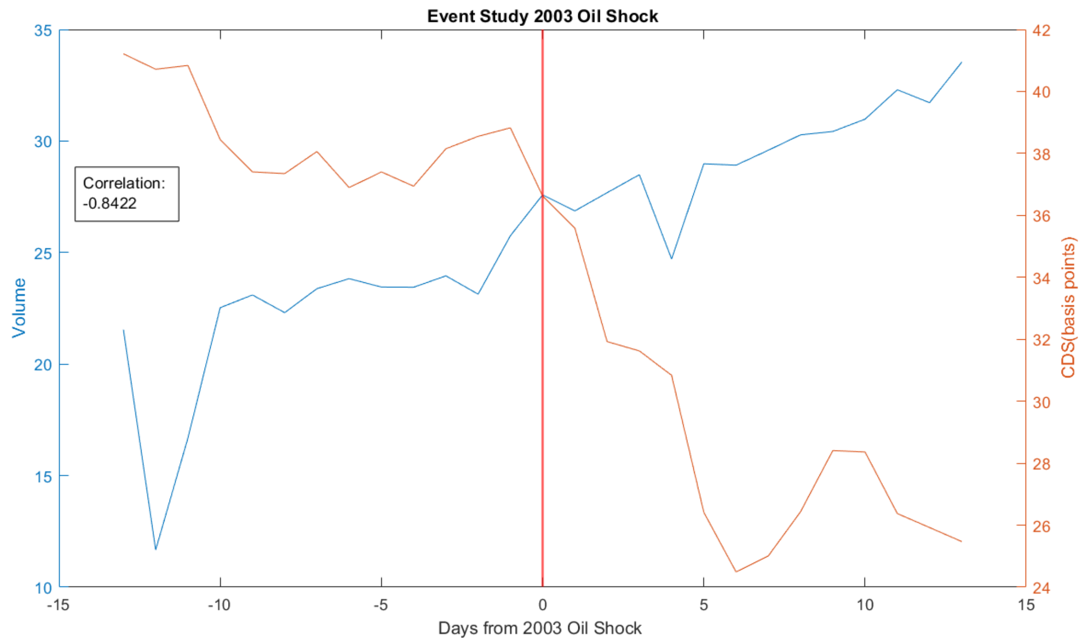
2018-2021	$\Delta Volume_t$		
	leverage volume (1)	real money (2)	sumvolume
$\Delta Volume_{t-1}$	0.3152***	-0.0772	0.1296*
	0.0718	*0.0735*	*0.0695*
$\Delta Volume_{t-1}$	-0.1928*	-0.0656	-0.2545
	0.1075	*0.1127*	*0.2074*
$\Delta Volume_{t-2}$	-0.0730	0.1481	0.0789
	0.1317	*0.1462*	*0.2793*
$\Delta Volume_{t-3}$	-0.2756**	-0.0680	-0.3894
	0.1173	*0.1290*	*0.2419*
$\Delta Volume_{t-4}$	-0.2178*	-0.3077**	-0.5730**
	0.1219	*0.1368*	*0.2553*
$adj - R^2$	0.2106	0.0588	0.1026
Nobs	199	199	199

Table 21 shows the weekly results when Y is the change of Volume and X are lag change of volume and some lags of Δ cds. This table use robust standard error to do the time series regression.

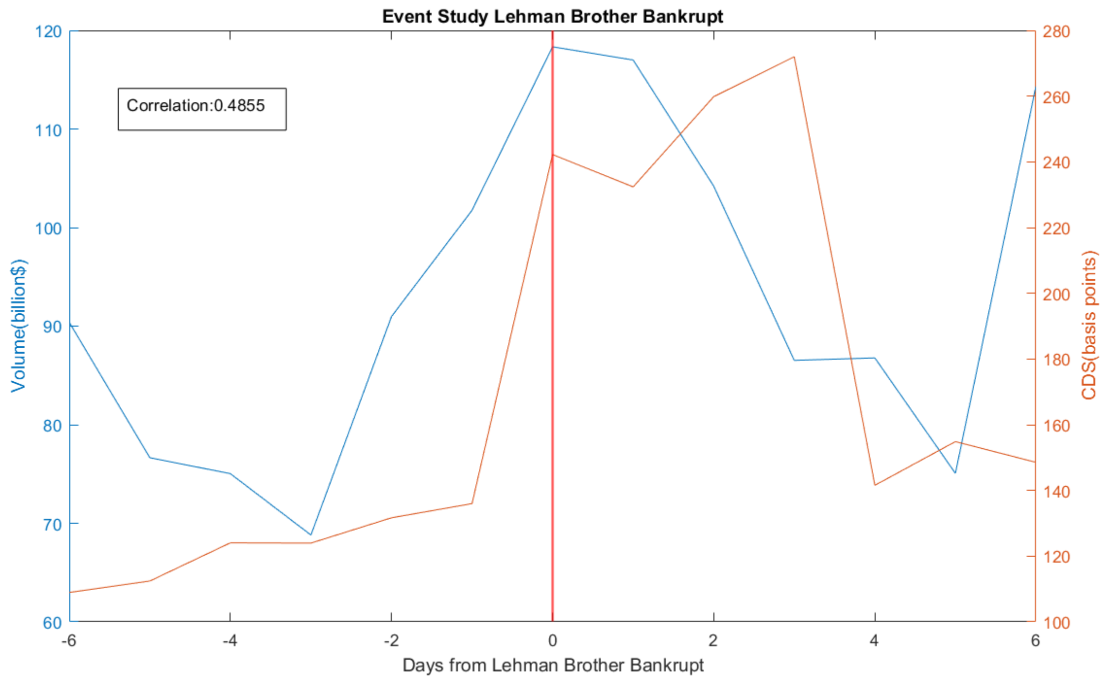
F Case Study

Figure 11: Case Study

(a) Oil Shock - Weekly



(b) Lehman Brother Bankrupt - Weekly



(c) Covid 19 - Daily

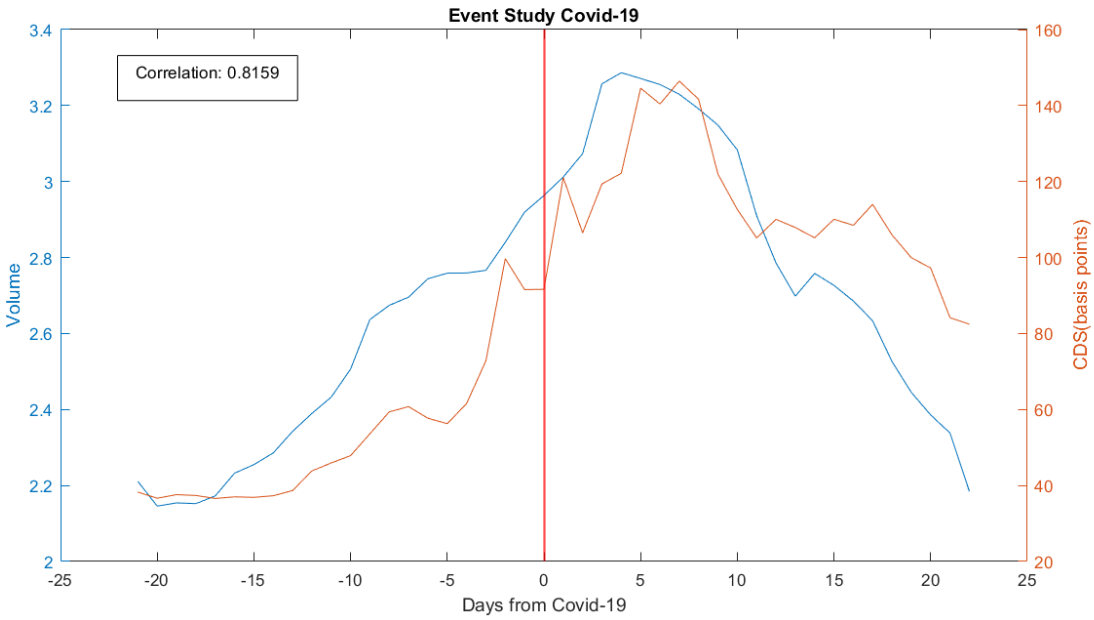


Figure 11 shows the fx volume and CDS relationship during the 2003 Oil Shock, Lehman Brothers bankruptcy and the Covid. We choose the oil shock and bankruptcy week , also the day on which COVID-19 was defined by WHO as time 0. Further, we draw the weeks and days before and after time 0.