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

Abstract:

Using two new proprietary (OTC) FX volume and order flow data, we study the informational role of FX volume around crisis periods. We show that post-2008, US dollar spot volume becomes impaired when dealer balance sheet constraints tighten. We focus on debt overhang costs (Myres, 1976) related to bank equity holders when the dealer supplies FX dollar liquidity during shocks. We also consider a novel interplay between the demand and supply of the dollars. Our analysis shows strong evidence that the predictability of FX volume stems from supply-side frictions, debt overhang costs. We present a model explaining the mechanism.

Keywords: JEL Financial Crises(G01); Asset Pricing, Trading Volume, Bond Interest Rates(G12); International Financial Markets(G15); Foreign Exchange(F31)

1 Introduction

Does foreign exchange (FX) trading volume contain information about future exchange rate movements? If so, what type of information does it contain, and under what conditions does this information become economically relevant? The literature studying the informational role of order flow and volume in FX markets, largely abstracts from the role of dealer balance-sheet constraints in shaping how quantity pressure translates into prices. This paper shows that the predictive content of FX spot dollar volume is fundamentally a post-2008 phenomenon that arises when large FX dealer banks face tight balance-sheet constraints. Our central result is that FX volume predicts U.S. dollar appreciation only when dealer balance sheets are impaired, and that this predictability reflects a steepening of the dollar supply curve driven by debt overhang costs borne by bank equity holders. Therefore, capital structure incentives drive the predictability of the dollar volume.

We study this mechanism using two proprietary, bilateral over-the-counter FX datasets from two of the largest global FX dealers, spanning periods both before and after the Global Financial Crisis (GFC). These data allow us to observe dealer-level FX spot volumes and matched order flows across client types over nearly two decades. This unique coverage enables us to document a sharp contrast between the pre- and post-2008 eras: before 2008, FX spot dollar volume contains no predictive information about exchange rate movements; after 2008, the same volume becomes strongly predictive, but only during periods when debt overhang tighten. This structural break coincides with a regime in which dealer funding costs, leverage, and therefore debt overhang become first-order determinants of FX intermediation.

Our core contribution is to identify and explain this change in the informational content of FX volume. We show that, following 2008, dealer balance-sheet frictions proxied primarily by the dealer CDS spread (Andersen et al, 209; Cerrato and Mei, 2024) but also by leverage measures from He et al. (2017), dealer CDS spreads, and market-wide funding stress, such as the LIBORIS spread-alter the elasticity of dollar supply. When debt overhang costs rise, dealers face a higher shadow cost of expanding their balance sheets to intermediate FX spot transactions. As a result, the supply curve for dollar liquidity becomes steeper: given the same quantity pressure, prices move more. In this case, FX trading volume becomes informative not because it reveals private information, but because it interacts with constrained intermediation capacity to generate larger price responses.

We provide direct empirical evidence for this supply-side mechanism. First, panel regressions show that lagged FX spot dollar volume predicts subsequent dollar appreciation only when dealer balance-sheet constraints are high; the effect disappears when constraints are low and is entirely absent in the pre-2008 sample. Second, we exploit high-frequency changes in dealer CDS spreads to identify exogenous shocks to balance-sheet tightness. Event-time analyses reveal that FX prices respond sharply to trading pressure only when balance-sheet stress coincides with high volume, with no pre-trends and no comparable response outside these joint states. Third, we estimate the marginal price impact of volume as a function of dealer CDS spreads and show that the implied slope of the dollar supply curve rises steeply during the GFC, the euro-area sovereign debt crisis, and the COVID-19 shock. Together, these results provide consistent evidence that post-2008 FX volume predictability reflects supply-curve steepening driven by dealer debt overhang.

Our interpretation departs from the dominant view in the FX-volume literature, which emphasises asymmetric information and demand-side learning (e.g., Campbell et al., 1993; Llorente et al., 2002; Cespa et al., 2022). While such mechanisms may be present, they cannot explain why volume predictability is absent before 2008 and emerges only in periods of severe dealer balance-sheet stress. Nor can they account for why the same quantity pressure generates much larger price effects during crises. Instead, our findings align with a growing literature on post-crisis financial intermediation that emphasises the role of balance-sheet constraints in asset pricing (Adrian et al., 2015; He et al., 2017; Duffie, 2010; Duffie et al., 2023).

To rationalise our empirical findings, we develop a simple model of FX spot intermediation in which a risk-neutral dealer faces leverage constraints and debt overhang costs. Following Myers (1977) and Andersen et al. (2019), debt overhang arises because expanding balance sheets transfer value from equity holders to creditors when funding costs are high. In the model, debt overhang cost directly maps into the slope of the dollar supply curve.

As we mentioned above, a large literature emphasises the role of intermediary balance-sheet constraints in periods of financial stress. When dealer capital is scarce, intermediation becomes more costly, and asset prices respond to changes in intermediaries's ability to absorb risk or expand their balance sheets (He et al, 2022, Duffie et al, 2023). Our paper builds on this insight but emphasises a different mechanism. This literature primarily treat intermediary capital scarcity as a state variable-captured by leverage, net worth, or a shadow cost of capital. We focus on incentives and on how equity holders respond to this scarcity when pricing intermediation. When equity is scarce, expanding the balance sheet transfers value to existing creditors, generating a debt-overhang incentive distortion that directly affects quotes (Andersen et al, 2019; Cerrato and Mei, 2024). This distinction has important implications. In standard balance-sheet-constraint models, tighter constraints often lead to reduced intermediation or quantity rationing. In contrast, a debt-overhang mechanism operating through equity-holder incentives could lead to continued intermediation but at higher prices: supply curves steepen, price impact rises, but trading volume need not collapse. These predictions align closely with the empirical patterns we document in FX markets during periods of stress and are supported by our model.

Importantly, our analysis also highlights a complementary demand-side channel that helps explain why FX volume increases precisely when debt overhang costs rise. Using detailed order-flow data, we show that surges in dollar demand during crises originate primarily from leveraged financial clients, while non-financial clients, such as corporates, tend to supply dollars. Leveraged clients are price-sensitive and prefer to trade with dealers that have stronger balance sheets and lower funding costs, consistent with intense competition among large FX dealers (Duffie, 2010; Butz and Roel, 2019; Krohn and Sushko, 2022). When dealer capital deteriorates, accommodating this demand requires greater price concessions, amplifying the price impact of volume. This demand-supply interaction generates the observed positive correlation between lagged FX volume and subsequent dollar appreciation during periods of stress.

Our results connect several strands of the literature. First, they complement recent work documenting increased FX liquidity costs and steeper supply curves in the post-crisis era (Czech et al., 2021; Huang et al., 2025; Klocks et al., 2023), while shifting the focus from regulatory constraints to debt overhang costs borne by equity holders. Second, they relate to studies of dollar funding shortages and financial channels of exchange rates (Bruno and Shin, 2015; Du et al., 2018a; Jiang et al., 2021; Kekre and Lenel, 2024), showing that spot FX volume contains information about these frictions when intermediation capacity is constrained. Third, they complement evidence on the failure of covered interest parity during crises (Du et al., 2018b; Burnside and Cerrato, 2025b) by documenting analogous mechanisms in the spot FX market.

More broadly, our findings have implications for financial stability and policy. They suggest that FX markets become more fragile when dealer balance sheets are impaired by debt overhang, as quantity shocks translate into disproportionately large price movements. This insight is relevant for understanding FX market stress during the GFC and COVID-19, and for evaluating the effectiveness of central bank interventions when dollar liquidity is scarce (Ferreira et al., 2024). Our model further implies that higher equity capital, while costly for shareholders in the short run, can enhance future profitability by easing intermediation constraints, echoing arguments in Admati et al. (2012).

Our analysis is closely related to a growing literature on FX predictability and trading activity, including Cespa et al. (2022), Cenedese et al. (2021), and Ranaldo et al. (2019). These papers document important links between FX returns, volume, and investor behaviour, emphasising risk premia, information, or disagreement as key drivers of exchange rate dynamics. Our contribution is complementary but distinct. We show that FX volume becomes predictive of dollar returns only when dealer balance-sheet constraints bind, and that this predictability reflects a steepening of the dollar supply curve driven by debt overhang costs. We exploit quasi-exogenous, high-frequency shocks to dealer balance-sheet tightness, and identify conditional price responses around those shocks. This perspective helps explaining why FX volume has little predictive information before 2008 but becomes strongly informative during periods of financial stress, a feature that demand-based or information-based mechanisms alone cannot account for.

Once again, it is important to distinguish the mechanism we study from the standard balance-sheet-constraint view of intermediation. In the literature, intermediary capital scarcity operates as a input int he model that limits quantities or risk-bearing capacity. In contrast, our mechanism operates via equity-holder incentives. When dealer equity is scarce or funding costs are high, expanding intermediation transfers part of the marginal surplus to existing creditors. As a result, equity holders face a private incentive distortion-classic debt overhang in the sense of Myers (1977). Debt overhang can affect prices even when balance-sheet constraints do not mechanically bind. This distinction is crucial as it implies that intermediation may continue during stress, but at worse prices, generating a steeper supply curve rather than a fall in supply.

Finally, this paper shows that the informational content of FX spot dollar volume is not a timeless feature of the market, but a regime-dependent outcome shaped by dealer balance-sheet constraints. By combining proprietary dealer data, event-based identification, and a structural interpretation grounded in debt overhang, we provide new evidence on how post-crisis financial frictions alter price formation in the world's largest financial market.

2 Data and Summary Statistics

Summary statistics of the data.

2.1 *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. (2025a).

The second dataset consists of daily US$ equivalent volume across the G9 currencies. We have volume data for the 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 measures the average daily volume based on client trades over the last 20days normalized by the 6-month median volume of those trades. The volume indicators are based on the total buy and sell trades of a currency by client type and are aggregated in USD equivalent terms regardless of the cross in which they are transacted. These are calculated separately for hedge funds, asset managers and other clients. A value greater than one indicates median volume higher in the last 6 months. The data spans the period 2014 to 2023 at 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 also have, for the same dealer, order flows 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. (2025a).

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$ equivalent trades, spanning Jan 2018 to Dec 2021. Trading volume is expressed relative to the median volume. The average is slightly above 1, suggesting increasing volume over time. Both investor categories have a positive skew - i.e. higher volume periods are more common.

Table 2 reports aggregate and disaggregated order flow from the second dealer over the 2018-2021 period. Order flow is defined as net buying minus selling, with positive values indicating purchases of foreign currency (sales of USD). All figures are normalised by recent median trading volumes. Over the full sample, aggregate clients are net sellers of EUR and AUD and net buyers of CHF and GBP. Financial clients are small net buyers for most currencies, while non-financial clients, predominantly corporates, are net sellers of all currencies except CHF.

2.2 *The Empirical Model*

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:

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

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 (B), we also show the results when using the one-month and the one-week maturity. Note that we use excess returns only 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 study the information of the FX volume and not exploiting this for FX trading.

3 Does FX Volume Contain Information?

We begin by documenting the empirical patterns emphasised in the FX-volume literature, which interprets volume predictability as evidence of information asymmetry. Our goal in this section is diagnostic: to establish when these patterns arise, not to adopt their interpretation. Does FX volume contain information? What sort 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 focus on asymmetric information driving the FX volume. This is a plausible explanation. For example, if FX volume moves with FX volatility, then one can assume that higher volatility increases the demand for dollar liquidity, and this affects the FX volume and the dollar exchange rate. Therefore, one would observe a predictive power of the volume on returns (or excess returns). In this context, demand-based models resting on asymmetric information could provide a possible explanation (for example, as in Cespa et al., 2022). However, those models do not consider the possibility that the supply of dollars can also contribute to the predictability of the volume. We shall discuss this in greater detail in the next sections.

Furthermore, the data used in that literature, including Cespa et al. (2022), originate in a settlement-specific platform, CLS Group. In this paper we use bilateral flow data. This is important as the two sources of FX data are structurally very different. Therefore, to corroborate the results of Cespa et al. (2022), as a first step, we re-do their analysis using our data sets. 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[1] To mitigate heteroskedasticity and trends in the time series of volume, we follow Cespa et al. (2022) and calculate the normalized volume as:

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

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

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

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

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.

4 Preliminary Results

This section documents descriptive patterns in FX volume and order flow that motivate our later analysis of balance-sheet-driven price impact. Table 3 shows the results. We include time and currency fixed effects and use double-clustered standard errors.

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 it.[2]

Table 3 shows already shows some novel and interesting differences with respect to what is reported in the literature. For example, our estimated interaction coefficients are much larger than the ones reported in many recent papers, including Cespa et al. (2022). This may suggest that customers' volumes are more informative than the ones used in most papers (Cespa et al., 2022 and Czech et al., (2021) make a similar remark.

More importantly, the degree of persistence in currency returns that we document is surprisingly higher, given that we use weekly data. Finally, and very important, volume on its own, is

[2]We have also used daily volume data for the second dealer and the period 2018-2021, confirming that the interaction coefficient is also highly significant. Results are, in general, supportive of the Cespa et al (2022) argument. See online Appendix D

always highly significant while in most recent FX empirical papers (and in the model in Cespa et al. (2022)), volume on its own is insignificant.

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[3]

These patterns indicate substantial variation in quantity pressure, but by themselves do not explain how such pressure translates into prices, which depends on the elasticity of FX supply.

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 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. [4]

The empirical evidence in Table 3 and Table 4 suggest that while FX volume can predict currency returns during the post-2008 period, it fails during the period before 2008. In this paper, we show that this difference can be rationalised once supply-side factors are considered, as they drive the slope of the supply curve for US dollars post-2008.

A recent paper (Huang et al. 2025) suggests that the supply curve for FX liquidity is steeper between 2014 and 2022. The paper proposes two liquidity cost measures based on the triangular no-arbitrage condition and controlling for FX volume to show that in times when the dealer is constrained (VaR reaches risk limits or funding costs are higher), the relationship between FX volume and cost of providing liquidity becomes weaker. The important difference between this paper and ours is that, first, we do not rely on CLS data but on OTC bilateral volumes from two of the largest FX dealers.

Second, we cover a much longer period that spans before and after 2008, and the main objective of our study is not to conduct a systematic analysis of the FX liquidity but rather to study the

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

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

predictability content of the FX dollar volume. Crucially, we study the relevance of FX (dollar) balance sheet costs, but the focus of our paper is on equity holders' incentives. That is, we show that the slope of the dollar supply curve can be interpreted as a shadow cost for banks' equity holders when providing dollar immediacy. We shall discuss this in greater details in the next sections.

It is important to note that the FX data set used in this paper originates from two of the largest FX dealers. Their balance sheets are the primary source of US$ liquidity as they intermediate a significant share of FX volume every day. Therefore, 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 the example of FX volatility again 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., 2018a), macroeconomic factors, or dash for cash, as during the 2008 financial crisis and COVID-19. The inelastic supply of US$ can instead be related to different factors, for example, dollar funding costs (Du et al., 2018b). Therefore, the demand for US$ liquidity (in bilateral and also interdealer market) is expected to increase with volatility. When volatility increases, higher demand for the 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 on dollar returns. This introduces shareholders incentives to supply dollars. We that this mechanism drives the predictive information of the FX volume post-2008.

Our mechanism does not exclude asymmetric information. Asymmetric information is also consistent with the (demand-side) theory discussed in the next sections, where dealers and leveraged clients trade in the bilateral FX market.

Balance sheet costs, post-2008, have increased, and, as a consequence, the renting to provide US$ liquidity, especially during shocks, has also increased. There is a large amount of recent literature in different markets supporting this argument. These balance sheet costs create a sort of debt overhang (Myers, S. C., 1977; Andersen et al., 2019). This cost steams from a lach of incentives to provide immediacy, particularly during stress. And it is related to higher funding costs post-2008 (Berndt et al. (2024)).

Higher funding costs have exacerbated capital structure frictions, for example debt overhang. For example, the Dodd-Frank Act in the US, may have contributed to this situation [5]. In this paper, we show that these sort of frictions can also have a significant impact on the intermediation US$ spot FX liquidity (Du et al., 2023; Anderson et al., 2019).

In a spot FX bilateral market, from the FX dealer's side, the intermediation of spot OTC dollar is very similar to the intermediation of a (dollar)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 higher 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).

4.1 *Balance Sheet Constraints and Debt Overhang*

In this section we focus on debt overhang and explain how it relates to the balance sheet of an FX dealer trading bilaterally with a client. We use debt overhang in the Myers marginal-incentive sense. As we shall discuss in this section, the periods we study in this paper are periods where the equity of the banks was already low, and debt overhang was high.

Consider the simplified balance sheet in Figure 11. We assume that the FX dealer has US$ lending on one side of the balance sheet and US$ borrowing on the other side. This could represent 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,

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

especially in times of shocks, to search for the necessary liquidity to meet clients' demands. However, given the stiffness of (internal and external) capital at times of market turmoil, dealers will try to run a matching book with clients as much as possible as a way to reduce the consumption of capital. [6]

Suppose that following an exogenous 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 accommodate the demand, dealers will need to commit their own capital. However, generally, they are reluctant to do so to support the liquidity, particularly when their capital is already lower. For example, for the Treasury market, Duffie et al. (2023) show that dealers post large bids and ask prices to recover these costs or as a way of not being hit by customer flows. Adrian et al. (2017) make a similar case but relate it to higher regulatory capital after 2008.

This situation introduces debt overhang costs and it can drive the slope of the US dollar supply curve (see Figure 12 (a,b)). In this situation, given the increase in demand and inelastic supply, the supply curve for US dollars becomes steeper, and the exchange rate appreciates. 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.

In this paper, we show that it is the slope of the supply curve for dollars post-2008 that is driving the predictability of the FX volume. 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. The empirical results in recent papers (for example, Huang et al., 2025) are also consistent with this, although those papers do not focus on and study this novel mechanism based on shareholders' incentives.

Note that in this paper, we use the term debt overhang broadly to capture the idea that, when equity is scarce, dealers face an elevated shadow cost of balance-sheet expansion, even absent

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

binding regulatory constraints. Therefore ours is a capital structure friction driving the supply curve rather than a binding constraint as in the literature. In the empirical analysis, we shall distinguish this mechanism from generic funding stress by exploiting variation in dealer CDS spreads and the timing of balance-sheet shocks.

4.2 *Motivating Evidence*

Is debt overhang relevant during the period we study in this paper? In this section we present and discuss evidence in support of debt overhang. 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 intermediaries' financial frictions is also supported empirically and theoretically in Adrian et al. (2015), He et al (2017), only to cite a few. Larger leverage corresponds to times when equity capital is lower, and, therefore, the marginal utility of the wealth of the dealer is higher (balance sheet constraints following debt overhang). See also the discussion in Burnside et al. (2025a) and He et al. (2017). According to 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 [7]. 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 dealers' leverage before and after the COVID-19 shock in 2020. We observe a very similar picture. Leverage peaked sharply 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). This cost can be proxied by the dealer's credit spread. Cerrato and Mei (2025) use a balance sheet model to motivate it.

Burnside and Cerrato (2025b) proxy debt overhang cost related to FVA when studying Covered Interest Rate Parity (CIP), using the 5-year CDS spreads of the 12 largest dealer banks.[8]

To dive deeper into our discussion above, we follow Burnside and Cerrato (2025b), 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 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 market-based proxy.

The picture emerging from Figure 2 is consistent with Figure 1. Debt overhang cost stemming from funding costs is significantly higher during the period we study in this paper. It was very small before 2008, but it has increased sharply starting from 2008, and again in 2009 and remained higher since then. As documented in Burnside and Cerrato (2025b), and Andersen et al (2019), the increase in dealers' debt overhang has had a significant impact on arbitraging Covered Interest

[7] Leverage may also be affected by the equity injection in banks starting in 2009.

[8] 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 manipulate 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.

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 studied in this paper.

Since we have granular data on the FX volume for the first dealer, we dive deeper into 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 supplies dollar liquidity at any given level of dollar demand. This suggests that (unconstrained) dealers were able to accommodate the dollar demand with only a modest impact on dollar liquidity and the exchange rate. However, the 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 dollars 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, Kottimukkalur (2019) makes this case to explain the presence of arbitrage opportunities due to supply side constraints.

Figure 5 shows (the cross-sectional average) 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 the bid-ask spread in Figure 5 are also consistent with higher balance sheet frictions. As explained by Anderson et al. (2019) and Cerrato and Mei (2025), in the presence of debt overhang, dealers will need to extract some "donations" 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 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.

The evidence in this section would suggest that debt overhang has been persistent during the period we study in this paper, and it could be a plausible explanation for the dynamics observed in our data. We conjecture that this supply-side constraint 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.

4.3 *Debt Overhang and 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 set a baseline 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 the demand for US dollars. We employ a set of fixed effects and control for variables which generally correlate 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)[9]

The bank's CDS spread is a direct and relevant proxy measure of debt overhang cost arising from debt (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., 2025). When the spread is larger, the 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, LIBOR-OIS) and form two groups: larger (smaller) CDS spreads (leverage). We associate this with a 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 the controls we have

[9] While the focus in Cespa et al. (2022) is on the interaction coefficient term as their model suggests that asymmetric information directly affects it, and they employ FX trading strategies, the focus of our paper is on the 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 is already reported in Table 5.

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). The dollar FX volume does contain predictive information, but only conditionally to higher debt overhang. This suggest that the predictive content of the FX volume stems from the supply side. Recently, Huang et al (2025) make a similar case for the FX spot liquidity. Our results are in line with theirs. They are also in line with Kloks et al. (2023), although that paper focuses mainly on the effect of dealers' constraints on the 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 that unconditional estimates of the beta coefficient and volume are insignificant, and the coefficient is much smaller in size than the conditional ones.

In Appendix B, 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 Online Appendix E, we also control for the dealer order flow. We do not show the estimated coefficient on the order flow, but they are all statistically insignificant. The overall results stay unchanged.

The results in this section suggest that dollar volume can predict dollar returns but only when debt overhang is significant. This evidence is consistent with the motivation discussed in Figure 11 and Figure 12. Debt overhang induces a change of the slope of the supply curve for dollar lending. Note that debt overhang does not imply a monotonic effect on aggregate FX volume. Instead, as we should discuss, it can alter how quantity pressure is accommodated, affecting the price impact of trades rather than mechanically reducing trading activity.

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. (2021), Kekre & Lenel (2024)) [10]

Given that, the intermediaries in this paper are also the largest players in the interdealer

[10] 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. (Krohn and Sushko (2022)).

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 studied, 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 we observe 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.

5 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 leveraged investors, while Panel B shows the results for Real Money, and Panel C shows 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 above its longer-term median, and less than one, means the opposite.

The results in Table 6[11] 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 is 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).

[11] In April 2020, the U.S. FED implemented a very large asset program purchase (QE) in response to the financial market turmoil following the COVID. Appendix D shows the same results when the period of the FED intervention has been dropped. As we can see, we obtain even stronger results in this case

6 Core Empirical Results / Supply Curve Evidence

In this part, we firstly do the regression according to equation (6), and then calculate the Marginal effect of Volume on log return (varying with CDS).

$$r_{it} = \beta_1 r_{i,t-1} + \beta_2 nv_{i,t-1} + \beta_3 \left(nv_{i,t-1} \times CDS_{i,t-1}\right) + \boldsymbol{\delta}' Control_{it} + \gamma_c + \varepsilon_{it} \tag{6}$$

$$\frac{\partial r_{it}}{\partial nv_{i,t-1}} = \beta_2 + \beta_3\, CDS_{i,t-1} \tag{7}$$

7 Mechanism and Identification: Supply Curve Steepening

The results so far show that FX spot dollar volume predicts exchange rate movements only when dealer balance sheets are impaired. While this evidence is consistent with a supply-side mechanism, it does not by itself distinguish between alternative channels through which balance-sheet stress could affect prices. In this section, we provide direct evidence on the mechanism underlying our main findings and clarify the source of identification. We show that the predictive content of FX volume arises from equity-holder pricing incentives associated with debt overhang. Empirically, that means that the same quantity pressure (high volume) moves prices more precisely around constraint shocks (large Δ CDS) and especially in the joint state (high constraints $\times$ high demand/pressure). This is the mechanism driving our empirical results and illustrated by our theoretical model.

We use changes in dealer CDS spreads to identify shocks to balance-sheet tightness that are plausibly exogenous to contemporaneous FX volume. CDS spreads reflect the market valuation of the intermediary's default risk and funding costs, and therefore the severity of debt overhang borne by equity holders (see Andersen et al, 2019; Cerrato and Mei 2025). Unlike measures of trading activity or volatility, CDS spreads respond directly to changes in the relative claims of creditors and equity, making them a theoretically motivated proxy for the private marginal cost of balance-sheet expansion.

We define CDS change:

$$\Delta CDS_{i,t} = CDS_{i,t} - CDS_{i,t-1}. \tag{8}$$

We use CDS spreads to capture shocks to dealer balance-sheet tightness. We interpret changes in CDS spreads larger than one as an unexpected worsening in the dealer's effective marginal cost of balance-sheet expansion. This is the timing ingredient for the event study in this section.

We also introduce a stress event indicator:

$$Shock_{i,t} = \mathbf{1}\big(\Delta CDS_{i,t} \geq Q90\big(\Delta CDS_i\big)\big)\,, \tag{9}$$

The indicator focuses on extreme tightenings where steepening should be most visible.

Second Step: We define the joint state. Joint equals 1 when both the balance sheet constraint (in our case, debt overhang) and trading pressure are high:

$$Constraint_{i,t} = \mathbf{1}(CDS_{i,t} \geq Q50(CDS_i)) \tag{10}$$

The shock date tells us when something happened, but the steepness depends on how tight conditions are. The supply curve is expected to be steeper when constraints are high, not necessarily whenever there's a one-off change.

$$Demand_{i,t} = \mathbf{1}(Volume_{i,t} \geq Q75(Volume_i)) \tag{11}$$

This captures periods when fx dollar demand is significantly high.

$$Joint_{i,t} = Constraint_{i,t} \times Demand_{i,t} \tag{12}$$

Finally, in line with our earlier empirical results, we define the joint-state.

To make dynamic price adjustments around stress events visible, we estimate stacked event-time regressions. Let e index events and τ time (in days or weeks) around stress events.

Define a time dummy:

$$D_\tau = \mathbf{1}(t - t_e = \tau) \tag{13}$$

Equation (14) compares how prices behave around balance-sheet stress events. We first identify moments when dealer balance-sheet conditions suddenly worsen (large CDS increases). Around each such moment, we line up returns in event time. Then we split observations into two groups: (i) periods when trading pressure is high, and balance sheets are already tight, and (ii) all other periods. Equation (14) estimates two average return paths around the same type of shock one for each group, while absorbing any shock-specific or currency-specific effects. If the FX supply curve steepens under balance-sheet stress, prices should move more after the shock only in the first group. That difference in post-shock behaviour is evidence for supply-curve steepening. This event study will help us to identify that when the marginal cost of expanding dealer balance sheets rises, dealer CDS spread rises, which is consistent with our debt overhang mechanism and our model.

$$r_{i,e,\tau} = \sum_{\tau \neq -1} \beta_\tau^{Joint} D_\tau \times Joint_{i,e} + \sum_{\tau \neq -1} \beta_\tau^{Other} D_\tau \times (1 - Joint_{i,e}) + \alpha_i + \delta_e + \varepsilon_{i,e,\tau}. \tag{14}$$

Where:

- $\tau = -1$ is omitted as the reference pre-event period;
- α_i are currency fixed effects;
- δ_e are event fixed effects.

Figure 7 plots FX returns in event time around large CDS increases (balance-sheet stress shocks), separately for High CDS $\times$ High Volume (joint state), and

all other states. Therefore results show that prices move more only after stress shocks are combined with higher volumes. The results show that there are no pre-trends in either group, and we observe a sharp and economically large post-event price response only in the joint state. Little or no response outside the joint state. This figure provides direct dynamic evidence of supply-curve steepening. Prices move only when balance-sheet stress coincides with strong quantity pressure.

This is exactly what a steep supply curve implies: prices respond strongly to quantities only when the marginal cost of intermediation is high. Crucially, the absence of pre-trends rules out anticipation, gradual information diffusion, or slow-moving risk premia.

Figure 7 shows that supply-curve steepening bites when trading pressure is high during COVID. Evidence on the composition of that pressure is provided in Figures 13 and 14 in Appendix A.1.

Figure 8 shows that non-leveraged client volume is also associated with price responses during COVID stress events, though differences in persistence become clearer in online-Appendix Figures 13 and 14

Finally, while Figures 7 and 8 show that high trading pressure during COVID balance-sheet stress is associated with FX price responses for both client types, Figures 13 and 14 in Appendix A.1 reveal that these responses are more persistent and economically larger when trading pressure originates from leveraged clients.

Figure 18 in the online-Appendix shows the results during the 2008 financial crisis. These are in line with what we have already discussed regarding the COVID-19 period. Figure 19 report a placebo test suing data between 2003-2007. Clearly, the strong empirical evidence reported for the 2008 financial crisis and the COVID-19 shock disappears.

In Figures 15-17, we now focus on the slope of the fx supply curve. We use equation 6 to estimate the key parameters, and thereafter equation 7 and CDS spreads data, to estimate the slope of the supply curve. Finally, we plot the marginal effect. On the y-axis, we show the price impact per unit of volume (the supply-curve slope). Differently than before, here the analysis shows the same mechanism but in averages, not around events as above.

In Figure 15, we use the volume sample over the 2008 Global Financial Crisis. FX trading volume here is aggregate dealer FX volume (no client breakdown). During the 2008 crisis (but also during the 2011-2012 euro-area sovereign debt crisis), FX volume had a much larger price impact when dealer balance-sheet stress (CDS) was higher.

Figures 16 and 17 show that during periods of very high dealer CDS, such as the COVID episode, FX trading volume from both leveraged and non-leveraged clients is associated with similarly large price impacts.

8 Demand for US Dollars

In this section we focus now on the demand side and consider the interplay between the supply friction discussed earlier and the demand for dollars. This interplay is key to explain the positive estimated (interaction) coefficient on FX volume. This is also in line with the results reported in the previous section.

To dive deeper into this, we present three distinct event studies in the online Appendix G. Two of them relate to the two shocks we study in this paper (2008 financial crisis in panel b and COVID-19 in panel c), while the third one relates to the 2003 oil shock, panel a. Clearly post-2008 there is a positive and strong correlation between surge in FX volume and balance sheet constraints as proxied by the 5 year CDS of the largest 6 US and 6 European banks. Therefore, following the shock, FX volume surges and the dealer balance sheet constraint tightens. In this situation, the dollar appreciates.

Before 2008, the correlation between FX volume and dealers' balance sheet constraints flips in sign, becoming negative. This result, together with the evidence from Figure 3 and Figure 4, would suggest that before 2008, the dealer could accommodate the surge in demand with less impact on price.

As suggested by our model, leveraged customers prefer trading with dealers whose capital is higher (debt overhang is lower), while flows from non-financial customers are not related to the capital of the dealer. There is abundant literature in FX microstructure showing that non-financial customers trade with the dealers for different reasons, and they provide dollar liquidity to the market (Cerrato et al.,2011; Menkhoff et al.,2012; Burnside et al.,2025a).

In the rest of this section, we dive deeper into the way the dealer and clients trade in the bilateral market, focusing on the demand side. In line with the evidence in the Online Appendix G, we now present evidence suggesting that during the period we study in this paper, the demand of US dollars has been also significantly higher. We focus on two large shocks (the 2008 financial crisis and COVID-19) covering our sample period. The combination of higher demand for dollars and constrained dealers would explain the empirical results in Table 5 and Table 6 (and consistent with Figure 12).

In Figure 9 (a,b) and Figure 10 (a,b), we plot the cumulative (aggregate and disaggregate) order flows of the two dealers. Negative flows suggest a larger demand for dollar liquidity. Clearly, there is a significant demand for dollars. The increase in demand for the dollar arises mainly from financials, while non-financials (especially during COVID-19) take the opposite side. Given that the dealer is balance sheet constrained (supply side constraints), she will have to trade with clients in a way that attracts foreign flows to match dollar ones.

Du et al(2018b), and other recent papers (see, for example, Krohn and 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, such as the Treasury market (Duffie, 2010). Leveraged clients prefer to trade with dealers with lower debt overhang costs (i.e. lower funding costs in our case), as they can obtain better quotes from these ones.

Based on recent empirical evidence (for example Du et al, 2018b), we conjecture (and our model explains this) that the dealer's capital plays an important role (amongst other things) for the dollar market. Dealers with higher levels of capital (or lower leverage) are better positioned to match their clients' dollar demand. 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 for dollars from clients. This is what our model would suggest. However, we can still study the time series effect of dollar flows from clients and dealer leverage (or capital).

We do this in Table 9. We study if changes of the capital of the dealer can predict change of her own 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. In Table 9, we use quarterly data as we wish to match the flows of our dealer with its balance sheet data. We do not have daily balance sheet data for this dealer. We collect balance sheet data for our second dealer from Bloomberg and construct the He et al (2017) measure of leverage to match the flows data of this dealer.

Table 9 shows the empirical results. Results in (1)-(3) refer to the flows across different segments (aggregate, Financial, Non-Financial). Leverage refers to the leverage of the second 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 9 suggest that changes in leverage predict subsequent changes in dollar flows. Leveraged clients prefer trading with dealers whose capital is higher (debt overhang in lower). For example, note that the predictability of the leverage arises from financial clients, while it is insignificant for non-financials. This suggests that price-sensitive customers are important, as it is the demand for dollars arising from this segment that have a significant price impact on the dealer balance sheet.

The demand-side evidence in this section is in line with the earlier event studies showing that FX prices respond precisely during periods in which dollar demand, especially from financial clients elevated and balance-sheet stress is high, while no such responses appear when these demand patterns are absent.

9 Model: FX Spot Intermediation with Debt Overhang and Capital-Dependent Demand

Time is discrete. $t = 0, 1, 2.....$The dealer intermediates USD vs foreign currency spot trades across currency pairs indexed by $i \in 1, ..., N$. Let $P_{i,t}$ denote the USD price of one unit of foreign currency i at time t.

The dealer faces two frictions:

Equity holders maximise their own continuation value; they do not internalise creditor gains: when the dealer expands its gross balance sheet, part of the marginal surplus from intermediation accrues to existing creditors, so equity holders face a private marginal cost of balance-sheet expansion. This incentive distortion operates through pricing and is present even when balance-sheet constraints do not bind Andersen et al, 2019). Therefore the key friction in our model is not merely a binding balance-sheet constraint, but an incentive distortion faced by equity holders. When the dealer expands its balance sheet to intermediate FX trades, part of the resulting surplus accrues to existing creditors. Equity holders do not internalize these creditor gains and therefore require compensation to expand intermediation. This generates a debt-overhang wedge that directly affects quoted prices. It turns that, this wedge can be present even when regulatory or leverage constraints are slack, and should be interpreted as a pricing distortion rather than a hard constraint on quantities

Second, client-side market frictions on the demand side: the mass of price-sensitive clients reaching the dealer depends on the dealer's capital position, reflecting slow-moving capital and OTC competition (Duffie, 2010).

We model the dealer as the marginal price setter in a bilateral OTC market.

Demand Side

Let per-client demand for USD liquidity in currency i be $d_{i,t}(P_{i,t})$, with

$$\frac{\partial d_{i,t}(P_{i,t})}{\partial P_{i,t}} < 0 \tag{15}$$

higher USD price (a worse quote for the client) reduces the demanded quantity.

Let the mass of price-sensitive clients reaching the dealer be $m_{i,t}(K_{t-1})$, with

$$\frac{\partial m_{i,t}(K_{t-1})}{\partial K_{t-1}} > 0 \tag{16}$$

better-capitalized dealers offer better expected execution or quotes and therefore attract more client flow (tight OTC competition; Duffie slow-moving capital).

Total dealer demand is

$$D_{i,t}(P_{i,t}, K_{t-1}) = m_{i,t}(K_{t-1})\, d_{i,t}(P_{i,t}) \tag{17}$$

and thus

$$\frac{\partial D_{i,t}}{\partial P_{i,t}} < 0, \qquad \frac{\partial D_{i,t}}{\partial K_{t-1}} > 0 \tag{18}$$

Supply Side

Let $X_{i,t}$ denote the gross amount of intermediation in currency i (in foreign currency units), so the USD notional is $P_{i,t}X_{i,t}$. Intermediation expands gross assets and gross liabilities even if the dealer "matches" economically (net risk may be small, but the gross balance sheet still grows).

Write the dealer's gross assets as

$$A_t = R_t^A A_{t-1} + \sum_{i=1}^{N} P_{i,t}X_{i,t}, \tag{19}$$

and gross liabilities as

$$L_t = R_t^L L_{t-1} + \sum_{i=1}^{N} F_t X_{i,t} \tag{20}$$

F_t is the USD funding needed per unit of $X_{i,t}$. $P_{i,t}X_{i,t}$ is the dealer's USD asset exposure created by buying or selling foreign currency; $F_t X_{i,t}$ is the associated funding requirement on the liability side.

Define equity capital as

$$K_t \equiv A_t - L_t \tag{21}$$

A minimal leverage (balance-sheet) constraint is

$$K_t \geq \underline{K}_t \tag{22}$$

where $\underline{K}_t$ can be interpreted as a minimum equity buffer. This follows the logic of predetermined capital as in Admati et al (2018).

$\underline{K}_t$ can also be interpreted as the inelastic USD supply constraint. After a negative shock, K_{t-1} falls closer to $\underline{K}_t$, making the constraint bind more often.

It is useful to distinguish this feasibility constraint from the mechanism that drives pricing in the model. The constraint above limits how far the dealer can expand its balance sheet, as in standard balance-sheet-constraint models. By contrast, debt overhang operates through equity-holder incentives: when equity is scarce, expanding intermediation transfers value to creditors, so equity requires compensation and adjusts prices accordingly. As a result, balance-sheet constraints determine whether intermediation is feasible, while debt overhang determines how intermediation is priced.

We now define an endogenous shadow funding wedge that captures the equity-holder cost of expanding the balance sheet when the dealer is levered.

Let the dealer face an effective equity-holder funding cost:

$$\widetilde{F}_t = F_t + \phi_t, \tag{23}$$

where $\phi_t \geq 0$ is the debt-overhang wedge: the private marginal cost (for equity) of raising one more unit of funding.

When new funding is raised, part of the benefit accrues to existing creditors, so equity requires compensation. This reduces the equity-relevant margin. affecting the price even when the shadow cost of capital is zero. This is explicitly motivated by creditor wealth transfers (Andersen et al, 2019).

Now impose that ϕ_t is increasing as equity becomes scarce (high leverage / low K):

$$\phi_t = \phi\left(\frac{L_t}{A_t}, K_t\right), \qquad \frac{\partial \phi}{\partial (L/A)} > 0, \qquad \frac{\partial \phi}{\partial K} < 0 \tag{24}$$

when leverage is higher (or capital lower), debt overhang is more severe, and the wedge is larger. This corresponds to the common implication of Admati and Andersen: equity scarcity creates a private wedge. Empirically, we approximate this using leverage, CDS spreads, or LIBOR–OIS.

Using (19)–(20) and (21), capital evolves as

$$K_t = R_t^A A_{t-1} - R_t^L L_{t-1} + \sum_{i=1}^{N} \big(P_{i,t} - F_t\big) X_{i,t} \tag{25}$$

Alternatively, if one wishes to embed the debt-overhang wedge directly into capital accumulation from an equity perspective, we can replace F_t with $\widetilde{F}_t$:

$$K_t = R_t^A A_{t-1} - R_t^L L_{t-1} + \sum_{i=1}^{N} \big(P_{i,t} - \widetilde{F}_t\big) X_{i,t} \tag{26}$$

The term $\big(P_{i,t} - \widetilde{F}_t\big)X_{i,t}$ is the equity-relevant intermediation margin. When ϕ_t rises, the effective margin shrinks, making USD provision "more expensive" in equilibrium.

Define period-t intermediation profit as

$$\pi_t \equiv \sum_{i=1}^{N} \big(P_{i,t} - F_t\big)X_{i,t} \tag{27}$$

Alternatively, one can also consider profits net of the debt-overhang wedge (equity valuation relevant):

$$\pi_t^E \equiv \sum_{i=1}^{N} \big(P_{i,t} - \widetilde{F}_t\big)X_{i,t} = \pi_t - \phi_t \sum_{i=1}^{N} X_{i,t} \tag{28}$$

ϕ_t is the private shadow cost (FVA-like) that equity requires to expand gross intermediation.

The dealer maximises equity value:

$$J_t = \pi_t^E + \mathbb{E}_t[M_{t+1}J_{t+1}]\,, \tag{29}$$

where M_{t+1} is a stochastic discount factor (SDF).

Equitmediation.

The dealer sets quotes $P_{i,t}$. Client demand determines quantities:

$$X_{i,t} = D_{i,t}(P_{i,t}, K_{t-1}) \tag{30}$$

The dealer is choosing price; quantity is the demand response. This makes the model directly interpretable as a supply curve (price as a function of quantity pressure).

The dealer also must satisfy the capital constraint (22), where K_t depends on $\{P_{i,t}, X_{i,t}\}$ through (26).

The dealer chooses $\{P_{i,t}\}_{i=1}^N$ to maximize (29) subject to (30) and the capital constraint (22), with capital given by (26).

The period-t Lagrangian is:

$$\mathcal{L}_t = \pi_t^E + \mathbb{E}_t[M_{t+1}J_{t+1}] + \lambda_t\big(K_t - \underline{K}_t\big), \qquad \lambda_t \geq 0 \tag{31}$$

λ_t is the tightness of the balance-sheet constraint. When $\lambda_t > 0$, the dealer prices with a binding scarcity of capital.

After differentiating with respect to $P_{i,t}$, and using that $X_{i,t} = D_{i,t}(P_{i,t}, K_{t-1})$, so

$$\frac{\partial X_{i,t}}{\partial P_{i,t}} = \frac{\partial D_{i,t}}{\partial P_{i,t}} < 0, \tag{32}$$

the first-order condition with respect to $P_{i,t}$ is

$$\frac{\partial \mathcal{L}_t}{\partial P_{i,t}} = \frac{\partial \pi_t^E}{\partial P_{i,t}} + \frac{\partial}{\partial P_{i,t}} \mathbb{E}_t[M_{t+1} J_{t+1}] + \lambda_t \frac{\partial K_t}{\partial P_{i,t}} = 0 \tag{33}$$

Using now the continuation-value part in the Lagrangian, and noting that the continuation value depends on today's capital, the chain rule implies

$$\frac{\partial}{\partial P_{i,t}} \mathbb{E}_t[M_{t+1} J_{t+1}] = \mathbb{E}_t\left[M_{t+1} \frac{\partial J_{t+1}}{\partial K_t}\right] \frac{\partial K_t}{\partial P_{i,t}} \tag{34}$$

Plugging (34) into (33) yields

$$\frac{\partial \pi_t^E}{\partial P_{i,t}} + \left(\lambda_t + \mathbb{E}_t\left[M_{t+1} \frac{\partial J_{t+1}}{\partial K_t}\right]\right) \frac{\partial K_t}{\partial P_{i,t}} = 0 \tag{35}$$

Define the effective shadow value of capital as

$$\bar{\lambda}_t \equiv \lambda_t + \mathbb{E}_t\left[M_{t+1} \frac{\partial J_{t+1}}{\partial K_t}\right] \tag{36}$$

Even if the contemporaneous constraint is slack ($\lambda_t = 0$), equity may still value capital because it relaxes future distortions (under-intermediation). This is also in line with Admati et al (2018). Thus, $\bar{\lambda}_t$ is forward-looking. It reflects equity scarcity and could also exist even without creditor-equity conflict. The shadow value of intermediary capital arises as a state variable because capital is scarce relative to risk-bearing needs (He et al, 2022). In this paper, we interpret it also as a measure which captures the marginal value of balance-sheet capacity from the perspective of equity holders, incorporating both current funding conditions and anticipated future constraints. In this sense, the shadow cost, in our case, reflects an intertemporal debt-overhang cost: expanding intermediation today reduces the equity value of future opportunities by tightening expected balance-sheet conditions. This forward-looking incentive channel is important for our interpretation.

After solving for the shadow cost, rearranging (35) gives

$$\bar{\lambda}_t = -\frac{\dfrac{\partial \pi_t^E}{\partial P_{i,t}}}{\dfrac{\partial K_t}{\partial P_{i,t}}} \tag{37}$$

This is your shadow-cost formula.

To connect our empirical price impact per unit volume, we want the relation between the chosen quote $P_{i,t}$ and quantity $X_{i,t}$. Using $X_{i,t} = D_{i,t}(P_{i,t}, K_{t-1})$, and inverting locally,

$$P_{i,t} = S_{i,t}\big(X_{i,t}; K_{t-1}, \phi_t, \bar{\lambda}_t\big)\,, \tag{38}$$

where $S_{i,t}$ is the dealer's effective supply curve.

Note that

$$\frac{\partial P_{i,t}}{\partial X_{i,t}} \text{ increases when } \bar{\lambda}_t \text{ increases and/or } \phi_t \text{ increases} \tag{39}$$

When capital is scarce (high $\bar{\lambda}_t$) or when debt overhang is severe (high ϕ_t), the dealer requires a larger price concession per unit of intermediation, generating a steeper supply curve. Therefore, during stress, volume can rise while constraints tighten. Our model rationalises this through a combination of a higher debt-overhang wedge pushing prices up, a negative shock shifting $d_{i,t}(\cdot)$ and increasing quantities, and capital-dependent matching $m_{i,t}(K_{t-1})$, which can amplify reallocation across dealers.

Formally, a crisis demand shift can be represented as a parameter θ_t entering per-client demand:

$$d_{i,t}(P) = d_i(P;\theta_t)\,, \qquad \frac{\partial d_i}{\partial \theta_t} > 0 \tag{40}$$

Then, even if ϕ_t rises, $X_{i,t}$ can increase if θ_t rises sufficiently.

10 Discussion on the Model

This section discusses how the model helps interpret the empirical findings and clarifies its relationship to the balance-sheet literature, with particular emphasis on the distinction between balance-sheet tightness, the shadow cost of capital, and equity-holder debt overhang.

Large negative shocks such as the Global Financial Crisis and the COVID-19 episode substantially reduced dealer equity, pushing intermediaries into states of elevated leverage and capital scarcity. In the model, this state is summarised by a higher shadow value of capital, reflecting the increased value of balance-sheet capacity when equity is scarce. This captures the balance-sheet tightness emphasised in the existing literature and describes the state of the intermediary following adverse shocks.

Debt overhang then operates as the mechanism through which this state affects pricing. When equity is scarce, expanding the dealer's gross balance sheet transfers value to existing creditors, so equity holders internalise a private marginal cost of intermediation. This debt-overhang wedge enters directly into pricing decisions and steepens the dealer's supply curve for dollar liquidity. Importantly, this mechanism can operate even when minimum-capital constraints do not bind, implying that balance-sheet stress need not result in quantity rationing. Instead, intermediation can continue at higher prices, generating larger price impact and sharp exchange-rate movements.

This distinction helps reconcile our empirical findings with the balance-sheet literature. Standard balance-sheet-constraint models often predict reduced intermediation or market shutdowns when constraints tighten. In contrast, our model predicts continued trading accompanied by worse prices. This prediction aligns closely with the behaviour of FX markets during stress episodes, where trading volume remains elevated while dollar funding becomes increasingly expensive.

Figures 8 and 9 provide direct empirical support for the demand-side frictions embedded in the model. Following large shocks, demand for U.S. dollars rises sharply and remains elevated for several weeks, consistent with slow-moving, price-sensitive client demand in OTC markets. Moreover, the composition of flows differs across client types, indicating that dollar demand is concentrated among clients that are particularly sensitive to execution quality and dealer balance-sheet conditions. In the model, this capital-dependent demand interacts with the steepened supply curve generated by debt overhang, amplifying price impact and contributing to persistent exchange-rate dynamics.

Overall, the model clarifies how balance-sheet stress-summarised by the shadow cost of capital-translates into exchange-rate movements through an equity-holder debt-overhang pricing mechanism. By shifting attention from intermediation capacity to the pricing of liquidity when equity is scarce, the model complements the balance-sheet literature and provides a unified interpretation of both the supply- and demand-side dynamics observed in the data.

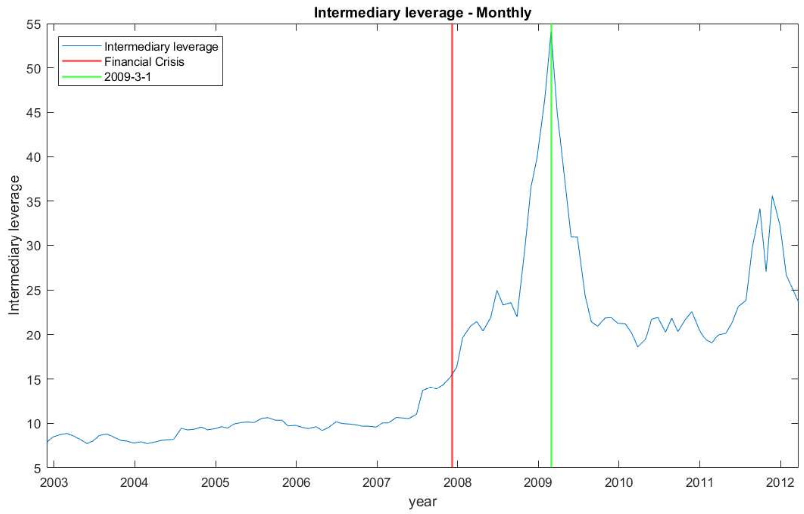
11 Conclusion

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 (i.e. surge in demand of dollars), in combination with debt overhang cost (Myres(1977), Andersen et al (2019)) lead to an appreciation of the dollar vis-a-vis the other currencies. The dealer faces a shadow cost to supply extra dollars, which is related to the dollar supply curve.

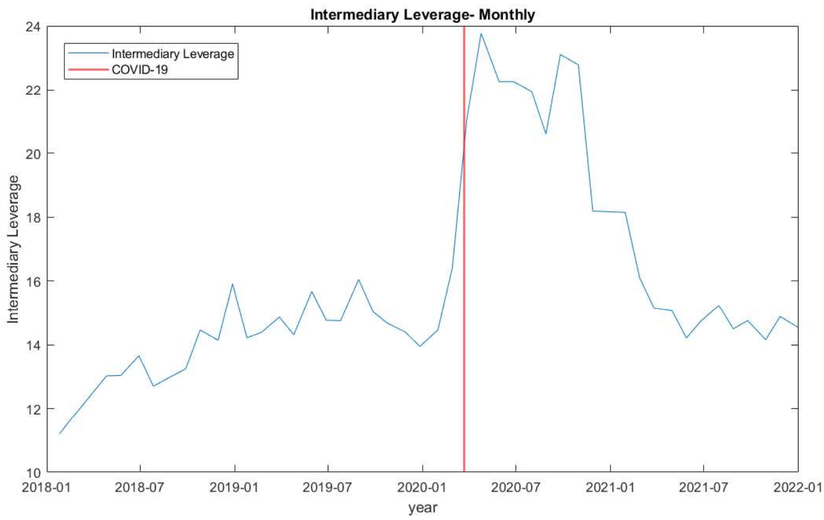
We do not fully exclude leverage ratio requirements (LRR) as an additional explanation, but we point out that LLR is only the tip of the iceberg as additional and more persistent forces may be at work. The scope of this paper is to study debt overhang costs stemming from dollar funding costs in greater detail relaying on novel proprietary FX data spanning a long period before and after 2008, for several currencies.

Figure 1: Intermediary Leverage

(a) Financial Crisis - Monthly



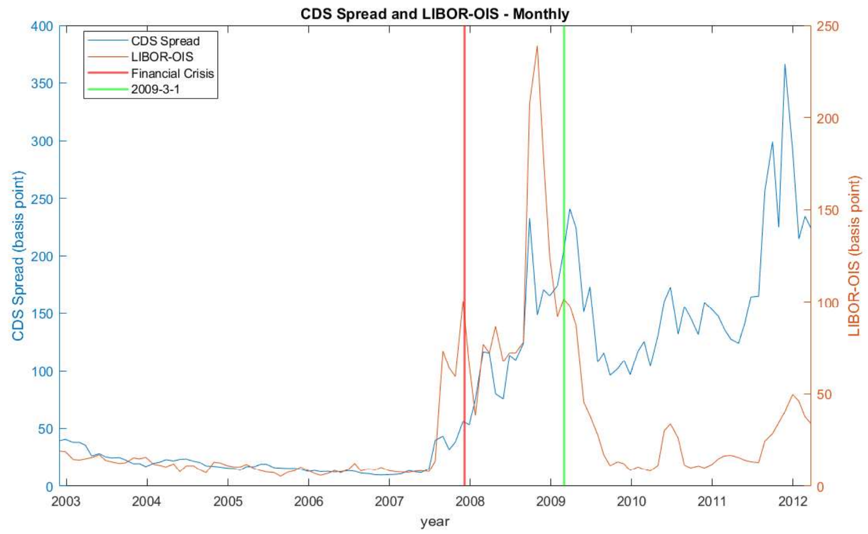
(b) Covid-19 - Monthly



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).

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

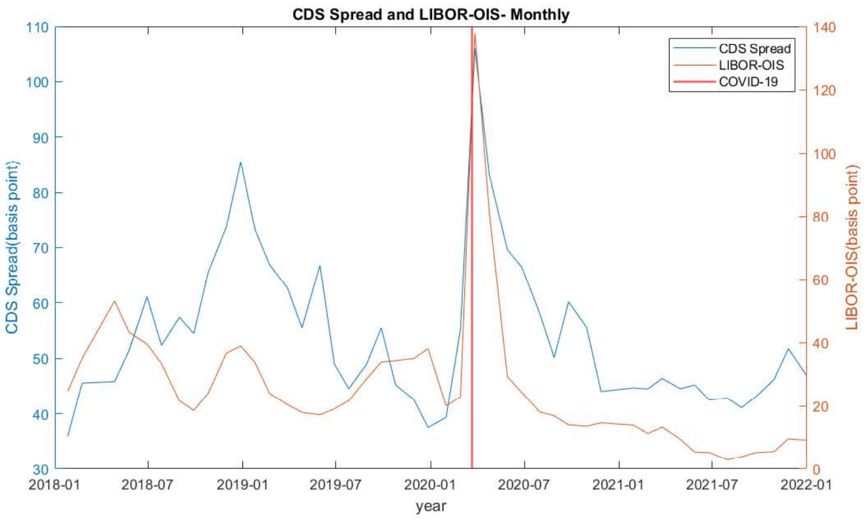
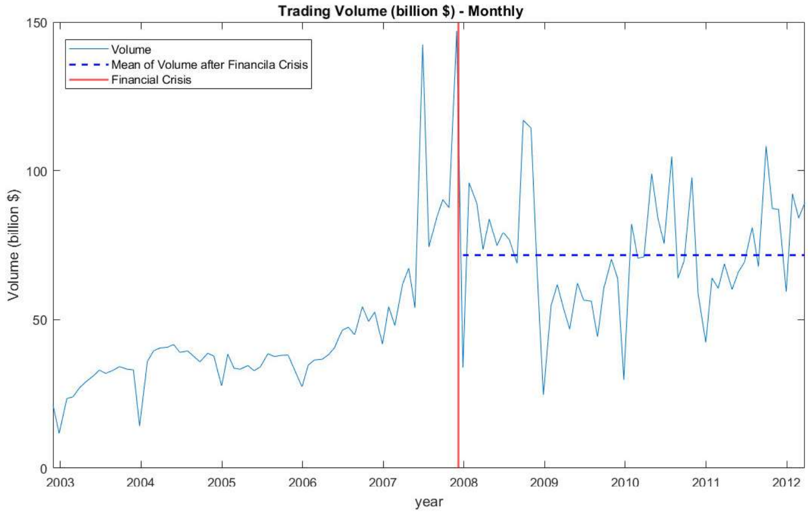


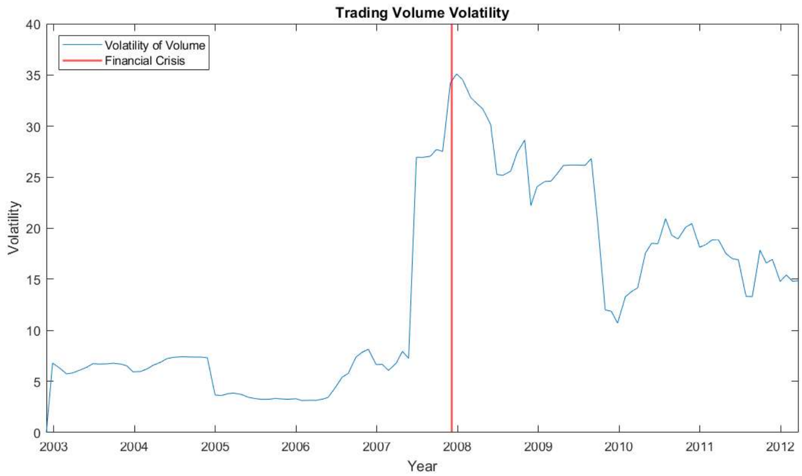
Figure 2 plots the average cross-sectional CDS spread of the largest six US and six European banks, as well as the three-month LIBOR minus OIS spread, as an alternative market-based proxy.

Figure 3: Volume



In Figure 3, we plot the trading volume data by using the first dealer's data which uses the sample from 2003 to 2012.

Figure 4: Volatility of Volume



In Figure 4, we show the volatility of trading volume in Figure 3.

Figure 5: Bid-Ask Spread

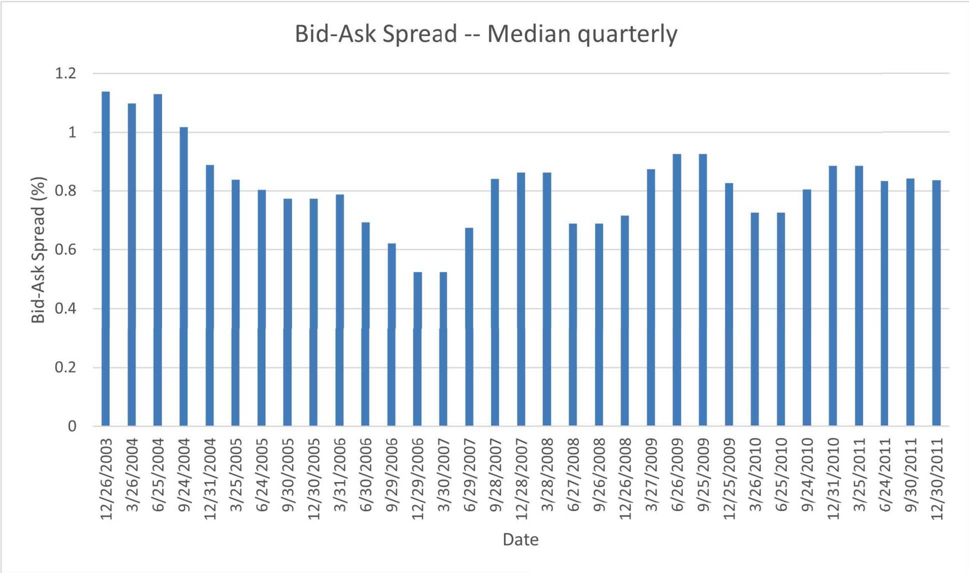
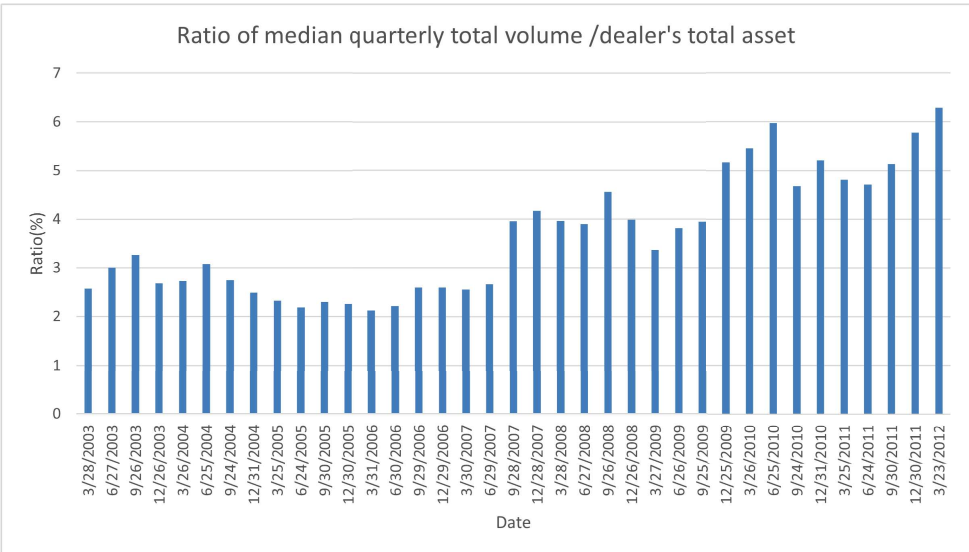


Figure 5 shows (the cross-sectional average) the bid-ask spread of our currencies (median quarterly). Bid-ask prices fell until the end of 2007 and then started to increase.

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



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.

Figure 7: Event Study - 2020 - Leverage Volume

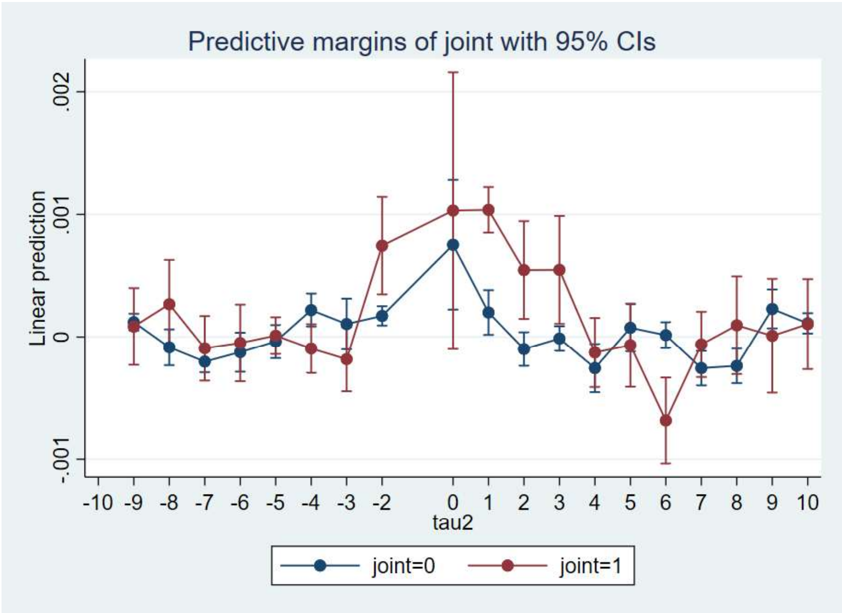


Figure 8: Event Study - 2020 - Real Money

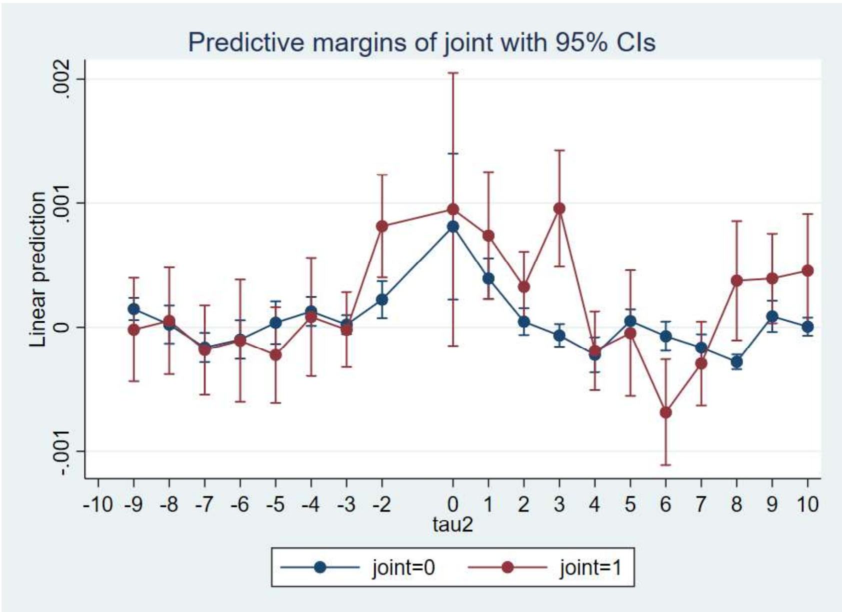


Figure 7 and 8 show the results of equation (14) by using the sample from 2018 to 2021. Here red line shows the β_{τ}^{Joint}, which is the coefficient when both constraints and trading pressure are high. Blue line shows the β_{τ}^{Other}, in the opposite scenario.

Figure 9: Aggregated Cumulative Order Flow

(a) Financial Crisis - Weekly (b) Covid 19 - Daily

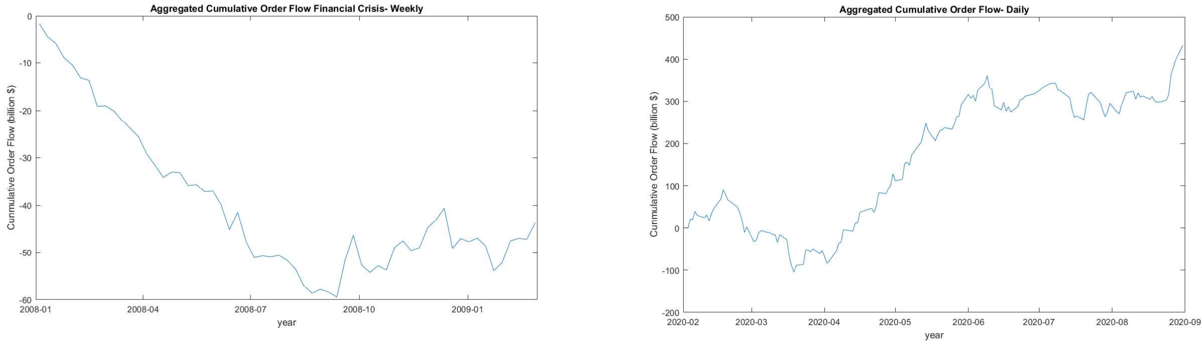


Figure 9 shows the aggregated cumulative order flow. We calculate it from 2008 January to 2009 March in (a). We show the cumulative flow from 2020 February to September. For our order flow data, negative suggests buying USD while positive is selling it.

Figure 10: Disaggregated Cumulative Order Flow

(a) Financial Crisis - Weekly (b) Covid 19 - Daily

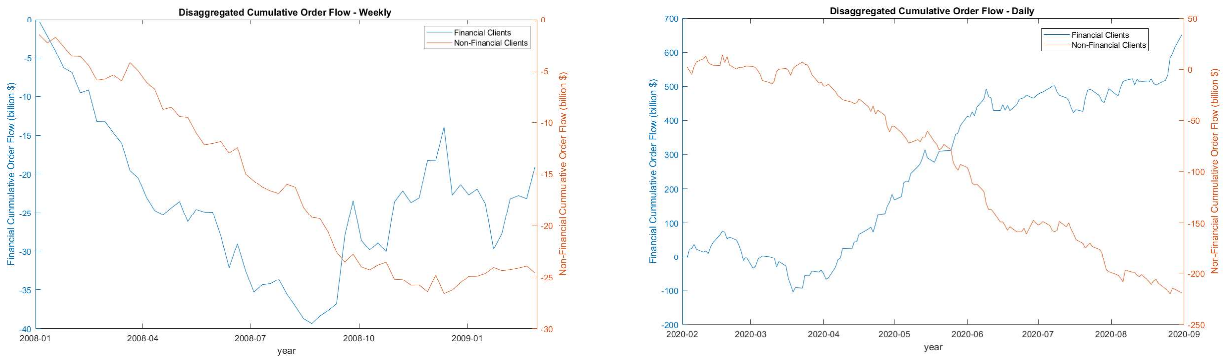


Figure 10 shows the disaggregated cumulative order flow. We use the same period as in Figure 9.

Figure 11: Balance Sheet

(a) Normal Period (b) During Shocks

We show the simplified balance sheet in Figure 11. We assume that the FX dealer has US$ lending on one side of the balance sheet and US$ borrowing on the other side.

Figure 12: Supply Demand Curve

(a) Normal Period (b) During Shocks

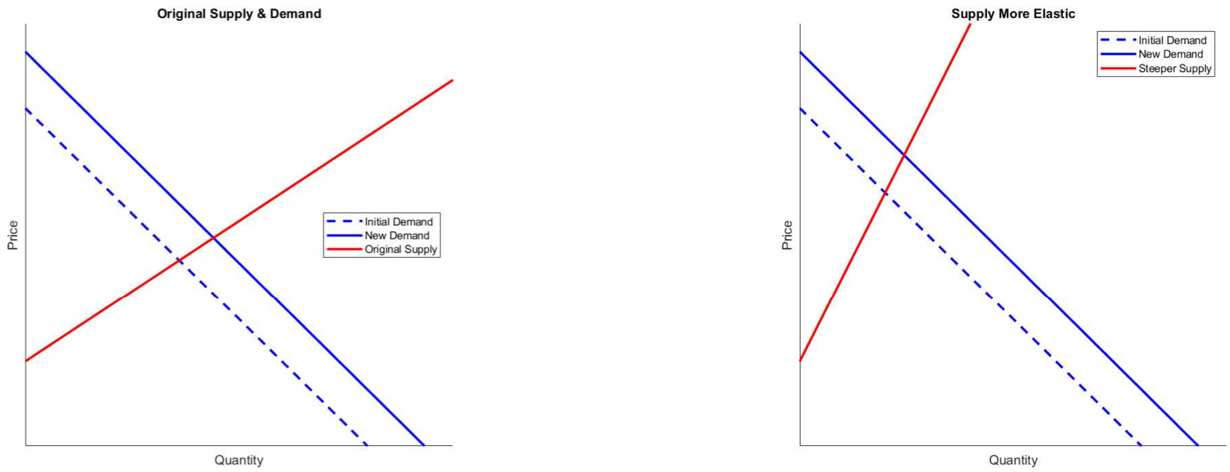


Figure 12 shows the supply-demand curve. In Figure 11 and 12, we show the normal period in Panel (a). And we suppose that following an exogenous shock, the equity capital of the dealer falls and, at the same time, the demand of US$ from clients surges (additional demand). The balance sheet of the dealer will show an imbalance between US$ demand from clients and the financing resources available (Figure 11 Panel b). To accommodate the demand, dealers will need to commit their own capital. However, generally, they are reluctant to do so to support the liquidity, particularly when their capital is already lower. This situation introduces debt overhang costs and it can drive the slope of the US dollar supply curve (see Figure 12 (a,b)).

Table 1: Summary of Volume

Panel A: First Dealer- Volume (billion$)					
Variables	N	Mean	S.D.	Min	Max
EUR	493	23.738	11.553	4.805	84.437
JPY	493	9.434	3.764	1.787	25.915
GBP	493	8.228	5.026	1.299	50.699
CHF	493	7.030	3.309	1.898	24.790
AUD	493	3.888	2.518	0.135	11.691
CAD	493	2.717	1.592	0.283	12.303
NZD	493	0.834	0.592	0.066	3.171
HKD	493	0.629	0.485	0.028	2.539
MXN	493	0.505	0.386	0.012	2.217
ZAR	493	0.491	0.424	0.010	2.395
SGD	493	0.455	0.333	0.015	1.790
Panel B: Second Dealer - Volume (billion$)					
Variables	N	Mean	S.D.	Min	Max
Leverage Volume	1,044	1.045	0.167	0.631	1.703
Real Money	1,044	1.112	0.137	0.650	1.626

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

Panel A: Aggregrated Order Flow -Second Dealer (billion$)							
Variables	N	Mean	S.D.	Min	Max	Skew	Kurt
EUR	1,044	-0.245	3.262	-12.331	8.125	-0.151	3.174
AUD	1,044	-0.483	4.948	-15.022	17.557	0.063	3.085
CAD	1,044	-0.009	5.729	-17.325	20.187	0.019	3.183
CHF	1,044	0.917	6.644	-22.856	21.291	-0.045	3.153
GBP	1,044	0.168	3.788	-14.742	11.637	-0.200	3.312
JPY	1,044	0.098	3.616	-10.790	12.785	0.181	3.264
NOK	1,044	-0.138	9.243	-29.638	33.424	-0.016	3.660
NZD	1,044	-0.201	6.140	-19.212	21.100	0.003	3.491
SEK	1,044	-0.171	7.864	-29.571	28.748	0.001	3.622
Panel B: Financial Order Flow -Second Dealer (billion$)							
Variables	N	Mean	S.D.	Min	Max	Skew	Kurt
EUR	1,044	0.065	3.193	-11.431	10.208	0.208	0.159
AUD	1,044	0.019	5.049	-13.350	17.732	0.818	0.377
CAD	1,044	0.645	5.623	-16.796	18.252	0.781	0.210
CHF	1,044	0.046	6.713	-27.823	20.831	0.023	0.058
GBP	1,044	0.343	3.726	-11.787	10.366	0.031	0.202
JPY	1,044	0.100	3.710	-11.729	12.649	0.246	0.586
NOK	1,044	1.004	9.223	-28.632	35.297	0.915	0.014
NZD	1,044	0.144	6.505	-22.191	22.270	0.520	0.007
SEK	1,044	0.270	7.832	-27.880	26.939	0.675	0.003
Panel C: Non-Financial Order Flow -Second Dealer (billion$)							
Variables	N	Mean	S.D.	Min	Max	Skew	Kurt
EUR	1,044	-0.309	1.371	-4.322	3.647	0.787	0.031
AUD	1,044	-0.502	1.665	-5.856	4.909	0.090	0.150
CAD	1,044	-0.654	1.639	-6.388	5.943	0.596	0.004
CHF	1,044	0.871	1.938	-6.572	6.855	0.746	0.179
GBP	1,044	-0.174	1.598	-5.889	4.614	0.827	0.747
JPY	1,044	-0.003	1.772	-5.367	5.463	0.059	0.586
NOK	1,044	-1.143	2.474	-9.009	9.156	0.000	0.000
NZD	1,044	-0.344	1.866	-6.473	6.609	0.677	0.914
SEK	1,044	-0.441	2.215	-6.768	6.330	0.243	0.018

Table 2 shows the summary of the order flow. This table shows the number of observations, mean, standard deviation, minimum value to maximum value, skew, and kurtosis. 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 (5). 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 (5). 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 normalized volume the independent variable. We control for GARCH volatility and bid-ask spread. This table uses the sample from 2007 December to 2012 March using double fixed effect and double cluster standard errors. 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

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Panel A : Leverage Volme							
	CDS		LIBOR-OIS		Leverage		Full
	High	Low	High	Low	High	Low	Period
$Return_{t-1}$	8.6534**	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

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Panel B : Real Money							
	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

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Panel C : Total Volume							
	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 a panel regression with currency fixed effects and currency cluster standard errors. We split the sample into two parts according to the median of CDS Spread/ LIBOR-OIS Spread/ Leverage. This regression is similar to the one in Table 5; We use daily frequency during the COVID-19 period, which is from January 2018 to the end of 2021. The coefficient and standard error in this table are all multiplied by 100.

Table 7: Volume and Interaction - 2008

	(1)
$Return_{t-1}$	-0.1291***
	0.0361
$Volume_{t-1}$	-0.0023
	0.0016
$CDS_{t-1} * Volume_{t-1}$	0.0026*
	0.0012
Controls	Yes
$adj - R^2$	0.3881
Nobs	2,464

*** indicates statistical significance at 10 % level

** indicates statistical significance at 5 % level

* indicates statistical significance at 1 % level

Table 7 shows the coefficient results of equation (6) by using the sample from Dec.2007 to Mar.2012. Here, we use the double fixed effect and double cluster standard error.

Table 8: Volume and Interaction - 2020

	(1) Leveage Volume	(2) Real Money
$Return_{t-1}$	0.0271*	0.0291*
	0.0134	*0.0139*
$Volume_{t-1}$	0.0004*	0.0006***
	0.0002	*0.0001*
$CDS_{t-1} * Volume_{t-1}$	0.0007***	0.0005***
	0.0001	*0.0001*
Controls	Yes	Yes
$adj - R^2$	0.0064	0.0050
Nobs	9,387	9,387

*** indicates statistical significance at 10 % level

** indicates statistical significance at 5 % level

* indicates statistical significance at 1 % level

Table 8 shows the coefficient results of equation (6) by using the sample from 2018 to 2021. Here, we use the currency fixed effect and the currency cluster standard error. In columns (1) and (2), we separately show the results for leverage volume and real money volume.

Table 9: Order Flow and Dealer 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 9 shows the results of the relationship between order flow and dealer leverage. For the dealer leverage, we use the approach as in He et al (2017). We generate the market leverage equals to

$$DealerLeverage_t = (MarketEquity_t + BookDebt_t)/MarketEquity_t \tag{41}$$

We us the second dealer's monthly data from January 2018 to December 2021 for the regression, and employ robust standard errors. Column (1) shows the results of aggregated order flow, and columns (2) and (3) show the order flow of financial and non-financial clients.

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Appendices

A Supply Evidence

A.1 Event-Time Evidence Around Dealer Constraint Shocks

In this section, we use Stacked event-time regressions.
We define CDS change:

$$\Delta CDS_{i,t} = CDS_{i,t} - CDS_{i,t-1}. \tag{42}$$

And the stress event indicator:

$$Shock_{i,t} = \mathbf{1}\big(\Delta CDS_{i,t} \geq Q90\big(\Delta CDS_i\big)\big)\,, \tag{43}$$

Furthermore, we use the following regression:

$$r_{i,e,\tau} = \alpha_i + \delta_e + \sum_{\tau} \beta_\tau D_{i,e,\tau}\, nv_{i,t_e-1} + \sum_{\tau} \theta_\tau D_{i,e,\tau}\,(nv_{i,t_e-1} \times CDS_{i,t_e-1}) + \rho\, r_{i,t_e-1} + \varepsilon_{i,e,\tau}, \tag{44}$$

where

- $r_{i,e,\tau} = r_{i,t_e+\tau}$ is the log return of currency i at event-relative time τ;
- nv_{i,t_e-1} is *lagged normalized volume* (one day before the event) for currency i;
- CDS_{i,t_e-1} is *lagged CDS* (one day before the event);
- $D_{i,e,\tau}$ is an indicator for event time τ ;
- α_i are currency fixed effects ;
- δ_e are event fixed effects ;
- r_{i,t_e-1} = *logreturn_event* is the one day before event-day return used as a control;
- β_τ is the event-time-specific effect of lagged volume;
- θ_τ is the event-time-specific effect of lagged Volume×CDS;
- $\varepsilon_{i,e,\tau}$ is the error term.

Figure 13: 2020 - Leverage Volume

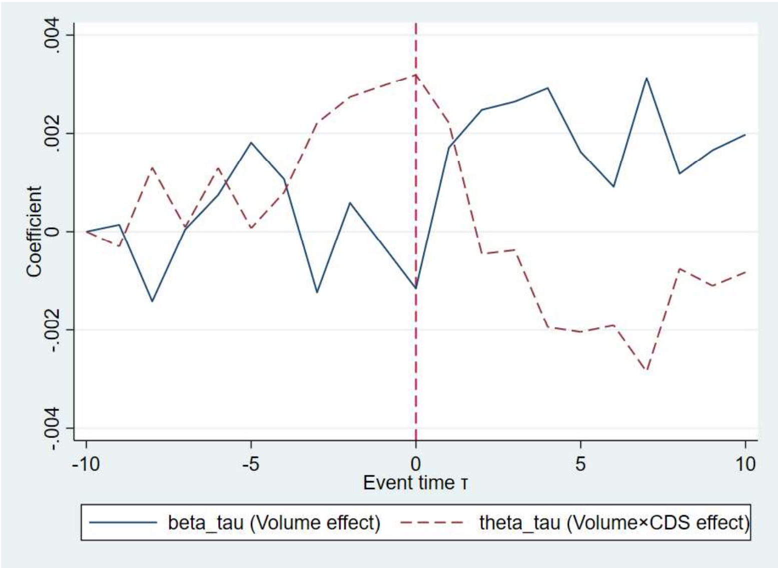
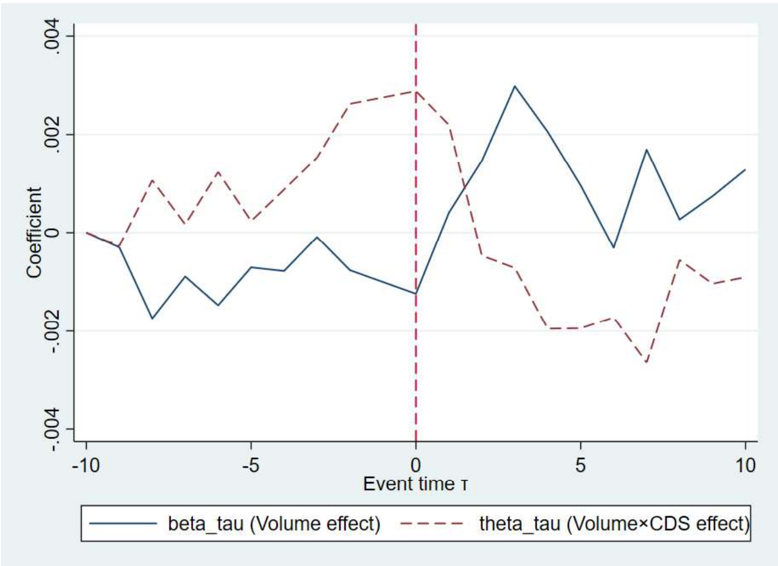


Figure 14: 2020 - Real Money



In Figure 13 and 14, we use equation (18) and stacked event-time regression to compute the coefficient of volume and the interaction term.

A.2 Crisis-Specific Slope Evidence

Figure 15: 2008 - margin

Figure 15 shows the results of equations (6) and (7) by using the 2008 sample. Here, we use the β_2 and β_3 values obtained in Table 7, along with the CDS data, to draw Figure 15.

Figure 16: 2020 - Leverage Volume -Slope

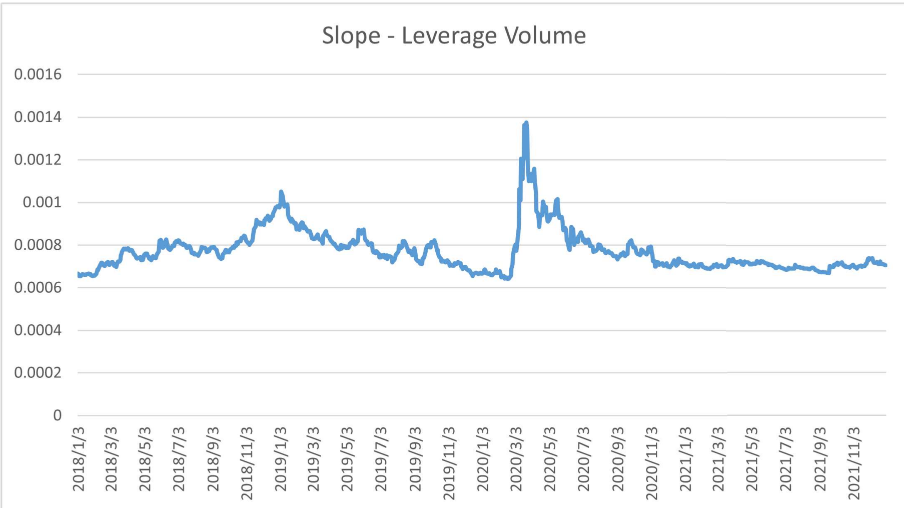


Figure 17: 2020 - Real Money - Slope

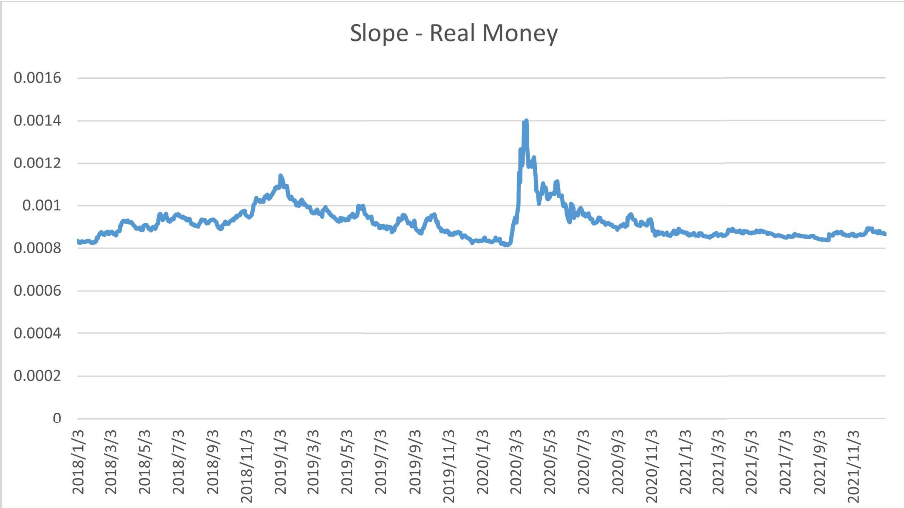


Figure 16 and 17 show the results of equations (6) and (7) by using the 2020 sample. Here, we use the β_2 and β_3 values obtained in Table 8, along with the CDS data, to draw Figure 16 and 17.

B Before Financial Crisis

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

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
$Return_{t-1}$	0.9810	-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

In Table 10, we redo Table 5 by using the sample from November 2002 to November 2007, which is before the financial crisis.

C Different Volume Windows

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

C.1 window equals 8

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
$Return_{t-1}$	-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

In Table 11, We show the results when we redo Table 5. In Table 11, we use the normalized volume, which was calculated by windows equals to 8.

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
$Return_{t-1}$	0.9817	-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

In Table 12, We show the results when we redo Table 10. In Table 12, we use the normalized volume, which was calculated by windows equals to 8.

C.2 window equals 16

Table 13: 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

In Table 13, We show the results when we redo Table 5. In Table 13, we use the normalized volume, which was calculated by windows equals to 16.

Table 14: 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

In Table 14, We show the results when we redo Table 10. In Table 14, we use the normalized volume, which was calculated by windows equals to 16.

D Results without Quantitative Easing Period

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

Table 15: Return and Normalized Volume - high and low groups - Before QE

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
$Return_{t-1}$	8.0431*	12.0863***	11.2651**	4.8474**	13.0271**	4.5550**	10.1916***
	4.2579	*1.5952*	*4.0371*	*1.6833*	*4.7911*	*1.8710*	*2.7657*
$Volume_{t-1}$	0.2473***	-0.0125	0.2072***	-0.0136	0.1343**	0.0224	0.0853**
	0.0582	0.0190	*0.0566*	*0.0147*	*0.0427*	*0.0293*	*0.0314*
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
$adj-R^2$	0.0226	0.0111	0.0266	0.0042	0.0254	-0.0007	0.0138
Nobs	2,070	2,142	2,106	2,106	2,106	2,106	4,212
	Panel B : Real Money						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	CDS		LIBOR-OIS		Leverage		Full
	High	Low	High	Low	High	Low	Period
$Return_{t-1}$	8.8372*	12.1055***	12.3544**	4.9864**	13.5772**	4.4447**	10.3284***
	4.4819	*1.5921*	*4.3590*	*1.6835*	*4.9902*	*1.8379*	*2.8619*
$Volume_{t-1}$	0.1347**	-0.0079	0.0938**	0.0257	0.0549	0.0729***	0.0612**
	0.0493	*0.0208*	*0.0403*	*0.0168*	*0.0408*	*0.0209*	*0.0264*
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
$adj-R^2$	0.0115	0.011	0.0159	0.0043	0.0187	0.0009	0.0117
Nobs	2,070	2,142	2,106	2,106	2,106	2,106	4,212
	Panel C : Total Volume						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	CDS		LIBOR-OIS		Leverage		Full
	High	Low	High	Low	High	Low	Period
$Return_{t-1}$	8.3941*	12.0959***	11.6676**	4.9232**	13.2899**	4.5253**	10.2344***
	4.3564	*1.5939*	*4.1718*	*1.6922*	*4.8836*	*1.8533*	*2.8041*
$Volume_{t-1}$	0.1112***	-0.0065	0.0990**	0.0007	0.0605**	0.0280*	0.0455**
	0.0307	*0.0105*	*0.0309*	*0.0086*	*0.0240*	*0.0145*	*0.0173*
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
$adj-R^2$	0.0176	0.011	0.0221	0.004	0.0221	0.0001	0.0131
Nobs	2,070	2,142	2,106	2,106	2,106	2,106	4,212

*** indicates statistical significance at 10 % level

** indicates statistical significance at 5 % level

* indicates statistical significance at 1 % level

Table 15 redo the table 6 by using the sample period before quantitative easing. In this table, we use a daily sample from January 2018 to March 2020 and still use the currency fix effect and currency cluster standard error to do the panel regression.

Online Appendix

Online Appendix Not For Publication

A Joint Constraint × Demand Event Study

A.1 Additional Joint-State Event Studies

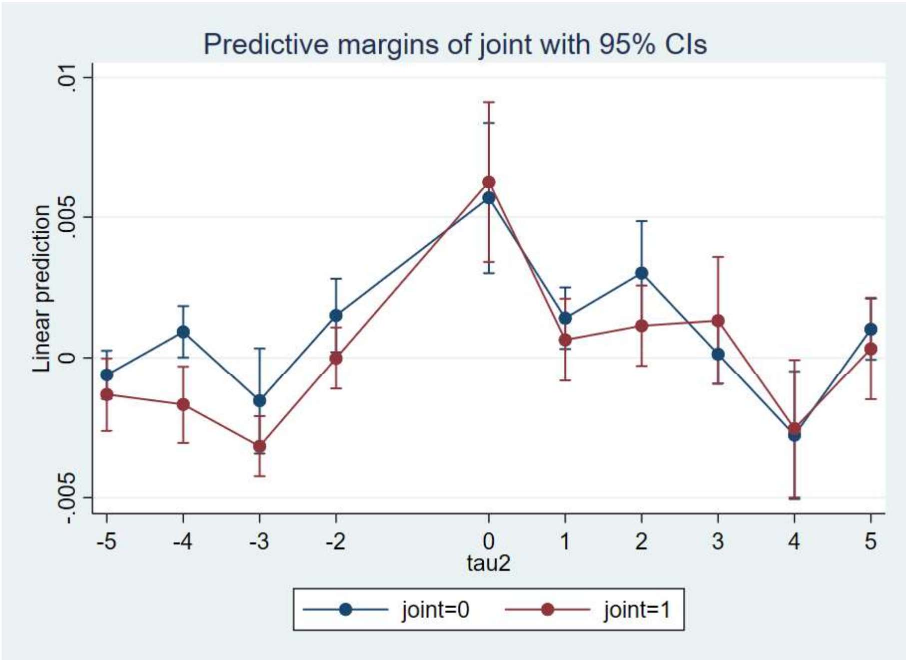


Figure 18: 2008-Top 10% change of CDS

Figure 18 shows the results of equation (14) by using the sample from 2007 Dec. to 2012Mar.. Here red line shows the β_τ^{Joint}, which is the coefficient when both constraints and trading pressure are high. Blue line shows the β_τ^{Other}, which represents the other situations.

A.2 Placebo Tests

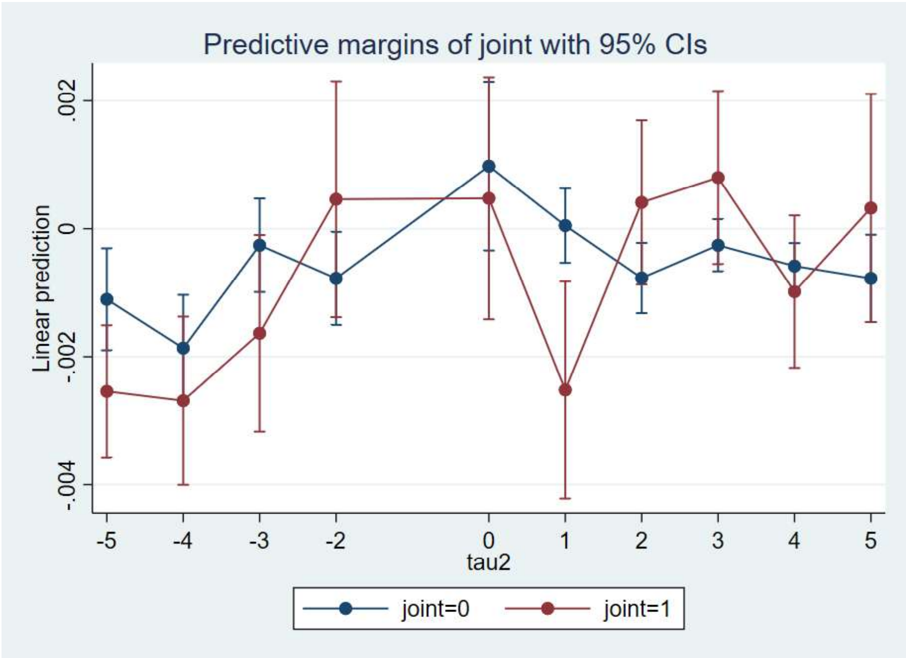


Figure 19: Before 2008-Top 10% change of CDS

Figure 19 shows the results of equation (14) by using the sample from 2003 Nov.. to 2007 Nov.. Here red line shows the β_{τ}^{Joint}, which is the coefficient when both constraints and trading pressure are high. Blue line shows the β_{τ}^{Other}, which represents the other situations.

B Different Maturity for Forward Rates

Table 16: 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 16 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 17: 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 17 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.

C Realized Volatility

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

Table 18: 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 18 uses the realized volatility to redo Table 3.

Table 19: 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 19 uses the realized volatility to redo Table 4.

D Second Dealer Results

Table 20: Excess Return and Normalized Volume - Covid

2018-2021

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
		All Currencies		Volume High	Volume Low	Bid-Ask Spread High	Bid-Ask Spread Low	Volatility High	Volatility Low
Panel A : Leverage Volume									
$Return_{t-1}$	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 High	Volume Low	Bid-Ask Spread High	Bid-Ask Spread Low	Volatility High	Volatility 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 20 shows the results of Table 3 when using the Covid period (2018-2021).

E Order Flow as Control

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

Table 21: 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 21 adds order flow as a control to redo Table 5, and the main results do not change.

Table 22: 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 22 adds order flow as a control to redo Table 6, and the main results do not change.

F Volume and CDS

Table 23: 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 23 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 24: Change of Volume and Change of CDS - COVID-19

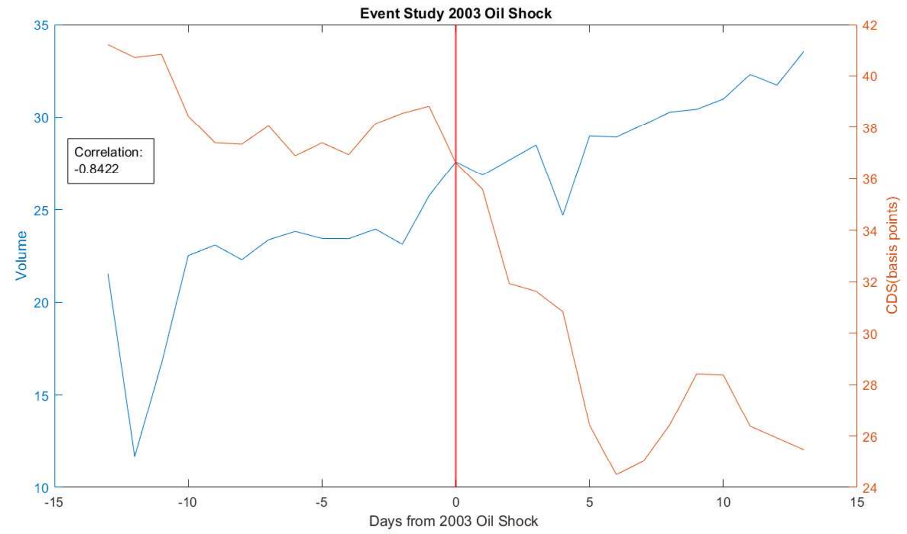
2018-2021	$\Delta Volume_t$		
	leverage volume (1)	real money (2)	sumvolume
$\Delta Volume_{t-1}$	0.3152***	-0.0772	0.1296*
	0.0718	*0.0735*	*0.0695*
$\Delta Volume_{t-1}$	-0.1928*	-0.0656	-0.2545
	0.1075	*0.1127*	*0.2074*
$\Delta Volume_{t-2}$	-0.0730	0.1481	0.0789
	0.1317	*0.1462*	*0.2793*
$\Delta Volume_{t-3}$	-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 24 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.

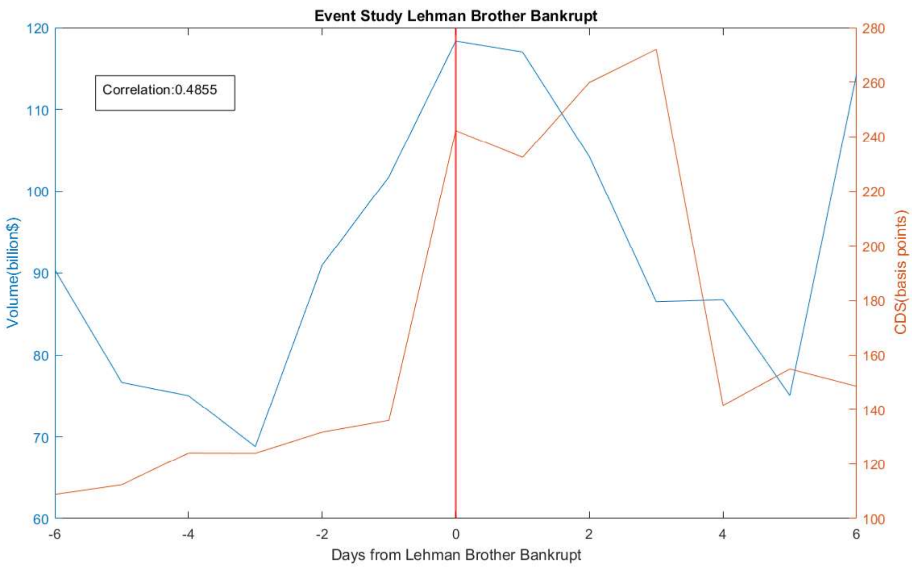
G Case Study

Figure 20: Case Study

(a) Oil Shock - Weekly



(b) Lehman Brother Bankrupt - Weekly



(c) Covid 19 - Daily

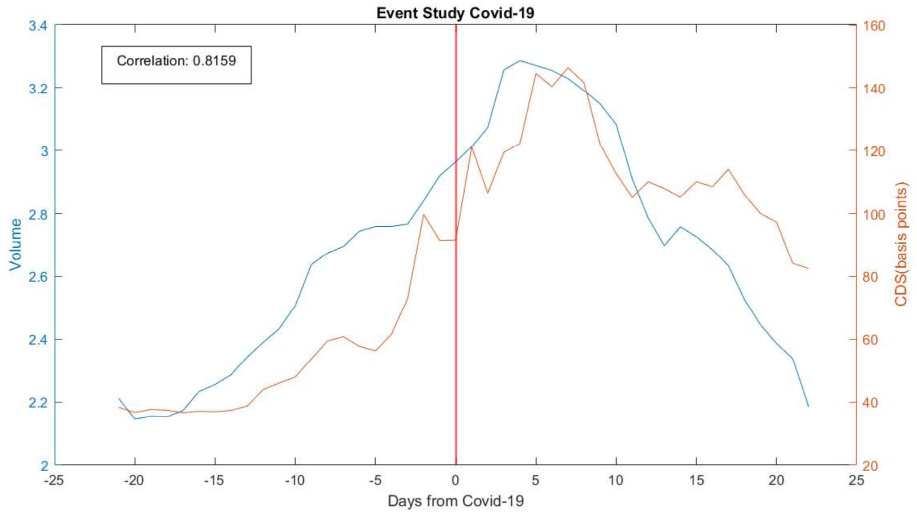


Figure 20 shows the FX volume and CDS relationship during the 2003 Oil Shock, the Lehman Brothers bankruptcy and the COVID-19 pandemic. We chose the oil shock and bankruptcy week, also the day on which COVID-19 was defined by the WHO as time 0. Further, we draw the weeks and days before and after time 0.