True Cost of Immediacy

TERRENCE HENDERSHOTT, DAN LI, DMITRY LIVDAN,
and NORMAN SCHÜRHOFF*

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Abstract

Traditional liquidity measures can provide a false impression of the liquidity and stability of financial market trading. Using data on auctions (bids wanted in competition; BWICs) from the collateralized loan obligation (CLO) market, we show that a standard measure of liquidity, the effective bid-ask spread, dramatically underestimates the true cost of immediacy because it does not account for failed attempts to trade. The true cost of immediacy is substantially higher than the observed costs for successful BWICs. This cost gap is higher in lower-rated CLOs and stressful market conditions when failure rates exceed 50%. Across our 2012-2020 sample period for trades in senior CLOs, the observed cost is four basis points (bps) while the true cost of immediacy is 13bps. In stressful periods, such as the COVID-19 pandemic, for junior tranches the observed cost of trading increases from an average of 12bps to 25bps while the true cost of immediacy increases from less than 3% to almost 15%.

JEL Classification: G12, G14, G24

Key words: Collateralized loan obligations, bids-wanted-in-competition, over-the-counter markets, liquidity, fragility

The 2007-2009 financial crisis and the 2020 pandemic have highlighted the importance of understanding the stability or fragility of liquidity in financial markets. This is a challenge for many important financial securities that trade in over-the-counter (OTC) markets where there are typically no firm quotes and trade is infrequent. In most OTC markets, only the prices of completed trades are observed. If investors choose not to trade when they are unable to obtain good prices, the observed trading costs are biased downward as they fail to account for the opportunity costs of not trading (Perold (1988)).[1] This bias can give the false impression of liquidity and stability, especially in less liquid markets. We propose a way to measure the true cost of immediacy (TCI) using data that captures failed attempts to trade.[2] TCI for a seller is the expected difference between the price at which an investor can buy the asset minus the seller's expected payoff from selling or continuing to hold the asset.

We estimate TCI for collateralized loan obligations (CLOs). Like many other structured products, CLOs trade in an OTC market that performed poorly during the 2007-2008 financial crisis (Dick-Nielsen, Feldhütter, and Lando (2012) and Friewald, Jankowitsch, and Subrahmanyam (2012)). CLOs consist of repackaged portfolios of loans issued by lower-rated, highly leveraged firms. CLOs have become popular due to the reach for yield by asset managers in a low-interest-rate environment (Becker and Ivashina (2015)). Regulators and market participants have raised the concern that CLOs may be the source of the next financial crisis.[3] CLOs now hold roughly 60% of all leveraged loans outstanding and are important sources of funding for lower-rated small and mid-sized businesses. Even though the trading mechanism of CLO securities has not changed much since the financial crisis, the liquidity risks associated with trading CLOs are not well understood.

Investors predominantly sell their CLOs through an email-based auction-like mechanism referred

[1] Bessembinder, Jacobsen, Maxwell, and Venkataraman (2018) and Bessembinder, Spatt, and Venkataraman (2020) discuss how execution costs for completed trades fail to account for the costs of trades that were desired but not completed.

[2] In centralized markets like stock exchanges, firm quotes exist, but only for relatively small sizes. Large orders are broken up into many small trades. Optimal trading strategies in theoretical models are typically price contingent and traders reduce their trading volume when price impact is higher. This behavior at the intensive trading margin causes measured trading costs for larger orders to be biased downward relative to the true cost of trading the original desired quantity.

[3] The Guardian reports that "The sub-prime time bomb is back—this time companies are lighting the fuse."[4] Vontobel Bank raises the question "How robust are CLOs through a recession?" (https://am.vontobel.com/en/twentyfour-asset-management/24-blog). The fundamental risks inherent in CLOs are better understood than before the financial crisis, and some of the features of the new generation CLOs potentially made them more structurally sound than older structures (see Federal Reserve financial stability report, May 2019, p. 26, https://www.federalreserve.gov/publications/files/financial-stability-report-201905.pdf).

to as bids-wanted-in-competition (BWIC).[5] In a BWIC, an institutional seller disseminates a list of securities to various securities dealers to bid on. Dealers then respond with bids on the listed securities and search for buyers. The dealers with the highest bids buy the securities at prices that equal their bids. We study BWICs using third-party collected auction data and supervisory trade reporting data.

Trade and BWIC bid data from 2012-2020 enable us to incorporate the cost of failed attempts to trade into the cost of immediacy. The cost of immediacy is often defined as the cost to an investor of simultaneously buying and selling an asset. If investors choose not to trade when they are unable to get good prices, estimates of the cost of immediacy derived from successful transactions are downward biased. To capture the investors' opportunity costs when failing to trade the true cost of immediacy must incorporate the value of continuing to hold the asset when a BWIC fails.

As in standard auction models that resemble BWICs, we focus on dealers' bidding to buy the CLO from a seller. When a BWIC trades, we observe the highest bid.[6] Using the reserve price to value the outside option, we show that the true cost of immediacy can be written as the expected bid-ask spread on observed trades plus the probability of BWIC failure times the cost of trade failure; where the cost of trade failure is the expect highest bid conditional on a trade minus the reserve price. The sellers' reserve price is the only component of the true cost that is not directly observable in the data. We estimate the reserve price using the theoretical link between the reserve price and quantiles of the distribution of accepted bids.

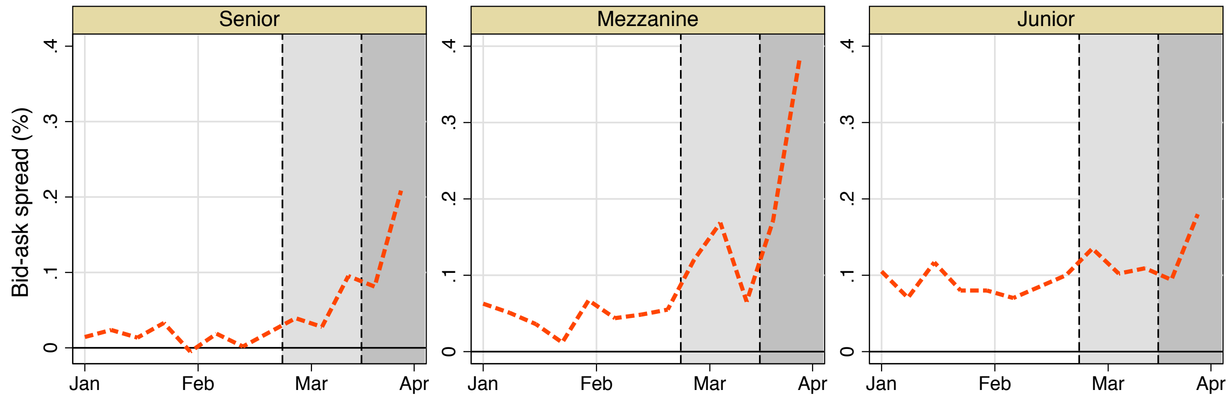
To illustrate how the bid-ask spread and TCI behave differently during the 2020 pandemic, Figure 1 plots weekly average bid-ask spreads (red lines) and TCI (blue lines) for different CLO credit tranches. Panel A shows that bid-ask spreads for senior tranche (AAA- rated) CLOs were only a few basis points (bps) at the start of 2020. Beginning in February 2020 bid-ask spreads rose to about 10bps.[7] As the pandemic hit in March 2020, spreads widen to 20bps. The bid-ask spreads

[5] Around 40% of customer-sell-to-dealer trades in the sample of US CLOs can be mapped to a BWIC auction in our data, which suggests that at least 40% of investors sells are through auctions, instead of direct bilateral negotiations with a dealer. The dealer-sell-to-customer leg is typically done through search. Offers wanted in competition (OWICs) are rare, likely reflecting the difficulty in pricing such securities for investors relative to dealers.

[6] We do not observe any bids in auctions that fail.

[7] Foley-Fisher, Gorton, and Verani (2020) examine AAA-rated CLO trading costs in 2020. They calculate imputed roundtrip costs using the Feldhütter (2012) methodology which is the maximum minus the minimum price of trades on the same day. If there are multiple buy and sell transactions on the same day, the max-min imputed cost is larger than measures of average costs based on the difference between the average customer buy price and the average customer sale price (Hong and Warga (2000)). In contrast, our bid-ask spread directly identifies roundtrips by matching trades of the same dealer within a two day window. Foley-Fisher, Gorton, and Verani (2020) also find that bid-ask spreads

Panel A: Bid-ask spreads in successful BWICs during 2020 pandemic



Panel B: TCI (solid) compared to bid-ask spreads (dashed) during 2020 pandemic

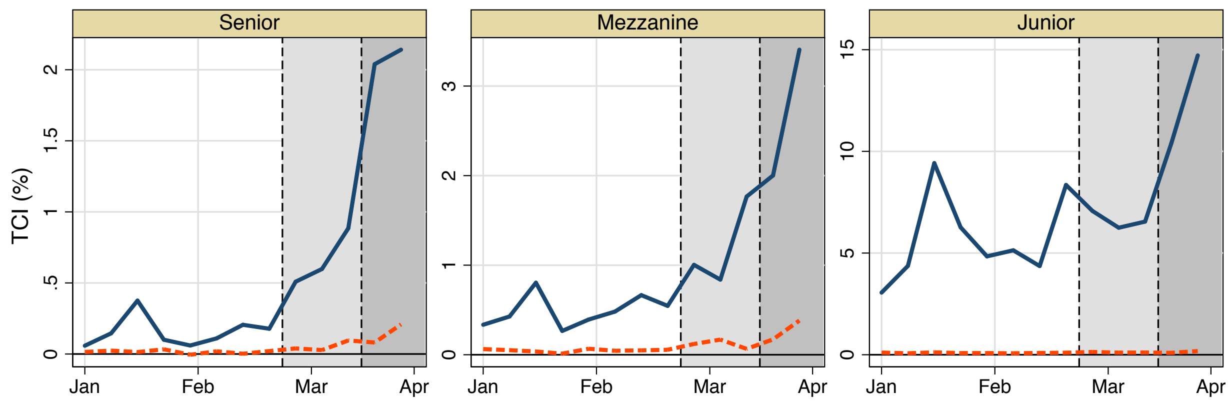


Figure 1: Bid-ask spreads and TCI during 2020 pandemic

The figure documents weekly bid-ask spreads and TCI in the CLO market during the onset of the 2020 pandemic between January 2020 and March 2020, split by tranche into the senior tranche rated AAA, mezzanine tranche rated AA–BBB, and junior tranche rated BB–equity. The lightly shaded area indicates early stages of the pandemic between 3rd week of February and 2nd week of March (before the first US shelter-in-place orders), while the darker shaded area indicates later stages of the pandemic between 2nd and 4th weeks of March, i.e., after first US shelter-in-place orders have been implemented.

for mezzanine tranches follow a similar pattern: spreads were about 5bps at the beginning of the year, rose to 15bps in February, and were 40bps by the end of March 2020.[8] Interestingly, realized bid-ask spreads for below-investment-grade junior tranches rose more modestly in March.

Panel B of Figure 1 compares our TCI measure (in red) against the bid-ask spread directly.

widen in March 2020. Additionally, consistent with an increase in adverse selection, Foley-Fisher, Gorton, and Verani (2020) find that price dispersion increases, and more so when uncertainty about the industries vulnerable to the pandemic increases. Our measure of TCI captures lower reservation values and higher BWIC failure rates due to both adverse selection and non-informational frictions, e.g., high search or hedging costs for intermediaries, that can increase bid-ask spreads and price dispersion.

[8] Kargar, Lester, Lindsay, Liu, Weill, and Zuniga (2020) and O'Hara and Zhou (2020) study liquidity for corporate bonds through this time period. They find that bid-ask spreads widen to three to four times their pre-pandemic level, with the increase occurring in trades where the dealer's act as principle.

The magnitude of the increases in TCI dwarfs that of the bid-ask spread in Panel B. For the senior tranches, TCI exhibits similar dynamics as the spread until late February then TCI spikes to almost 2%. For mezzanine tranches, TCI is above the spread at the start then increases to 3% by April. For the junior tranches, TCI starts around 3-4%, then increases to over 15%. Overall, TCI suggests more substantial market deterioration with the onset of the pandemic. We will see later in the paper that the dramatic increase in TCI is due to an increase in the BWIC failure rate as well as an increase in the failure cost. Failure rates for senior and mezzanine CLOs increase to over 20% while the failure rate for junior exceeds 60% by late March.

Bid-ask spreads at the onset of the 2020 pandemic are similar to bid-ask spreads over the 2017-2019 period: average bid-ask spreads are roughly 2bps/5bps/9bps for the senior/mezzanine/junior tranches. Other OTC traded assets, such as foreign exchange and institutional-size corporate bonds trades, have bid-ask spreads in this range. In the earlier part of our sample period, when the aggregate size of CLOs outstanding is smaller, bid-ask spreads are roughly twice as large as in the later years. There are two periods of market stress prior to the COVID-19 pandemic: the 2012 European debt crisis and the 2015-2016 credit market stress. During these periods, both the leverage loan spread and CDS spread for primary dealers increased significantly. Bid-ask spreads increased during these periods, but still remain modest at below 30bps.

Over our sample period, the rate at which BWICs fail to trade follows a similar pattern as bid-ask spreads: failure rates are higher for lower-rated tranches, in the earlier years of the sample and in more stressful periods. Failure rates rise more for lower-rated tranches in stressful periods than do bid-ask spreads. We find that the cost of a failed auction has similar time series patterns. The cost of failed auction is the difference between the expected best bid and the seller's reserve price. In stressful periods both the expected best bids and the reserve prices fall, but reserve prices fall more, causing the cost of auction failure to spike in stressful periods for the lower-rated tranches.

TCI is the bid-ask spread plus the failure rate times the failure cost. Because bid-ask spreads, failure rates, and failure costs follow similar time series patterns, TCI has the same patterns: TCI is lower in the later years and increases in stressful periods. Moreover, TCI is significantly higher in lower-rated tranches. Average TCI is close to 3% for junior CLOs, versus 25bps for senior CLOs. Because failure costs and failure rates co-move with both increasing in stressful periods, this amplification causes TCI to spike significantly more than bid-ask spreads. In the earlier stress periods TCI spikes to similar levels as in Figure 1. TCI spiking so dramatically emphasizes how the selection bias in bid-ask spreads can cause them to dramatically underestimate illiquidity in crises. Liquidity measures that use trading volume may also significantly underestimate illiquidity if trading volume is driven by forced liquidations by investors at fire-sale prices. Regulators concerned about the smooth functioning of asset markets must monitor failure rates and failure costs.

While the trading of CLOs has not been studied before, OTC markets in many important asset classes have been studied: foreign exchange, spot commodities, derivatives, and corporate and municipal bonds. For fixed income securities Bessembinder, Spatt, and Venkataraman (2020) provide an extensive survey of the literature. Our bid-ask spread estimates for CLOs (5-10bps) are somewhat smaller than institutional trading costs in other OTC markets. However, it is important to note that CLO BWICs last from a day to several days, complicating direct comparisons as the time dimension of immediacy likely differs. Moreover, average trade size for CLO BWICs is around $5 million, larger than a typical institutional corporate bond trade.

Bessembinder, Jacobsen, Maxwell, and Venkataraman (2018) examine changes in liquidity provision over time. They find that trading costs in corporate bonds have remained fairly constant, but traditional dealers have become less likely to take on inventory risk to facilitate customer trading. This is consistent with a decrease in customers' ability to trade and an increase in the opportunity costs of failed trades. However, the paper does not directly measure either of these. Dick-Nielsen, Feldhütter, and Lando (2012) and Friewald, Jankowitsch, and Subrahmanyam (2012) show that corporate bond liquidity significantly decreased during the 2007-2009 financial crisis. However, our results showing increases in bid-ask spreads substantially underestimate the cost of immediacy during crises suggest that illiquidity may have been much worse than previously measured during the 2007-2009 financial crisis.

Hendershott and Madhavan (2015) study corporate bond trading via traditional OTC search and request for quote (RFQ) auctions, which are similar to BWICs. Corporate-bond RFQs fail often and costs are higher for trades that occur after a failed auction.[9] However, the cost of failed auctions is likely higher in CLOs than corporate bonds for several reasons. First, corporate-bond RFQs

[9] Riggs, Onur, Reiffen, and Zhu (2020) study RFQs and bilateral trades in the index credit default swaps market. They focus on the costs and benefits of order exposure through RFQs: increased competition versus the winner's curse and maintaining dealer-customer relationships. For their index CDS, the vast majority of inquiries resulted in trades, so the cost of failure is less relevant in their setting.

are shorter lived (5-10mins) than CLO BWICs. Second, corporate bonds trade significantly more frequently than CLOs. Third, the number of corporate-bond dealers is substantially higher. Fourth, a larger share of customer sells for CLOs are done through BWICs than via RFQs in corporate bonds. Finally, Hendershott and Madhavan (2015) do not estimate the costs for attempted trades that fail to occur.

A number of approaches have been used to calculate transaction costs in sparsely traded OTC markets. The simplest approach is to compare roughly contemporaneous buy and sell prices of the same bond to impute a spread. Hong and Warga (2000) follow this approach by subtracting the average price for all sell transactions from the average buy price for each bond each day when there is both a buy and a sell. While imputed costs are easy to calculate, infrequent trading limits the amount of usable data. To allow buy and sell trades to occur on different days, Harris and Piwowar (2006), Bessembinder, Maxwell, and Venkataraman (2006), and others calculate trading costs using regressions of the change in price between transactions on the change in the trade sign.[10] Similar to our approach to measure effective bid-ask spreads, Green, Hollifield and Schühoff (2007) and Li and Schürhoff (2019) identify matching buys and sells to calculate round-trip trading costs. TCI extends these approaches by incorporating the costs of not trading.

While little has been done in OTC markets, measuring the opportunity costs of not trading has been recognized as important in equity markets (Perold (1988)). Because institutional trading data from Plexus and Ancerno only have realized trading volume, limited progress has been made in measuring the opportunity costs bias in execution costs for institutional trading. The opportunity costs for individual orders has been examined. For example, Harris and Hasbrouck (1996) compare the performance of limit versus market orders on the New York Stock Exchange. Limit orders impose opportunity costs due to delay and failure to execute.[11] Harris and Hasbrouck (1996) impute the cost of a failed limit order execution as being the cost if that limit order is converted to a market order. However, with the advent of high-frequency trading, limit orders are more likely to be replaced by repriced limit orders than converted into market orders. Hence, the imputed-fills approach is difficult to apply now.

[10]Hendershott and Madhavan (2015) use a variant of this approach by using interdealer trades as a benchmark price to calculate trading costs transaction by transaction.

[11]Bessembinder, Panayides, and Venkataraman (2009) extend this by examining opportunity costs for hidden limit orders.

The remainder of the paper is organized as follows. Section 1 provides institutional details about CLOs. Section 2 describes the data. Section 3 documents our findings on bid-ask spreads, trading volume, and BWIC failures. In Section 4 we introduce the true cost of immediacy which we then estimate in the data. Section 5 describes the true cost of immediacy during the COVID-19 pandemic. Section 6 concludes.

1 Background: CLOs and How They Trade

1.1 What are CLOs?

CLO securities are asset backed securities (ABS), where the underlying collateral is a pool of syndicated loans issued by lower-rated highly indebted corporations. The issuers of CLO securities are special purpose vehicles or trusts that own the pool of collateral and finance the holding by issuing debt and equity claims that are of different seniority to the cash flow from the collateral. The collateral for CLOs are mostly leveraged loans that Standard & Poors defines as senior secured bank loans rated BB+ or lower (i.e., below investment grade) or yielding at least 125 basis points above a benchmark interest rate (typically LIBOR or EURIBOR) and secured by a first or second lien.[12]

CLOs are complicated structures that consist of many debt tranches and a sliver of equity. The tranches are ranked highest to lowest in order of credit quality and cash flow priority and, thus, lowest to highest in order of riskiness. Although leveraged loans themselves are mostly rated below investment grade, a large fraction of CLO tranches is rated investment grade, benefiting from diversification and subordination of cash flows. CLOs aim to capture the excess spread between the portfolio of leveraged bank loans (assets) and the classes of CLO debt (liabilities), with the equity investors receiving any excess cash flows after the debt investors are paid in full. The popularity of CLOs has grown tremendously since the financial crisis, both in the US and in Europe.

Figure 2 shows the amount of US CLO securities outstanding over the sample period 2012–2020, split by tranche into the senior tranche rated AAA, mezzanine tranche rated AA–BBB, and

[12]Several characteristics make leveraged loans particularly suitable for securitizations, they pay interest on a consistent monthly or quarterly basis; they have a reasonably active secondary market; they have a high recovery rate in the event of default historically; and they originate from a large, diversified group of issuers.

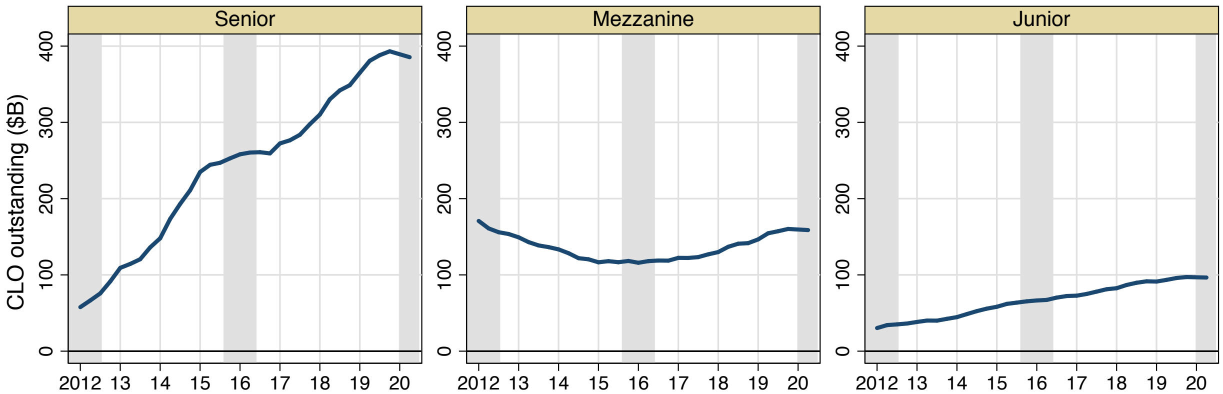


Figure 2: CLO amount outstanding by credit risk

The figure plots quarterly CLO amount outstanding in $ billions over the sample period 2012–2020, split by tranche into the senior tranche rated AAA, mezzanine tranche rated AA–BBB, and junior tranche rated BB–equity. Grey areas indicate stress periods in the credit market: 2012 European debt crisis, 2015-16 credit stress, and 2020 COVID-19 pandemic.

junior tranche rated BB–equity.[13] The market more than doubled since 2012. This trend partly reflects the growth of the leveraged loan market as issuers took advantage of investors' reaching-for-yield demand under a generally low interest rate environment. The amount of US leveraged loans outstanding was just over one trillion dollars as of late 2019. CLOs currently hold about two-third of the leveraged loan universe, and they are expected to bear the brunt of losses in leveraged loans when the business cycle turns. The three grey shaded areas in Figure 2 correspond to periods of credit market stress: the 2012 European debt crisis, the 2015-16 energy sector related credit stress, and the 2020 COVID-19 pandemic.

Ownership of CLOs varies by tranche. The least risky, most senior tranches are mainly owned by insurance companies (which favor income-producing investments) as well as banks (which need high-quality capital to meet regulatory requirements), particularly foreign banks.[14] The equity tranche is the riskiest, offers potential upside and a degree of control, and appeals to a wider universe of investors. According to the BIS, banks hold more than 50% of senior CLOs and none of the equity, which are held primarily by hedge funds, and structured credit funds and other asset

[13]The growth in AAA rated tranche in 2012-2014 partly reflects a substantial amount of AA rated tranches being upgraded to AAA.

[14]The Volcker Rule prevents banking entities from holding ownership interests in "covered funds". Many CLOs, especially those issued prior to the publication of the final rule, have features that would make them fall into the category of "covered funds". As a result, banking entities would not be permitted to hold an "ownership interest" in those CLOs. An exemption to the rule applies to CLOs that hold only loans. CLOs issued since 2014 (CLO 3.0) typically hold only loans, and can be held by banks.

managers, including CLO managers.[15]

The majority of outstanding CLOs are actively managed. Managers of these CLOs play an important role in selecting loans into the portfolio, actively monitoring the quality of collateral and trading in and out of loans.[16] To help ensure the cash flows generated by the underlying loans meet the distribution obligations in the various CLO tranches, CLOs face a series of coverage tests.Many of the CLO structures also have limits on the concentration of collateral in certain issuers or industries, and restrict the amount of loan collateral in the lowest rating categories (CCC and below).

1.2 How Do CLOs Trade?

Much like corporate bonds, municipal bonds, and other debt instruments, CLO securities are traded over-the-counter with dealers intermediating trade. Existing CLO investors sell their holdings through an auction where many dealers can simultaneously bid on the security. Such auctions are called BWICs (bids-wanted-in-competition). Investors choose a dealer to run the BWIC. The dealer send outs the BWIC to a list of other dealers to solicit bids before the bidding deadline. Typically, the organizing dealer decides which other dealers are contacted and collects the bids through email. The dealer communicates with the seller and whether the seller accepts the highest bid or lets the BWIC fail. The email mechanism is more flexible than fully automated trading, so the exact process is not fully standardized.

BWIC auctions operate as first-price sealed bid auctions, in that the winning dealer pays her bid. After the auction is completed, only the seller and the winner know the transaction price. The only information disseminated back to the market and to losing dealers is the second highest bid in the auction known as the "cover". In the case of not enough bids or bids below the seller's reservation value, the auction is disclosed as "DNT (Did Not Trade)". Because the seller is unable to exit his/her position in the security, we classify such an outcome as "auction failure". Sellers' reservation values are private and are not announced during or after the auction. As intermediaries, dealers mainly bid in auctions with the intention of resale. Dealers' profits are the difference between the resale price and their winning bid net of search cost and inventory holding cost.

[15] https://www.bis.org/publ/qtrpdf/r_qt1909w.htm

[16] Cordell, Roberts, and Schwert (2020) examine CLO and manager performance.

CLOs are, thus, traded in a unique hybrid fashion where the dealer-buy leg is conducted through auction and the dealer-sell leg is conducted through bilateral search. Shorting is rare in this market, likely due to the idiosyncratic nature of the securities. Therefore, dealer intermediation almost always starts with a dealer buy followed by a dealer sell, rather than the opposite. Many other types of structured products such as auto-ABS, credit card ABS and CMBS/RMBS are traded in a similar hybrid fashion. Our analysis is likely applicable to those securities as well.

2 Data

Our main data sources combine BWIC auction data from Creditflux with regulatory transactions data from FINRA.

2.1 Auction Data

Our BWIC auction data are from Creditflux. For each auction, we have information about the CUSIP, the cover (second highest bid), and a flag that indicates if the auction failed. We limit our sample to the period from 2012 to March 2020, when TRACE reporting for structured products was available and when the number of auctions was large enough for our estimation. The sample includes the onset of the COVID-19 pandemic with dramatic market volatility. We adopt a couple of filters for the sample, including requiring the CLO securities to be “US CLOs” denominated in USD. We keep only CUSIPs that appear in the TRACE master file. The majority of BWICs correspond to CUSIPs that are in the TRACE master file. The Appendix reports statistics on the cleaning filters that we have applied to the CLO BWIC data. After cleaning, we are left with a sample of 33,408 BWICs.

2.2 Trading Data and Bid-Ask Spread

The SEC started requiring structured products, including CLOs, to report trades in May 2011. Reported trades are not disseminated to the public. Only aggregate trading statistics are publicly disseminated. We use FINRA supervisory TRACE for transactions on CLOs. Transaction data, when matched to auction data, allow us to infer winning bids in the auction.[17] To the extend that

[17] Supervisory TRACE data is only available to regulators and not yet public.

some residual clients sell directly to their relationship dealers, instead of conducting auctions, we can observe those prices as well.

There are roughly 290K observations from TRACE for securities labeled as CDO/CLOs. Roughly 190K of these trades are for CUSIPs in the auction data. Roughly 40% of TRACE customer to dealer trades of CLOs can be matched to our auction data on a CUSIP-date basis. About 85% of our successful BWICs can be uniquely matched to a TRACE transaction that is customer-buy-from-dealer of the same bond on the same day. The Appendix reports statistics on the number of transactions that can be merged between TRACE and Creditflux.

CLOs trade very infrequently. A typical CLO in our sample has only traded 11 times (roughly 4 dealer buys, 6 dealer sells, 1 interdealer) over the entire span of our sample. The trading frequency also varies by the seniority of the tranches, with a typical (median) AAA rated tranche trading 15 times in the sample and a typical equity tranche trading 9 times.

Another notable observation is that, relative to the municipal bond and corporate bond markets, inter-dealer trades are not as prevalent in the CLO market. Roughly speaking, there is only 1/3 of an interdealer trade for every dealer-buy trade. The number is 1.7 for the municipal bond market in 2018, 1.8 for investment-grade corporate bond, and 1.4 for high-yield corporate bonds in 2019. This is perhaps not surprising given the competitive nature of the customer-to-dealer leg of the transaction. In the empirical OTC market literature, a common way to measure transaction costs or liquidity of infrequently-traded fixed income securities is through effective bid-ask spread, or realized return for dealers, which calculates the difference between dealer buy prices and dealer sell prices. The effective bid-ask spread can be viewed as a measure of compensation for dealers' intermediation services.

Following Li and Schürhoff (2019), which extends upon Green, Hollifield and Schühoff (2007), we form dealer roundtrips by matching trades of the same bond that are dealer-buy-from-customer to the dealer-sell-to-customer trade by the same dealer. Roughly 46K roundtrips can be found for the sample of bonds in our auction data. Over 95% of these roundtrips has only one dealer between the selling customer and the buying customer (CDC roundtrips, as in Li and Schürhoff (2019)). Roughly 17 thousand of these CDC roundtrips can be uniquely matched to a successful auction in our BWIC data, where the first leg of the roundtrip happened on the same day of the auction. These rountrips correspond to about 60% of all successful auctions. Approximately half

Table 1: Summary statistics

The table reports summary statistics for BWICs in all CLOs over the sample period 2012–2020 for different sample splits. Panel A reports results for the senior tranche rated AAA, Panel B for the mezzanine tranche rated AA–BBB, and Panel C for the junior tranche rated BB–equity.

Variable	Mean	SD	5%	25%	50%	75%	95%
Panel A: Senior tranche (I = 9,000 BWICs)							
CLO vintage: 1.0/2.0/3.0				15%/11%/74%			
CLO rating: AAA				100%			
BWIC fail rate				7%			
Par value of trade ($M)	2.77	4.16	0.25	1.00	2.80	8.00	27.25
CLO issue size ($M)	228.24	2.45	30.00	225.72	302.50	363.05	492.75
Bid-ask spread (%)	0.04	0.08	0.00	0.01	0.02	0.05	0.13
Panel B: Mezzanine tranche (I = 12,955 BWICs)							
CLO vintage: 1.0/2.0/3.0				24%/16%/60%			
CLO rating: AA/A/BBB				27%/31%/42%			
BWIC fail rate				16%			
Par value of trade ($M)	2.48	2.69	0.49	1.25	2.75	5.00	11.00
CLO issue size ($M)	33.94	1.74	15.95	24.50	32.00	46.40	78.00
Bid-ask spread (%)	0.10	0.29	0.00	0.02	0.05	0.12	0.31
Panel C: Junior tranche (I = 11,453 BWICs)							
CLO vintage: 1.0/2.0/3.0				12%/29%/58%			
CLO rating: BB/B/Equity				70%/14%/16%			
BWIC fail rate				30%			
Par value of trade ($M)	2.72	2.32	0.60	1.70	3.00	5.00	9.80
CLO issue size ($M)	22.53	1.91	8.40	17.00	23.00	31.75	56.50
Bid-ask spread (%)	0.12	0.19	0.01	0.02	0.09	0.13	0.38

of the matched roundtrips happen on the same day, about 11% have an inventory time of one day; 16% of the roundtrips have an inventory time between one day and seven days; the rest of the roundtrips have an inventory time up to 300 days. For effective bid-ask spread, we restrict the sample to roundtrips no more than 1 day apart, to limit the effect of mark-to-market price changes in the price difference between the ask leg and bid leg.

Table 1 provides summary statistics of key variables in our sample. We split the BWICs into auctions of senior, mezzanine and junior CLO tranches. All of the Senior tranche CLOs are rated AAA by definition. Mezzanine tranche CLOs are roughly evenly split among AA, A, and BBB rated. Junior tranche CLOs are all below investment grade. The majority of the junior tranche CLOs are rated BB and only 16% of the junior tranche auctions are for the equity CLO tranche, underscoring how unlikely it is for an equity CLO tranche to trade in the secondary market. Depending on when the CLO was issued, each CLO is classified into vintage 1.0, 2.0 or 3.0. CLO 1.0s were issued before the 2007 financial crisis. CLO 2.0s were issued between 2008 and 2013, and are considered to have a robust structure compared to securities from earlier vintage. CLO 3.0s were issued after 2014, with most of them allowing only loans (no bonds) in the collateral pool, so as to be "Volcker" compliant. CLO 3.0s account for over half of our auctions across different tranches.

Since CLOs are held by institutional investors, they trade in large blocks. The median size of a trade (auction) in our sample is around $3 million. The median CLO security in our sample has a par outstanding value of $222/$24/$17 million for the senior/mezzanine/junior tranche.

Effective bid-ask spreads are small in our sample. Median bid-ask spreads are 2bps/5bps/9bps of the CLO face value for the senior/mezzanine/junior tranche. This is a tad smaller than the round-trip costs of corporate bonds with comparable ratings. This is likely due to the fact that trade sizes for CLOs are larger than the average size of an institutional trade for a comparable corporate bond and the bid-ask spread tends to decline with trade size for fixed-income securities.

Table 1 provides the average fraction of failed BWICs. Table 1 also tabulates the distribution of and variation in the predicted probability of failure in each auction based on the probit model in Equation 2 in Section 3.2. On average, only 7% of the senior tranche CLO BWICs fail and 16% of BWICs in the mezzanine tranche, while the junior tranche BWICs fail 30% of the time.

2.3 Time Series Data

Additional information about the CLOs such as amount outstanding and dates of issuance are from Bloomberg. Leveraged loan market spreads are from JP Markets. It captures the CLO market condition. Information about the CLO dealer CDS spread is from Markit. Dealer CDS spread captures CLO dealers' funding conditions. There are about 20 active dealers in the CLO market. We use average CDS spread of all primary dealers to proxy for the funding costs of dealers in the CLO market.

Figure 3 documents the market and dealers' funding conditions in the CLO market (Panel A), CLO trading volume (Panel B), and CLO realized bid-ask spread over the sample period 2012–2020. Results reported in Panels B and C are split by tranche. Grey areas indicate periods of market stress: 2012 European debt crisis, 2015-16 credit stress, and 2020 COVID-19 pandemic.

Panel A of Figure 3 shows leveraged loan spread (left plot) and dealer CDS spread (right plot).

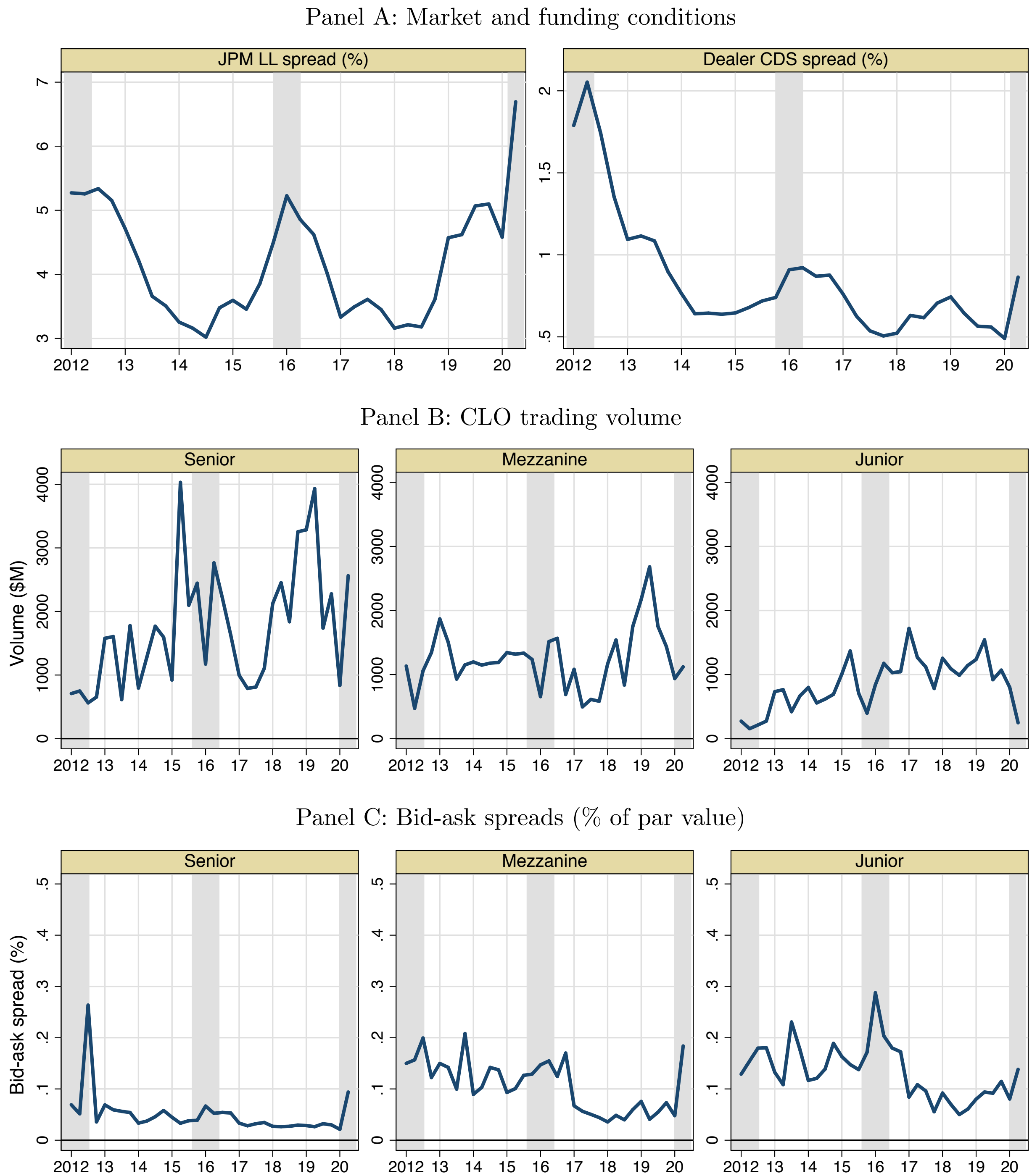


Figure 3: Economic conditions, CLO trading volume and bid-ask spreads

The figure documents in Panel A the market and funding conditions in the CLO market over the sample period 2012–2020. The left plots the evolution of the JPM leverage loan spread index, while the right plots the evolution of the average CDS spread on all primary dealers active in the CLO market. The figure documents in Panels B and C trading volume and bid-ask spreads in the CLO market over the sample period 2012–2020, split by tranche into the senior tranche rated AAA, mezzanine tranche rated AA–BBB, and junior tranche rated BB–equity. Grey areas indicate periods of market stress: 2012 European debt crisis, 2015-16 credit stress, and 2020 COVID-19 pandemic.

The leveraged loan spread fluctuates between 3% to 5.3% during most of the sample period, and has risen to almost 7% in March 2020, during the COVID-19 pandemic. Dealer CDS spreads follow the same time trend as the leveraged loan spread. Average dealer CDS spread were over 2% during the European crisis in 2012, and are mostly below 1% since 2013. Panel B shows CLO trading volume. CLO trading volume is consistent with the amount of CLO securities outstanding from Figure 2. Senior and junior amounts outstanding are comparable to each other in 2012, when the mezzanine tranche was approximately twice the size of the senior tranche. Consequently, senior and junior CLO tranches have lower trading volume in 2012 than the mezzanine tranche. Trading volume seems to be a leading indicator for credit stress events for all CLO tranches. Trading volume tends to fall ahead of credit stresses, and recovers about a quarter prior to the end of a stress period.

Panel C of Figure 3 plots the realized bid-ask spread. As discussed in Section 2, we measure bid-ask spreads on successful BWICs as the difference between the best bid submitted by the dealers in the BWIC and the ask price that the CLO buyer pays to the winning dealer, as a percent of the par value of the trade. We restrict the sample to roundtrips where the dealer sell leg and dealer buy leg are no longer than one day apart, if otherwise market movements start to contaminate the measurement of bid-ask spreads. Realized bid-ask spreads are quite low and equal to 5bps/10bps/12bps of the CLO face value for senior/mezzanine/junior tranches. Spreads tend to fluctuate with market-wide credit risk.

The next section focuses on the properties and determinants of traditional liquidity measures, effective bid-ask spread and trading volume, and introduce the concept of BWIC failure.

3 Measures of Liquidity

This section reports empirical findings on the effective bid-ask spread, calculated as a percentage of CLO value, and BWIC failure rate. The choice of the right explanatory variables, $\boldsymbol{X}$, that we use throughout the rest of the study, is quite important as they have to explain as much of variation in CLO bid-ask spreads and failure rates as possible. Having too many controls, however, shrinks our sample and makes some future empirical methodology challenging to implement. We thus include in $\boldsymbol{X}$ the par value of trade, CLO vintage and issue size, and market and dealer conditions (JPM leveraged loan spread and dealer CDS spread). We also add credit rating splits for mezzanine and

Table 2: Effective bid-ask spread: Splits by trade size, CLO type, and market state

The table reports bid-ask spread on successful BWICs over the sample period 2012–2020 for different sample splits. Panel A reports results for the senior tranche rated AAA, Panel B for the mezzanine tranche rated AA–BBB, and Panel C for the junior tranche rated BB–equity. Low/Medium/High column indicates value of the varied characteristic while other characteristics are held fixed at their medium value.

	Bid-ask spread (% of par) split by		
Split variable	Low	Medium	High
Panel A: Senior tranche (I = 2,234 BWICs)			
Par size of trade	0.04	0.05	0.04
CLO vintage (1.0/2.0/3.0)	0.06	0.04	0.04
CLO issue size	0.05	0.03	0.04
JPM LL spread	0.03	0.04	0.05
Dealer CDS spread	0.03	0.03	0.06
Panel B: Mezzanine tranche (I = 3,370 BWICs)			
Par size of trade	0.10	0.11	0.10
CLO vintage (1.0/2.0/3.0)	0.13	0.11	0.08
CLO rating (AA, A, BBB)	0.08	0.10	0.11
CLO issue size	0.11	0.09	0.10
JPM LL spread	0.09	0.10	0.11
Dealer CDS spread	0.07	0.10	0.14
Panel C: Junior tranche (I = 2,853 BWICs)			
Par size of trade	0.12	0.12	0.13
CLO vintage (1.0/2.0/3.0)	0.15	0.14	0.11
CLO rating (BB, B, Equity)	0.11	0.14	0.16
CLO issue size	0.13	0.10	0.14
JPM LL spread	0.10	0.12	0.14
Dealer CDS spread	0.09	0.11	0.17

junior tranches.

3.1 Effective Bid-Ask Spreads

Table 2 shows how CLO bid-ask spread varies with the explanatory variables $\boldsymbol{X}$ using sample split approach. The Low/Medium/High columns indicate values of respective characteristic in its bottom/middle/top terciles. Panels A/B/C report results for the senior/mezzanine/junior tranche.

Unlike some other OTC markets with at least some retail investor participation, the effective bid-ask spread does not vary much with trade size, as participants in the CLO market are almost entirely institutions. Vintage is important for bid-ask spread. CLO 3.0s have the smallest spread and CLO 1.0s have the largest spread. The effective bid-ask spread declines with CLO credit rating.

It is equal to 8bps/10bps/11bps for AA/A/BBB rated mezzanine tranches, and 11bps/14bps/16bps for BB/B/Equity rated junior tranches. Issue size is only weakly related to effective bid-ask spread. Bid-ask spread increases with the JPM leveraged loan spread and with the dealer CDS spread for all CLO tranches. Overall, effective bid-ask spread is more sensitive to characteristics $\boldsymbol{X}$ for lower rated CLO tranches.

We then examine determinants of effective bid-ask spread using multivariate analysis. We estimate the following model for bid-ask spread that correspond to a successful BWIC for CLO i at time t:

$$\text{Bid-ask spread}_{it} = \alpha + \alpha_t + \boldsymbol{\beta}'\boldsymbol{X}_{it} + \epsilon_{it}, \tag{1}$$

where the α_t coefficients represent quarter fixed effects. The set of explanatory variables $\boldsymbol{X}$ includes characteristics of the trade (log of par value), of the CLO (log of amount outstanding, vintage, CLO rating), as well as market and dealer conditions (JPM leveraged loan spread and dealer CDS spread). We do not include CLO fixed effects α_i since individual CUSIPs do not trade often enough.

Table 3 reports parameter estimates for the determinants of the effective bid-ask spread on successful BWICs. All results are split by CLO tranche. The baseline specification (Column 1) include only trade and CLO characteristics. We add credit rating dummies to the baseline specification in the case of the mezzanine and junior tranches. Across specifications 2 to 5, we vary the set of explanatory variables by adding market and dealer characteristics, and, finally, quarter fixed effects α_t. This approach allows us to trace the explanatory power of the incremental variables.

Panel A of Table 3 presents results for the senior tranche. Results are generally consistent with the sample split results in Table 2. Vintage effect is quite robust to specifications, with newer vintages significantly cheaper to trade. The R^2 for the specification in Column (1) is relatively low at 1.3%, suggesting limited explanatory power from characteristics of the trade or the CLO. Adding market condition variable such as leveraged loan spread and dealer CDS spread (Column 2 and 3) improves R^2 noticeably. Bid-ask spread is significantly positively related to both leveraged loan spread and dealer CDS spread. Therefore, when market condition or dealer health worsens, bid-ask spread increases. When quarter-fixed effects are included together with market condition variables (Column 6), leveraged loan market spread continues to be significant.

Table 3: Effective bid-ask spread on successful BWICs

The table reports the determinants of the effective bid-ask spread on successful BWICs. The sample is restricted to CLO round-trip trades with one day or less in dealer inventory. Panel A reports results for the senior tranche rated AAA, Panel B for the mezzanine tranche rated AA–BBB, and Panel C for the junior tranche rated BB–equity. Standard errors are robust to heteroskedasticity. Significance levels are indicated by * (10%), ** (5%), *** (1%).

	Bid-ask spread (% of par value)				
	(1)	(2)	(3)	(4)	(5)
Panel A: Senior tranche (I = 2,234 BWICs)					
log(Par value of trade)	−0.00	−0.00**	−0.00*	−0.00**	−0.00**
CLO 2.0 vintage	−0.02***	−0.02***	−0.01	−0.01**	−0.02**
CLO 3.0 vintage	−0.02***	−0.03***	−0.00	−0.02***	−0.02***
log(CLO issue size)	−0.00	−0.00	−0.01	−0.00	−0.01
CLO issue size missing	−0.00	−0.00	−0.00	−0.00	0.00
JPM LL spread		0.02***		0.01***	0.02**
Dealer CDS spread			0.08***	0.03***	0.02
Quarter FE	No	No	No	No	Yes
R^2	0.013	0.067	0.044	0.071	0.103
Panel B: Mezzanine tranche (I = 3,370 BWICs)					
log(Par value of trade)	−0.01**	−0.01**	−0.01***	−0.01***	−0.01***
CLO 2.0 vintage	−0.03**	−0.02*	−0.00	−0.01	−0.01
CLO 3.0 vintage	−0.05***	−0.06***	−0.02	−0.04***	0.00
log(CLO issue size)	0.00	−0.00	0.00	0.00	0.00
CLO issue size missing	−0.05***	−0.05***	−0.05***	−0.05***	−0.03*
A rating	0.01	0.01	0.01	0.00	0.00
BBB rating	0.01	0.01	0.02*	0.02*	0.02
JPM LL spread		0.03***		0.02***	0.02
Dealer CDS spread			0.12***	0.08***	0.12
Quarter FE	No	No	No	No	Yes
R^2	0.016	0.037	0.034	0.042	0.072
Panel C: Junior tranche (I = 2,853 BWICs)					
log(Par value of trade)	0.00	0.00	−0.00	0.00	−0.00
CLO 2.0 vintage	−0.01	−0.00	0.01	0.01	0.00
CLO 3.0 vintage	−0.04***	−0.04***	−0.00	−0.01	0.01
log(CLO issue size)	0.00	0.00	0.00	0.00	0.00
CLO issue size missing	−0.02	−0.02	−0.01	−0.01	0.01
B rating	0.04***	0.04***	0.04**	0.04**	0.03**
Equity rating	0.05***	0.05***	0.05***	0.06***	0.07***
JPM LL spread		0.03***		0.02***	0.01
Dealer CDS spread			0.13***	0.09***	0.05
Quarter FE	No	No	No	No	Yes
R^2	0.016	0.035	0.035	0.042	0.106

Panel B of Table 3 shows results for the mezzanine tranche. The results are similar to the ones reported in Panel A for the senior tranche. Unique to this tranche, trade size is negatively significant across all specifications–larger trades are associated with smaller bid-ask spreads. Results reported in Column 5 indicate that once quarter fixed effects are included, only trade size retains explanatory power. The highest R^2 in Panel B is equal to 7.2% (Column 5). Panel C of Table 3 reports results for the junior tranche. Notably, credit rating plays a more prominent role. In fact, when quarter fixed effects are included, only rating matters. Perhaps unsurprisingly, equity tranches have the highest bid-ask spread.

Overall, effective bid-ask spreads do not vary much within a quarter for CLOs with the same vintage and credit rating. When bid-ask spreads do vary within a quarter, the variation is mainly due to major economy-wide credit events affecting the riskiness of leveraged loans held by the CLOs.

3.2 Trading Volume and BWIC Failures

The number of successful and failed trades are also natural liquidity measures. While the number of successful trades, or trading volume, have been extensively used in the literature, our paper is first to perform a comprehensive study of failed trades. Trading volume alone is a downward biased measure of illiquidity as it does not capture the lost trade value due to failure to strike a deal.

Panel A of Figure 4 documents BWIC activity (solid line) and trading volume (dashed line) in the CLO market. Panel B of Figure 4 plots the failure rate in percent. Each plot covers the sample period 2012–2020, and both panels are split by tranche. Panel A shows that the number of BWICs has been increasing over time across all tranches, consistent with the growth of the market. The number of BWICs and trades tend to decline during credit stress events and BWIC failure rate tends to increase during stress periods. The average failure rate is different across tranches. It ranges from 0% to 15% for the senior tranche, 5%–30% for the mezzanine tranche, and 8%–60% for the junior tranche.

It is notable that the number of BWICs and failure rate seem to be leading indicators of market stress. This is particularly notable during the 2015-2016 episode, when the number of BWICs dropped substantially early in the stress period and the failure rate rose sharply. This is possibly due to CLO sellers being slow to adjust their reserve prices in response to sharply declining demand. Sellers catch up with the declining demand by either reducing their reserve values or/and by reducing the supply.

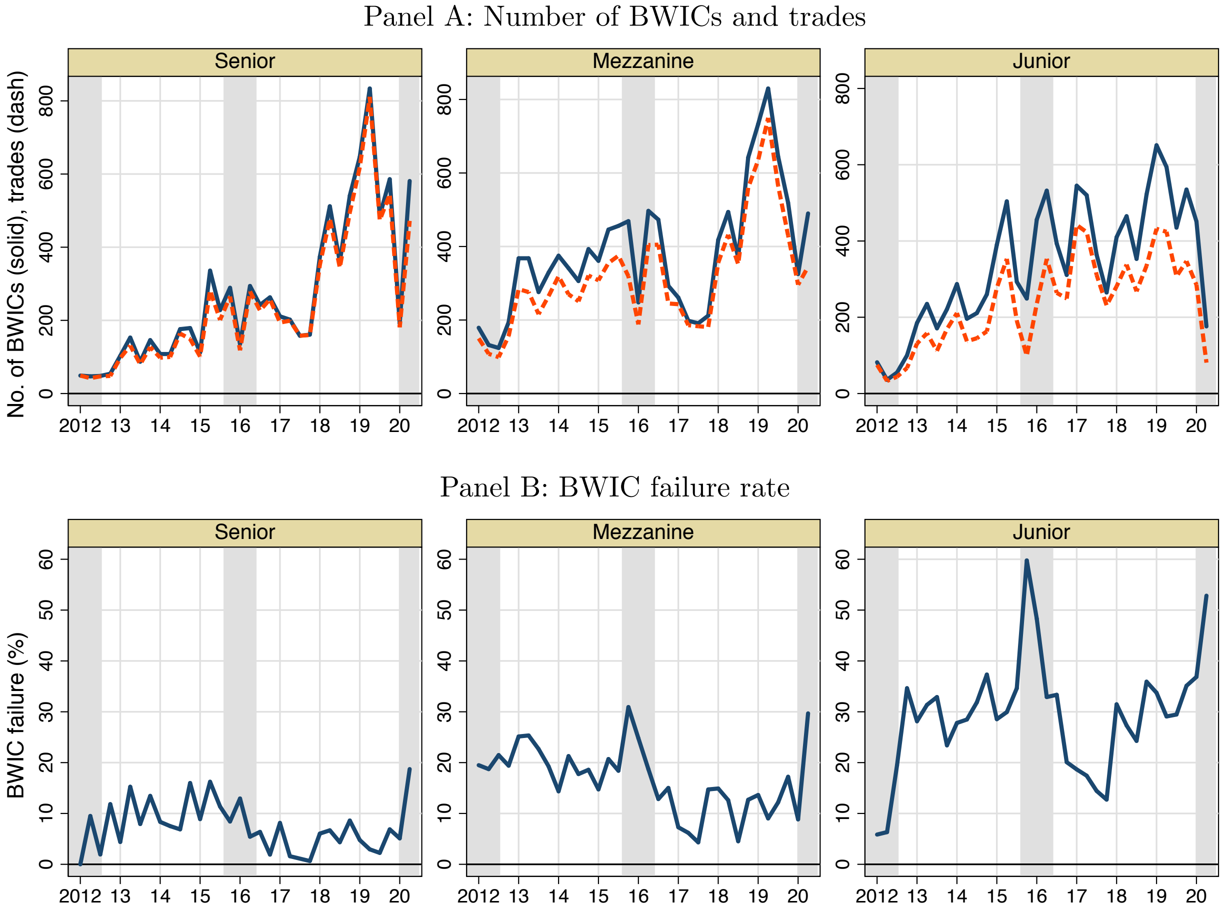


Figure 4: BWIC activity and failure rates

The figure documents quarterly BWIC activity (Panel A) and BWIC failure rates (Panel B) in the CLO market over the sample period 2012–2020, split by tranche into the senior tranche rated AAA (left), mezzanine tranche rated AA–BBB (middle), and junior tranche rated BB–equity (right). Grey areas indicate period of market stress: 2012 (European debt), 2015-16, and 2020 (COVID-19 pandemic).

Table 4 compares BWIC fail rate using sample splits based on different explanatory variables. Low/Medium/High columns indicate values of the varied characteristic in its bottom/middle/top tercile. Panels A/B/C report results for senior/mezzanine/junior tranches, respectively.

For the senior tranche, larger trades fail more often with rates equal to 3%/7%/12% for Low/Medium/High trade sizes. The relation between BWIC fail rate and CLO issue size is weak—BWICs of smaller CLOs fail a bit more at 9%, while medium and large CLOs both fail about 7% of the time. CLO 3.0 BWICs fail slightly less than CLO 1.0 and 2.0 BWICs, i.e., 7% compared to 10%. The BWIC fail rate increases with the dealer CDS spread, 5%/8%/9% for Low/Medium/High CDS spreads. This suggests that dealers may bid higher when the cost of funding is lower.

For the mezzanine tranche, BWIC fail rates vary quite a lot with trade, market, and dealer

Table 4: BWIC fail rate: Splits by trade size, CLO type, and market state

The table reports BWIC fail rates for different sample splits. Panel A reports results for the senior tranche rated AAA, Panel B for the mezzanine tranche rated AA–BBB, and Panel C for the junior tranche rated BB–equity. Low/Medium/High columns indicate values of the varied characteristic while other characteristics are held fixed at their medium value.

	BWIC fail rate split by		
Split variable	Low	Medium	High
Panel A: Senior tranche (I = 9,000 BWICs)			
Par size of trade	0.03	0.07	0.12
CLO vintage (1.0/2.0/3.0)	0.10	0.09	0.07
CLO issue size	0.09	0.07	0.07
JPM LL spread	0.08	0.07	0.08
Dealer CDS spread	0.05	0.08	0.09
Panel B: Mezzanine tranche (I = 12,955 BWICs)			
Par size of trade	0.13	0.17	0.20
CLO vintage (1.0/2.0/3.0)	0.19	0.18	0.15
CLO rating (AA, A, BBB)	0.12	0.16	0.20
CLO issue size	0.19	0.17	0.14
JPM LL spread	0.14	0.17	0.18
Dealer CDS spread	0.13	0.16	0.21
Panel C: Junior tranche (I = 11,453 BWICs)			
Par size of trade	0.26	0.31	0.35
CLO vintage (1.0/2.0/3.0)	0.25	0.31	0.31
CLO rating (BB, B, Equity)	0.27	0.37	0.39
CLO issue size	0.30	0.28	0.33
JPM LL spread	0.27	0.29	0.35
Dealer CDS spread	0.27	0.31	0.33

conditions. Similar to the senior tranche, BWIC with larger par amount fail more often. Fail rates increase with the riskiness of the tranches, with rates equal to 12%/16%/20% for AA/A/BBB ratings. BWICs of CLOs with a larger issue size fail less often. This is potentially due to the fact that larger issues may have a wider investor base, and are easier to find buyers. BWIC fail rates are higher when the leveraged loan spread is higher and when dealers' funding costs are higher. The qualitative nature of all these relations remains the same in the case of the junior tranche as Panel C demonstrates. In summary, unlike the effective bid-ask spread, BWIC fail rates vary significantly with trade, market, and dealer conditions.

We then examine the determinants of BWIC failure by estimating the following Probit regression

(Φ is the normal distribution function):

$$\Pr(\text{BWIC failure}_{it}) = \Phi(\alpha + \alpha_t + \boldsymbol{\beta}' \boldsymbol{X}_{it} + \epsilon_{it}). \tag{2}$$

As in Table 3, $\boldsymbol{X}$ includes characteristics of the trade (log of par), the CLO issue (log of amount outstanding, vintage, rating), as well as market and dealer conditions (JPM leveraged loan spread and dealer CDS spread).

Table 5 inherits its layout from Table 3 and reports parameter estimates for the determinants of BWIC failure, split by tranche. The baseline specification (Column 1) includes the trade and CLO characteristics only. We add credit rating dummies to the baseline specification of the mezzanine and junior tranches. Across specifications 2 to 5, we vary the set of explanatory variables by including market and dealer characteristics, and quarter fixed effects α_t, incrementally.

Panel A of Table 5 presents results for the senior tranche. The baseline specification (Column 1) confirms our findings from sample splits (Table 4) that the fail rate increases with trade size and decreases with CLO issue size. Adding leveraged loan spread (Column 2) slightly improves the pseudo-R^2 from 4.9% in the baseline specification to 5.5%. In addition, the coefficient on the leveraged loan spread is positive and statistically significant. Dealer CDS spread (Column 3) adds little in terms of the explanatory power to the baseline specification. The coefficient on the dealer CDS spread is positive and both statistically and economically significant. Depending if quarter fixed effects are included (Column 4 and 5), only one of the leveraged loan spread and dealer CDS spread stays significant and positive .

Panel B of Table 5 shows results for the mezzanine tranche. The results are similar to the ones for the senior tranche. The main difference is that the regression coefficients on both the leveraged loan spread and dealer CDS spread are positive and statistically significant at 1% level (Column 4). However, once the quarter fixed effects are included (Column 5), only the dealer CDS spread remains positive and statistically significant at 1% level. Another noteworthy result is that the fail rate increases monotonically with the credit rating. In fact, BWICs of A/BBB-rated CLOs are 14%/32% more likely to fail than BWICs of AA-rated CLOs (Column 5).

Panel C of Table 5 reports results for the junior tranche. Results are qualitatively similar to the ones reported for more senior tranches. Notably, Vintage effect is the most prominent in the

Table 5: BWIC fail rate

The table reports the determinants of BWIC failure. Estimates are obtained from Probit regressions. Panel A reports results for the senior tranche rated AAA, Panel B for the mezzanine tranche rated AA–BBB, and Panel C for the junior tranche rated BB–equity. Standard errors are robust to heteroskedasticity. Significance levels are indicated by * (10%), ** (5%), *** (1%).

	Probability of BWIC failure				
	(1)	(2)	(3)	(4)	(5)
Panel A: Senior tranche (I = 9,000 BWICs)					
log(Par value of trade)	0.21***	0.21***	0.21***	0.21***	0.21***
CLO 2.0 vintage	0.09	0.10	0.14*	0.10	0.15*
CLO 3.0 vintage	0.00	−0.05	0.09	−0.03	0.09
log(CLO issue size)	−0.07***	−0.07***	−0.07***	−0.07***	−0.08***
CLO issue size missing	−0.31**	−0.33**	−0.31**	−0.33**	−0.22
JPM LL spread		0.09***		0.09***	−0.11*
Dealer CDS spread			0.25***	−0.02	1.18***
Quarter FE	No	No	No	No	Yes
Pseudo-R^2	0.049	0.055	0.051	0.055	0.103
Panel B: Mezzanine tranche (I = 12,955 BWICs)					
log(Par value of trade)	0.13***	0.13***	0.13***	0.13***	0.12***
CLO 2.0 vintage	−0.00	0.02	0.07	0.05	0.10**
CLO 3.0 vintage	−0.07**	−0.10***	0.06	−0.02	0.23***
log(CLO issue size)	−0.08***	−0.09***	−0.08***	−0.09***	−0.08***
CLO issue size missing	0.03	0.03	0.09	0.06	0.17**
A rating	0.16***	0.16***	0.15***	0.15***	0.14***
BBB rating	0.32***	0.33***	0.32***	0.32***	0.32***
JPM LL spread		0.11***		0.08***	−0.07*
Dealer CDS spread			0.38***	0.20***	0.85***
Quarter FE	No	No	No	No	Yes
Pseudo-R^2	0.019	0.025	0.024	0.026	0.053
Panel C: Junior tranche (I = 11,453 BWICs)					
log(Par value of trade)	0.15***	0.15***	0.14***	0.15***	0.14***
CLO 2.0 vintage	0.15***	0.18***	0.21***	0.17***	0.18***
CLO 3.0 vintage	0.22***	0.21***	0.33***	0.19***	0.29***
log(CLO issue size)	−0.07**	−0.08**	−0.08**	−0.08**	−0.09**
CLO issue size missing	0.17***	0.15***	0.20***	0.14**	0.24***
B rating	0.22***	0.25***	0.23***	0.26***	0.29***
Equity rating	0.31***	0.35***	0.34***	0.36***	0.41***
JPM LL spread		0.17***		0.18***	−0.04
Dealer CDS spread			0.33***	−0.08	0.86***
Quarter FE	No	No	No	No	Yes
Pseudo-R^2	0.018	0.029	0.021	0.030	0.059

junior and mezzanine tranches, with BWICs of CLO 2.0s/3.0s more likely to fail than BWICs of CLO 1.0s. This is likely due to the fact that newer vintages have smaller senior tranche and relative larger subordinated tranches to share potential credit loss.

These multivariate results confirm that there exists a lot of variability in BWIC failure rates with trade, market, and dealer conditions. This suggests that the true costs of immediacy that incorporate the expected losses from the failure to trade vary significantly across time, CLO and dealer types, as well as with trade characteristics. However, the value lost to both the seller and the buyer due to the inability to trade is not directly observed in the data. Therefore, it has to be estimated from the data which is done in the next section.

4 The True Cost of Immediacy

In this section we define the true cost of immediacy (TCI) and estimate TCI in the CLO market.

4.1 Definition

In markets without firm quotes, the observed cost of immediacy widely used in both academia and industry is the effective bid-ask spread calculated from successful transactions where a dealer buys the asset at the bid price B and sells it at the ask price A:

$$\mathbb{E}[A - B|\text{Trade}]. \tag{3}$$

For instance, the CLO secondary market is organized in sealed-bid first-price auctions and, therefore, $B \equiv B^{1:N} = \max\{B_n|n \in \{1, ..., N\}\}$, where B_n is the bid price for the CLO by dealer n out of $n = 1, ..., N$ dealers participating in the BWIC (N varies across BWICs). However, the canonical relation (3) ignores the fact that trades fail and this is costly since the outside option of the seller can be quite low. The failure to trade is especially costly when the seller's need to sell is very high or when the value of sellers' outside option is close to zero. For instance, CLO investors are long-term investors and tend to sell their holdings when hit by a liquidity shock. The examples of liquidity shocks include hitting capital constraints, portfolio rebalancing, reach for cash, and others. A seller unable to sell the CLO defaults to keeping it and, therefore, may suffer large losses due to CLO devaluation, legal fees, regulatory penalties, and credit rating downgrade. These losses have to be incorporated into the cost of immediacy.

In order to account for trade failures in the cost of immediacy, we propose to use in (3) the expected total payoff for the asset seller, Π, instead of the expected successful bid and, therefore, define the true cost of immediacy or TCI as

$$\text{TCI} \equiv \mathbb{E}[A - \Pi]. \tag{4}$$

Since we can see all dealer-initiated sales in our CLO data, we are going to treat the ask price A as fully known and focus our discussion on the costs of immediacy born by the CLO seller, Π. In order to obtain the expression for Π we assume that the seller accepts the highest bid when it is above her outside option, R. Consistent with a standard theory of reserve-price auctions, R can be viewed as a minimum bid (reserve price) the CLO seller accepts in a BWIC:[18]

$$R = \inf_{(B_1, B_2, \ldots, B_N)} \{B^{1:N} | \text{Trade}\}, \tag{5}$$

where the infimum is taken over all possible realizations of the N bids $B_1, B_2, \ldots, B_N$ that lead to trade. The sellers' outside option is likely to be at or below her reservation value for two reasons. First, if the BWIC fails, bidders have no incentive to bid above the reservation value in any subsequent auction. Second, sellers have no incentive to set the reserve price below their outside option. Therefore, we refer to R as the reserve price.

While we are going to treat R as a constant for now, later, when we estimate the TCI, we will use R as a source of heterogeneity across CLOs and their sellers. For instance, R may depend on the type of CLO and market conditions. More patient/impatient CLO sellers and sellers with higher/lower reputation are likely to set a higher/lower R, and more so during normal times than crisis periods during which CLO investors may be forced sellers.

Let $\Pr(\text{Fail}) = 1 - \Pr(\text{Trade})$ be the probability that a trade fails to materialize.[19] In the case

[18] Our CLO data supports the view that when auctions fail, the seller is unable to trade. Table IA.1 in the Internet Appendix shows that the probability of a failed auction to be followed by an OTC trade either on the same day or within a day of the auction is quite low.

[19] Note that we are unable to measure the frequency and costs for when investors want to sell, but do not even bother to try because the market is sufficiently illiquid.

of the CLO secondary market Pr(Fail) is the probability of a BWIC failure and, therefore, it is directly observable in the data. Then the seller of the asset should get the expected sale price if the trade succeeds, $\mathbb{E}[B|\text{Trade}]$, and she should get her outside option, R, if the trade fails and she keeps the asset. The expression below formalizes this intuition:

$$\mathbb{E}[\Pi] = \underbrace{(1 - \Pr(\text{Fail})) * \mathbb{E}[B|\text{Trade}]}_{\text{Trade}} + \underbrace{\Pr(\text{Fail}) * R}_{\text{Outside option}}. \tag{6}$$

In the BWIC case the sale price, B, is equal to the best-bid, $B^{1:N}$. Combining relations (4) and (6) leads to the following definition of the TCI.

DEFINITION: *The true cost of immediacy,* TCI*, is equal to*

$$TCI \equiv \mathbb{E}[A - \Pi] = \underbrace{\mathbb{E}[A - B|\text{Trade}]}_{\text{Effective bid-ask spread}} + \underbrace{\Pr(\text{Fail})}_{\text{Fail rate}} * \underbrace{(\mathbb{E}[B|\text{Trade}] - R)}_{\text{Cost of trade failure}}. \tag{7}$$

Relation (7) highlights three key components of the TCI. The first component is the traditional bid-ask spread. The other two components, the BWIC fail rate and the cost of failure, enter TCI as a product. TCI is equal to the bid-ask spread when the failure rate is zero. Figure 4 shows that the failure rate is rarely zero even for the senior CLO tranche which has mean(median) fail rate equal to 8%(6%). This implies that even for the "safest" CLOs the TCI should be greater, and, most of time, significantly greater than the bid-ask spread. The cost of trade failure or, in other words, the opportunity cost, is the third component of the TCI. It declines with R and increases in the expected sale price. Intuitively, the costliest failures are the ones where the seller has had a lousy outside option and expected to sell the CLO for a high price. This component is not directly observable in the data and, therefore, has to be estimated.

We believe that the expression (4) is much more comprehensive than the realized bid-ask spread (3) since it incorporates expected payoffs from all options available to the seller. In the next section we discuss how to measure the TCI in the data.

4.2 Measuring the True Cost of Immediacy

The true cost of immediacy for CLOs is comprised of the expected bid-ask spread in successful BWICs, the probability of BWIC failure, and the cost of BWIC failure. All three quantities have to be estimated in the data utilizing a cross-section of both successful and failed BWICs as functions of observable characteristics $\boldsymbol{X}_i$ in BWICs $i = 1, ..., I$. For the sake of consistency, we use the same set of explanatory variables $\boldsymbol{X}_i$ as in Section 2. It includes quarter fixed effects, characteristics of the trade (log of par), of the CLO (log of CLO amount outstanding, CLO vintage, CLO rating), as well as market and dealer conditions (JPM leveraged loan spread and dealer CDS spread). In addition, to account for differences in credit risks, we estimate TCI separately for senior, mezzanine, and junior CLO tranches. After presenting our estimates for TCI, Section 4.4 discusses theoretical and empirical issues with measuring TCI.

The relationship between bid-ask spreads and the explanatory variables, $\boldsymbol{X}_i$, is captured by relation (1). It has been estimated on successful BWICs in Subsection 3.2 and Table 3 reports parameter estimates. The relationship between BWIC fail rate, $\Pr(\text{Fail}_i|\boldsymbol{X}_i)$, and the explanatory variables $\boldsymbol{X}_i$, has been estimated in Subsection 3.2 using probit regression (2). Table 4 reports parameter estimates for the determinants of BWIC failure rates.

Unlike bid-ask spreads and BWIC failure rates, BWIC failure costs are not directly observed in the data and thus have to be extracted from it. It follows from equation (7) that failure costs are equal to the expected best bid from successful BWIC i, net of the seller's reserve price:[20]

$$\text{Failure Cost}_i = \mathbb{E}[B_i^{1:N} - R_i|\text{Trade}_i] \tag{8}$$

The main challenge is to impute sellers' reserves R_i in BWICs $i = 1, ..., I$ from the data. Sellers' reserve price can vary due to differing liquidity needs and non-trading motives for running a BWIC, e.g., information gathering. While the individual R_i's are not directly observed in the data, we can pool BWICs across sellers and estimate $\widehat{R_i} = R(\boldsymbol{X}_i, \varepsilon_{R,i})$ as a function of observable CLO, seller, and market characteristics, $\boldsymbol{X}_i$, and an unobservable noise component, $\varepsilon_{R,i}$, as

$$R(\boldsymbol{X}_i, \varepsilon_{R,i}) = \alpha_R + \boldsymbol{\beta}_R' \boldsymbol{X}_i + \varepsilon_{R,i}. \tag{9}$$

[20] For the empirical estimation we drop conditional on trade because we only observe bids for successful BWICs.

Since the model implies that the reserve price can be approximated by the minimum accepted bid, reserve prices must satisfy the following moment restrictions

$$\Pr(B_i^{1:N} < R_i) = \mathbb{E}[\mathbb{1}(B_i^{1:N} < \alpha_R + \boldsymbol{\beta}_R' \boldsymbol{X}_i + \varepsilon_{R,i}) | \boldsymbol{X}_i] = 0. \tag{10}$$

We start by relaxing this theoretical restriction and require that

$$\mathbb{E}[\tau^* - \mathbb{1}(B_i^{1:N} < \alpha_R + \boldsymbol{\beta}_R' \boldsymbol{X}_i) | \boldsymbol{X}_i] = 0, \tag{11}$$

where $\tau^* \in [0, 1]$ is the quantile that absorbs $\varepsilon_{R,i}$. In Section 4.4, we discuss the robustness of this approach and introduce an alternative estimation procedure.

Condition (11) is equivalent to estimating parameters α_R and $\boldsymbol{\beta}_R$ from the conditional best-bid distribution $G^{1:N}(b|\boldsymbol{X})$ using a non-parametric quantile regression (τ-QR) on realized best-bids $b_i^{1:N}$ at rotation τ^*. In general, the τ%-quantile of a random variable B with distribution $G(b)$ is given by

$$q_B(\tau) = G^{-1}(\tau) = \inf\{b : G(b) \geq \tau\}. \tag{12}$$

In line with (9), we postulate that the τth conditional quantile function can be parametrized as

$$q_{B|\boldsymbol{X}}(\tau) = \alpha_\tau + \boldsymbol{\beta}_\tau' \boldsymbol{X}. \tag{13}$$

For the conditional distribution function of best-bids, $G^{1:N}(b|\boldsymbol{X})$, α_τ and $\boldsymbol{\beta}_\tau$ can be estimated from the pooled sample by solving

$$(\alpha_\tau, \boldsymbol{\beta}_\tau) = \arg\min_{\alpha, \boldsymbol{\beta}} \sum_{i=1}^{I} \rho_\tau(b_i^{1:N} - \alpha - \boldsymbol{\beta}' \boldsymbol{X}_i), \tag{14}$$

where $\rho_\tau(\cdot)$ is the tilted absolute value function at quantile τ.

The determinants of R_i can be estimated, if $\varepsilon_{R,i} = 0$, by the 0-quantile of the best bids:

$$\mathbb{E}[R_i | \boldsymbol{X}_i] = \lim_{\tau \to 0} \; q_{B_i^{1:N} | \boldsymbol{X}_i}(\tau) = \alpha_0 + \boldsymbol{\beta}_0' \boldsymbol{X}_i, \tag{15}$$

that is, $\alpha_R = \alpha_0$ and $\boldsymbol{\beta}_R = \boldsymbol{\beta}_0$, and if $\varepsilon_{R,i} \neq 0$, by

$$\mathbb{E}[R_i|\boldsymbol{X}_i] = \alpha_{\tau^*} + \boldsymbol{\beta}'_{\tau^*}\boldsymbol{X}_i, \tag{16}$$

that is, $\alpha_R = \alpha_{\tau^*}$ and $\boldsymbol{\beta}_R = \boldsymbol{\beta}_{\tau^*}$. In our τ-QR implementation, we manually vary τ^* between 1%, 5%, 10%. In our GMM implementation, we estimate τ^*.

Estimated $(\alpha_\tau, \boldsymbol{\beta}_\tau)$, for all $\tau \in [0,1]$, allow us to compute also the expected best-bids conditional on characteristics that we require in expression (8) according to

$$\begin{aligned}
\mathbb{E}[B_i^{1:N}|\boldsymbol{X}_i] &= \int_0^1 (G^{1:N}(\tau|\boldsymbol{X}_i))^{-1}(\tau)d\tau \\
&= \int_0^1 q_{B_i^{1:N}|\boldsymbol{X}_i}(\tau)d\tau \\
&= \overline{\alpha} + \overline{\boldsymbol{\beta}}'\boldsymbol{X}_i, \qquad (17)
\end{aligned}$$

with coefficients $\overline{\alpha} = \int_0^1 \alpha_\tau d\tau$ and $\overline{\boldsymbol{\beta}} = \int_0^1 \boldsymbol{\beta}_\tau d\tau$. Expression (17) has an intuitive interpretation. The determinants of the expected best bid are captured by the average effect across all quantiles of the distribution, which yields a linear function of $\boldsymbol{X}_i$. The cost of BWIC failure conditional on $\boldsymbol{X}_i$ can, thus, be measured by

$$\text{Failure cost}_i = (\overline{\alpha} - \alpha_{\tau^*}) + (\overline{\boldsymbol{\beta}} - \boldsymbol{\beta}_{\tau^*})'\boldsymbol{X}_i, \; i = 1, ..., I. \tag{18}$$

Table 6 reports our results for specification in Equation (14). We choose to report quantiles τ^* =1%, 5%, 10%, and we report medians for comparison. The table shows that for all quantiles best bids vary significantly with the CLO vintage for all CLO tranches. CLO 2.0s and 3.0s tend to have higher best bids than CLO 1.0s for all best-bid quantiles for senior and mezzanine tranches. However, CLO 1.0s have higher best bids than CLO 2.0s and 3.0s in the case of the junior tranche.

Best bids decline across all quantiles when fixed income market conditions deteriorate, i.e., when the loan levered spread is high, and when the dealer's credit risk increases, i.e., when the dealer CDS spread is high. Trade size and CLO amount outstanding have explanatory power only for the senior CLO tranche. Panel A shows that best bids tend to be higher for larger trades and larger CLO issues. Panels B and C report estimates for credit rating dummies relative to the AA-rated mezzanine tranche and, respectively, the BB-rated junior tranche. For the expected best-bid (Column 5), the coefficients on A/BBB/B/Equity dummies are equal to -1.5bps/-2.5bps/-5.5bps/-26.5bps and show a steep increase in the discount when rating drops from A to Equity.

TCI in the sample of BWICs and its individual components are estimated in the next subsection.

4.3 TCI Determinants

Here we estimate TCI's individual components and use them to construct the in-sample average TCI across all BWICs from the perspective of a typical CLO seller. Our main goal is to study properties of the TCI and its individual components in the cross-section and over time. The empirical analog of expression (7) is computed as a sample average over all BWICs $i = 1, ..., I$:[21]

$$\widehat{\text{TCI}} = \frac{1}{I}\sum_{i=1}^{I} \widehat{\text{Bid-ask spread}}_i + \frac{1}{I}\sum_{i=1}^{I}\left(\widehat{\text{BWIC fail rate}}_i * \widehat{\text{Failure cost}}_i\right), \tag{19}$$

where the predicted bid-ask spreads are from (1), predicted failure rates from (2), and predicted failure cost from (18). Here I is the number of BWICs in a given partition of total BWICs. For instance, if we calculate the average quarterly TCI, then I is a number of BWICs in a given quarter.

Figure 5 plots the estimation results. Panel A shows dealers' expected bids (dashed line) and sellers' reserve prices (solid line) calculated as a percent discount from the par value. For example, the par discount of a seller with reservation price of \$95 per \$100 par value is \$5. Panel B shows the BWIC failure costs, which is the difference between the solid and dashed lines in Panel A.

To explore the robustness of our estimates, we compute the CLO seller's reserve par discount under different specifications. Expression (15) relies on the assumptions that the CLO seller's reserve corresponds to the lowest accepted bid and that all variation in reserve prices is due to observed characteristics $\boldsymbol{X}_i$. Expression (16) relaxes these assumptions. Reserve prices may vary across sellers due to some unobserved seller characteristics and quantile regressions at $\tau = 0$ may be sensitive to some sellers having low reservation values thus biasing our failure cost estimates. To debias the reserve price we need to estimate the non-zero best-bid quantile τ^*. For now, we use the 5% quantile of best bids, $q_{B^{1:N}|\boldsymbol{X}}(5\%)$, as our baseline specification (solid line), i.e., $\widehat{\mathbb{E}[R_i|\boldsymbol{X}_i]} =$

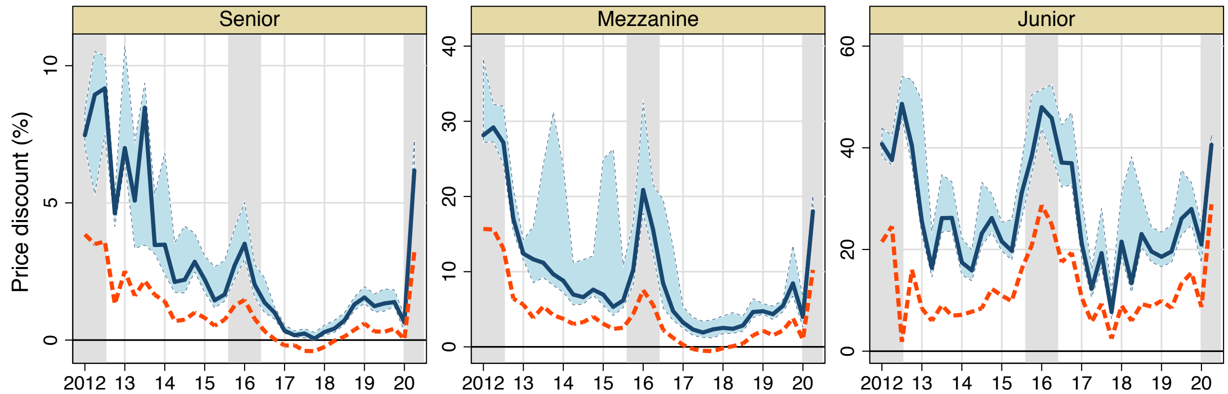
[21]Equation (19) is the population-average TCI across all CLO sellers if the variance of $\varepsilon_{R,i}$ in (9) is zero. The later GMM implementation provides evidence that the variance of $\varepsilon_{R,i}$ is small as the τ^* estimates are close to zero. In this case, the expected fail rate times the expected failure cost is close to the expected fail rate times failure cost.

Table 6: Quantiles of best-bid distribution in successful BWICs

The table reports the determinants of the expected best dealer bids and the quantiles of the best-bid distribution. Panel A reports results for the senior tranche rated AAA, Panel B for the mezzanine tranche rated AA–BBB, and Panel C for the junior tranche rated BB–equity. Standard errors for the expected best dealer bids are robust to heteroskedasticity. Standard errors for the quantiles of best-bid distribution are bootstrapped. Significance levels are indicated by * (10%), ** (5%), *** (1%).

	Quantiles of best-bid distribution $G^{1:N}(b\|\boldsymbol{X})$				
	1%	5%	10%	50%	$\mathbb{E}[B^{1:N}\|\boldsymbol{X}]$
	Panel A: Senior tranche (I = 7,563 BWICs)				
log(Par value of trade)	0.03***	0.01	0.00	0.01**	0.02***
CLO 2.0 vintage	3.18***	1.35***	0.91***	0.54***	0.70***
CLO 3.0 vintage	3.46***	1.85***	1.42***	0.78***	0.99***
log(CLO issue size)	0.44***	0.29***	0.23***	−0.03***	0.01
CLO issue size missing	0.06	0.45**	0.47***	0.10**	0.13
JPM LL spread	−1.04***	−1.21***	−1.08***	−0.62***	−0.98***
Dealer CDS spread	−1.27	−1.03**	−1.31***	−1.23***	−1.53***
Quarter FE	Yes	Yes	Yes	Yes	Yes
R^2	0.720	0.628	0.550	0.325	0.609
	Panel B: Mezzanine tranche (I = 9,277 BWICs)				
log(Par value of trade)	−0.17***	−0.01	−0.01	0.03	0.02
CLO 2.0 vintage	6.21	1.89**	1.53***	1.07***	1.29***
CLO 3.0 vintage	8.67*	1.58**	0.90*	0.65***	0.43**
log(CLO issue size)	−0.19	−0.01	0.03	0.01	−0.13
CLO issue size missing	0.88	−1.23	−0.53**	−0.25*	−0.49*
A rating	−2.53***	−1.11***	−0.78***	−0.66***	−1.49***
BBB rating	−3.99***	−3.72***	−2.99***	−1.24***	−2.50***
JPM LL spread	−4.21***	−3.42***	−3.00***	−1.89***	−2.26***
Dealer CDS spread	−4.39	−5.09***	−6.56***	−5.01***	−7.72***
Quarter FE	Yes	Yes	Yes	Yes	Yes
R^2	0.518	0.531	0.495	0.277	0.491
	Panel C: Junior tranche (I = 6,654 BWICs)				
log(Par value of trade)	−0.15	−0.22	−0.29**	−0.07	−0.32
CLO 2.0 vintage	4.94*	1.17	−0.66	−2.92***	−1.84**
CLO 3.0 vintage	4.04	−0.02	−1.59***	−4.03***	−1.01
log(CLO issue size)	1.06	0.19	0.21	0.39	0.76*
CLO issue size missing	−2.76	−1.95*	−1.21	−1.05**	0.90
B rating	−8.73***	−6.77***	−6.46***	−4.72***	−5.50***
Equity rating	−71.36***	−57.24***	−51.32***	−26.84***	−26.51***
JPM LL spread	−6.72***	−5.84***	−5.86***	−4.14***	−4.27***
Dealer CDS spread	−1.26	−2.67	−1.84	−5.67***	−8.01**
Quarter FE	Yes	Yes	Yes	Yes	Yes
R^2	0.672	0.660	0.641	0.408	0.394

Panel A: Dealers' expected bids and sellers' reserves



Panel B: BWIC failure cost

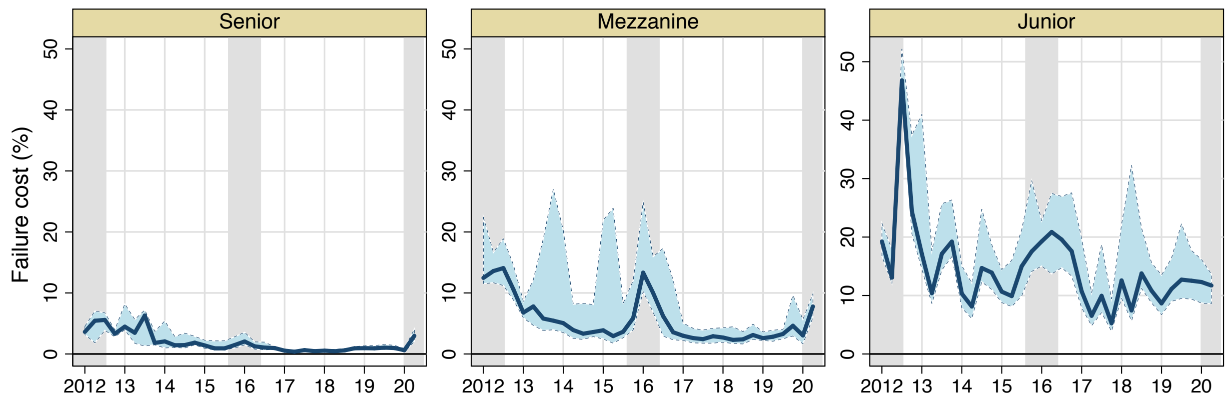


Figure 5: Dealers' expected bids and sellers' reserves and BWIC failure cost

Panel A of the figure documents dealers' expected bids (dashed line) and sellers' reserves (solid line) expressed in terms of discount from par value. For example, the par discount of a seller with reservation price of \$95 per \$100 par value is \$5. Panel B of the figure shows the BWIC failure cost (solid line) in the CLO market at a quarterly frequency. In both panels, solid line is constructed using 5%-QR as the seller's reserve price, while dotted lines below and above the solid line are constructed using 10%-QR and 1%-QR as the seller's reserve price, respectively. The sample period is 2012–2020 with grey areas indicating periods of market stress: 2012 European debt crisis, 2015-16 credit stress, and 2020 COVID-19 pandemic. In both panels, results are split by tranche into the senior tranche rated AAA (left), mezzanine tranche rated AA–BBB (middle), and junior tranche rated BB–equity (right).

$\widehat{\alpha_{5\%}} + \widehat{\boldsymbol{\beta}_{5\%}}'\boldsymbol{X}_i$. We provide further discussion and an alternative approach to Section 4.4. As a robustness check, we also report using dotted lines our results for the 10%-QR (below solid line) and for the 1%-QR (above solid line). We shade the enclosed area to indicate our "confidence interval."

Both sellers' reserve prices and dealers' expected bids tend to decline (rise in par discounts) during credit stress periods and increase during regular(expansion) times.[22] The junior tranche

[22]The reserve prices for the senior tranche are much lower and more volatile pre-2016Q1, than they are post-2016Q1, except for the COVID-19 pandemic period. This is largely due to market being dominated by CLO 1.0s and 2.0s

shows the largest price swings, both in dealer bids and reserve, while the senior tranche shows the smallest price swings. Reserve prices fall by approximately 3%/17%/35% of the CLO face value between 2015Q3 and 2016Q1 for the senior/mezzanine/junior tranche. Expected bids declined by approximately 1%/5%/20% during the same time period for the senior/mezzanine/junior tranche. Both transaction and reserve prices recovered sharply after 2016Q1 and reached their highest values in 2017Q3. During this time the senior tranche was traded at an approximately 0.5% above its face value, while sellers' reserve price was equal to the face value. A noteworthy observation from Panel A is that sellers' reserve prices can be quite low, down to 91% of the CLO face value, even for the safest senior CLO tranche. The reserve prices can be as low as 70% and 50% of the CLO face value for the mezzanine and junior tranches, respectively.

Using the 10% quantile of the best bids as a proxy for the seller's reserve price leads to small increases in the reserve price for all tranches. The most dramatic changes can be seen during 2012Q1 to 2016Q1 period, when the CLO 1.0s and 2.0s have dominated the CLO market. By way of contrast, using the 1% quantile of the best bid as a proxy for the seller's reserve price leads to significant declines in the reserve price for all tranches. For example, between 2017Q1 and 2018Q1, which represents the best of times for CLO sellers, the reserve price is lower by a quarter of a percent for senior tranche, by as much as 1% for the mezzanine tranche, and by as much as 8% for the junior tranche.

Most of the features from the plots in Panel A discussed above translate to BWIC failure costs depicted in Panel B of Figure 5. Failure costs are, on average, larger and more volatile during 2012Q1 to 2016Q1, than they are during later periods in our sample. Failure costs are the largest during credit stress times, while they are the lowest during regular(expansion) times for all tranches. For instance, the costs have increased by approximately 1%/8%/10% between 2015Q3 and 2016Q1 for the senior/mezzanine/junior tranche. The junior tranche has the highest failure costs, which fluctuate between 5% and 40% most of the time. The senior tranche has the lowest failure costs, and stays below 5% most of the time.

Figure 6 contrast the true cost of immediacy, TCI, (solid line) against the realized bid-ask spread (dashed line), both as a percentage of the face value and plotted at quarterly frequency. The solid line is constructed using the 5% quantile of the dealers' expected best bids. The blue shaded area

pre-2016Q1, and by CLO 3.0s post-2016Q1.

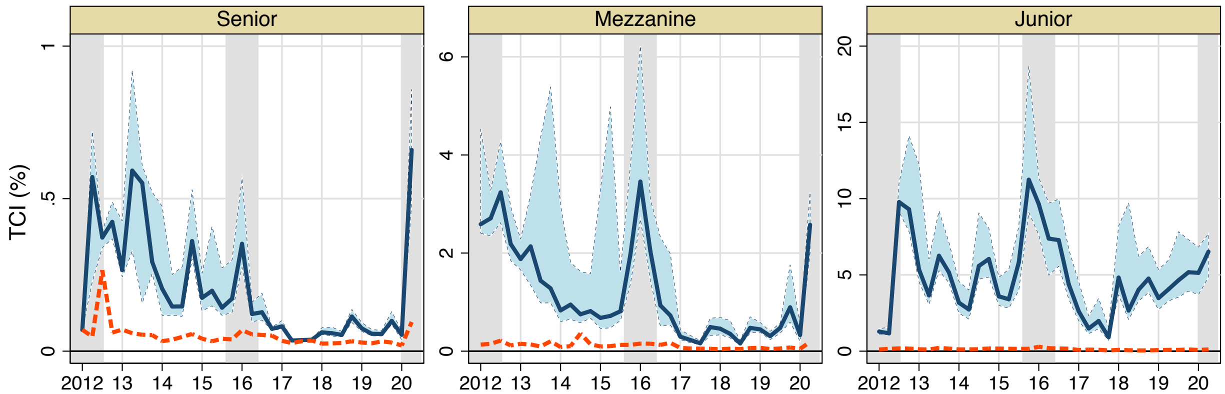


Figure 6: True cost of immediacy

The figure documents the quarterly true cost of immediacy (solid line) and bid-ask spreads (dashed line) in the CLO market. Solid line is constructed using 5%-QR as the seller's reserve price, while dotted lines below and above the solid line are constructed using 10%-QR and 1%-QR as the seller's reserve price, respectively. The sample period is 2012–2020 with grey areas indicate periods of market stress: 2012 European debt crisis, 2015-16 credit stress, and 2020 COVID-19 pandemic. Results are split by tranche into the senior tranche rated AAA (left), mezzanine tranche rated AA–BBB (middle), and junior tranche rated BB–equity (right).

around the solid line are bounded by 10% and 1% quantiles of the best bids, respectively. TCI is the largest for the junior tranche, ranging between 1% and 11% and dwarfs bid-ask spread, which ranges between a few bps and 38bps. The mezzanine tranche has the second highest TCI ranging between 20bps and almost 3%, whereas the bid-ask spread is in the range of 0 to 31bps. The senior tranche has the lowest TCI among the three tranches ranging between 10bps and 50bps. It is still much larger than the bid-ask spread ranging between 0bps and 13bps. TCI and bid-ask are comparable only during 2017Q2-Q3, and only in the case of the senior tranche. Overall, Figure 6 confirms that the true costs of immediacy are much larger than traditionally used liquidity measures such as the effective bid-ask spread. The next section investigates the determinants of the true cost of immediacy.

Table 7 reports sample averages of the TCI and its individual components from expression (19), split by CLO tranche. Following expression (18), the last two columns of Table 7 report two components of the failure costs, seller's reserve price and expected best bid, both expressed in terms of par discount. Panel A reports results for a baseline specification in which the seller's reserve is calculated as the 5% quantile of best bids, $q_{B^{1:N}|\boldsymbol{X}}(5\%)$. It shows that the average TCI increases with credit risk and is equal to 16bps/1%/4.6% for the senior/mezzanine/junior tranches. Average TCI increases because all three of its components increase with credit risk. Columns 2 to

Table 7: TCI and trading cost decomposition

The table reports the true cost of immediacy TCI and its components estimated from the data using the specification in Table 6. TCI is computed as the sample average over all BWICs $i = 1, ..., I$ in the tranche using the expression

$$\widehat{\text{TCI}}\ (\%\ \text{of par}) = \frac{1}{I}\sum_{i=1}^{I}\widehat{\text{Bid-ask spread}}_i + \frac{1}{I}\sum_{i=1}^{I}(\widehat{\text{BWIC fail rate}}_i * \widehat{\text{Failure cost}}_i),$$

with the opportunity cost of BWIC failure as in equation (18). The table reports sample averages across all BWICs during the sample period from January 2012 to March 2020, split by CLO tranche. Standard deviations are reported in parenthesis below the mean.

		TCI decomposition			Failure cost decomposition	
Tranche	TCI (% of par)	Bid-ask (% of par)	BWIC fail rate	Failure cost (% of par)	Seller (% of par)	Dealer (% of par)
Panel A: Base specification—Seller's reserve = $q_{B^{1:N}\mid\boldsymbol{X}}(5\%)$						
Senior	0.16	0.04	0.08	1.29	1.98	0.69
Mezzanine	1.01	0.10	0.16	4.81	8.07	3.26
Junior	4.65	0.12	0.30	12.84	24.98	12.14
Panel B: Robustness—Seller's reserve = $q_{B^{1:N}\mid\boldsymbol{X}}(1\%)$						
Senior	0.23	0.04	0.08	2.03	2.72	0.69
Mezzanine	2.01	0.10	0.16	10.45	13.72	3.26
Junior	7.08	0.12	0.30	20.29	32.43	12.14
Panel C: Robustness—Seller's reserve = $q_{B^{1:N}\mid\boldsymbol{X}}(10\%)$						
Senior	0.13	0.04	0.08	0.89	1.58	0.69
Mezzanine	0.76	0.10	0.16	3.45	6.71	3.26
Junior	3.63	0.12	0.30	9.89	22.03	12.14

4 show that expected bid-ask spreads at 4bps/10bps/12bps, BWIC fail rates at 8%/16%/30%, and BWIC failure costs at 1.3%/4.8%/12.8% for the senior/mezzanine/junior tranche. Seller's reserve par discount increases from 2% for the senior tranche to 8% for mezzanine tranche, to a massive 25% for the junior tranche. Dealers' expected discount increases from 69bps for the senior tranche to 3% for mezzanine and 12% for junior tranche. These results clearly indicate that credit risk leads to steep price discounts in the CLO secondary markets.

In results reported in Panels B and C of Table 7, we make alternative assumptions on the CLO seller's reserve. The seller's reserve price is the 1% quantile of best bids (which assumes less noise) in Panel B, and the 10% quantile (which assumes more noise) in Panel C. Compared to the base specification (5% quantile) in Panel A, TCI is higher under the more stringent assumptions in Panel B, with TCI equal to 23bps/2%/7% for senior/mezzanine/junior tranches. Under the less stringent assumptions in Panel C, TCI is equal to 13bps/76bps/3.6% for the senior/mezzanine/junior tranche, thus making it slightly smaller than in the baseline case. As it can be seen from the table's last two columns, the variation in seller's components of the failure costs contributes a lot to variation in the average TCI values reported in Panels A, B, and C.

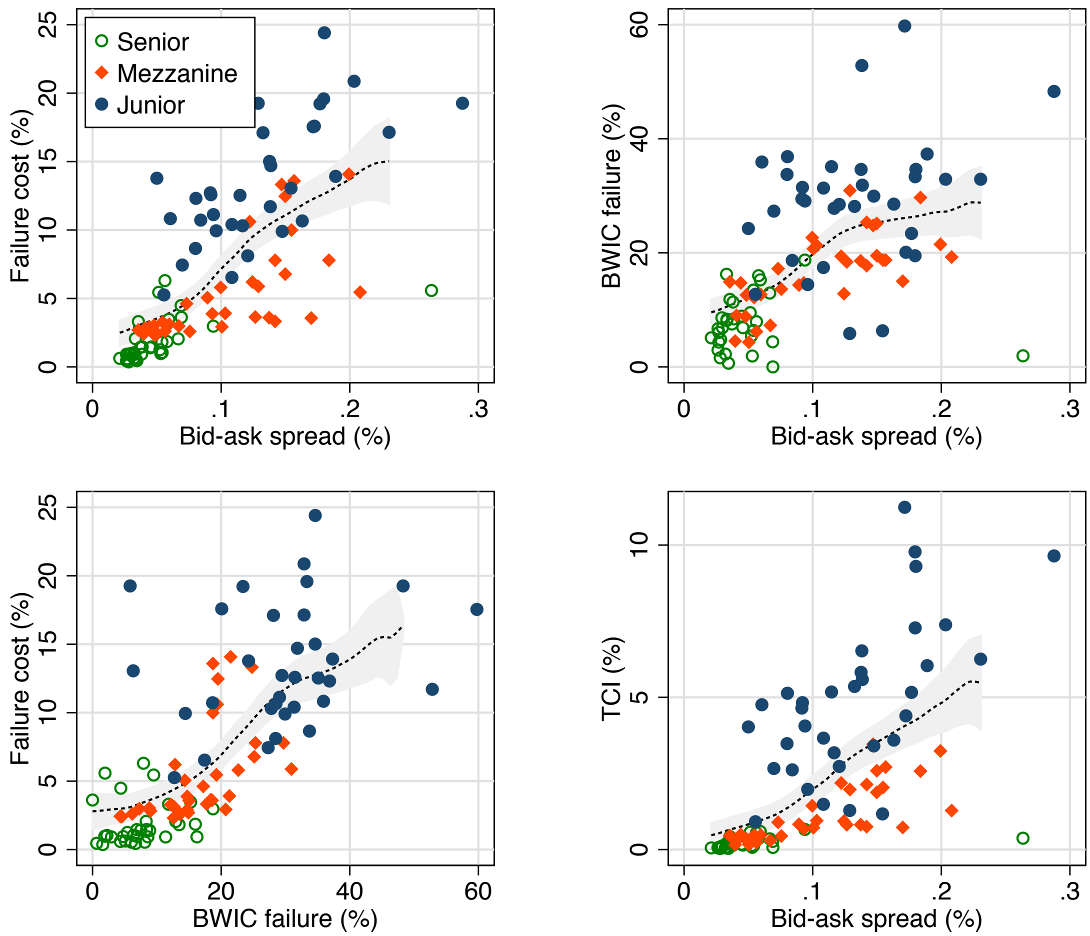


Figure 7: Relation between bid-ask spreads and TCI

The figure documents the relation between bid-ask spreads and TCI in the CLO market over the sample period 2012–2020. The dashed line and shaded area provide a local polynomial fit with 95% confidence bounds.

Average expected failure costs in expression (7) can be rewritten in terms of the covariance between BWIC fail rate and failure cost:

$$\widehat{\text{TCI}} = \frac{1}{I}\sum_{i=1}^{I}\widehat{\text{Bid-ask spread}}_i + \frac{1}{I}\sum_{i=1}^{I}\widehat{\text{Fail rate}}_i * \frac{1}{I}\sum_{i=1}^{I}\widehat{\text{Failure cost}}_i + \underbrace{\widehat{Cov}(\widehat{\text{Fail rate}}_i, \widehat{\text{Fail cost}}_i)}_{>0:\text{ Amplification}}, \tag{20}$$

where $\widehat{Cov}(\cdot,\cdot)$ is the empirical covariance. A negative correlation between BWIC fail rate and failure cost dampens the effect of BWIC failures on the true cost of immediacy, while a positive correlation acts to amplify TCI.

Figure 7 documents the unconditional empirical relation between failure costs and BWIC failure rates (bottom left). It also reports the empirical relations between the failure costs and bid-ask spreads (top left), probability of BWIC failure and bid-ask spreads (top right), and TCI and bid-ask spreads (bottom right). We show senior, mezzanine, and junior CLO tranches with different colored dots. Each observation is a tranche-quarter in the CLO market over the sample period 2012–2020. The dashed line and shaded area provide a local polynomial fit with 95% confidence bounds. The figure demonstrates a strong positive correlation between BWIC fail rate and failure cost both within tranche over time and across tranches. Both BWIC fail rate and failure cost co-move positively with bid-ask spreads over time and across tranches. As a result, BWIC failures amplify the cost of immediacy in excess of bid-ask spreads to form TCI.

In Table 8, we explore how TCI and its components vary with the explanatory variables $\boldsymbol{X}$ using sample splits. Low/Medium/High columns indicate values of characteristic in its bottom/middle/top tercile. Panels A/B/C report results for the senior/mezzanine/junior tranche. Note that, conditional on every characteristic in $\boldsymbol{X}$, TCI increases with the riskiness of the tranches.

The results across tranches are generally consistent. Larger trades have higher TCI. This is because larger trades are harder to execute and they have higher cost of failure. Older CLO vintages (CLO 1.0s and 2.0s) are more expensive to trade than the newer vintage (CLO 3.0). Bid-ask spread, failure rate, and failure costs decline with CLO vintage. A larger CLO issue size reduces TCI. CLO rating is the strongest cross-sectional determinant of TCI. In particular, the equity tranche has a TCI as high as 10%.

As expected, TCI varies over time with leveraged loan market conditions and with dealer funding conditions. Higher spreads of the leveraged loans underlying CLOs lead to higher TCI. TCI increases also when dealer funding costs proxied for by the dealer CDS spread go up.

A natural question is whether dealers bid their valuations or shade their bids. While it is beyond the scope of this paper, it may still be of interest to many readers. Internet Appendix C provides a comprehensive discussion on this topic.

Table 8: TCI: Splits by trade size, CLO type, and market state

The table reports TCI and its components for different sample splits. Panel A reports results for the senior tranche, Panel B for the mezzanine tranche, and Panel C for the junior tranche. The true cost of immediacy in a split are computed as the sample average over all BWICs $i = 1, ..., I$ using the expression

$$\widehat{\textbf{TCI}} \text{ (\% of par)} = \frac{1}{I}\sum_{i=1}^{I}(\widehat{\text{Bid-ask spread}_i}) + \frac{1}{I}\sum_{i=1}^{I}(\widehat{\text{BWIC fail rate}_i} * \widehat{\text{Failure cost}_i}).$$

The opportunity cost of BWIC failure is defined in equation (18).

Sample split	**TCI** (Bid-ask spread, BWIC fail rate, Failure cost)		
	Low	Medium	High
Panel A: Senior tranche			
Par size of trade	**0.09** (0.04, 0.03, 1.08)	**0.15** (0.04, 0.07, 1.34)	**0.25** (0.04, 0.12, 1.46)
CLO vintage (1.0/2.0/3.0)	**0.33** (0.06, 0.10, 2.90)	**0.15** (0.04, 0.09, 1.16)	**0.13** (0.04, 0.07, 0.97)
log(CLO issue size)	**0.23** (0.05, 0.09, 1.80)	**0.14** (0.04, 0.07, 1.08)	**0.12** (0.04, 0.07, 0.99)
JPM LL spread	**0.11** (0.03, 0.08, 0.85)	**0.15** (0.04, 0.07, 1.29)	**0.23** (0.05, 0.08, 1.75)
Dealer CDS spread	**0.09** (0.03, 0.05, 0.89)	**0.13** (0.03, 0.08, 1.04)	**0.27** (0.06, 0.09, 1.98)
Panel B: Mezzanine tranche			
Par size of trade	**0.77** (0.10, 0.13, 4.46)	**1.05** (0.10, 0.17, 4.86)	**1.23** (0.09, 0.20, 5.12)
CLO vintage (1.0/2.0/3.0)	**1.53** (0.14, 0.19, 7.10)	**1.14** (0.10, 0.18, 5.21)	**0.76** (0.08, 0.15, 3.76)
CLO rating (AA, A, BBB)	**0.68** (0.09, 0.12, 4.24)	**0.85** (0.10, 0.16, 4.17)	**1.35** (0.11, 0.20, 5.66)
log(CLO issue size)	**1.27** (0.11, 0.19, 5.56)	**0.96** (0.10, 0.17, 4.54)	**0.79** (0.09, 0.14, 4.25)
JPM LL spread	**0.57** (0.08, 0.14, 3.21)	**0.95** (0.11, 0.17, 4.34)	**1.53** (0.11, 0.18, 6.93)
Dealer CDS spread	**0.54** (0.06, 0.13, 3.30)	**0.74** (0.09, 0.16, 3.63)	**1.80** (0.15, 0.21, 7.64)
Panel C: Junior tranche			
Par size of trade	**3.37** (0.12, 0.26, 11.06)	**4.06** (0.12, 0.31, 11.41)	**6.79** (0.13, 0.35, 16.42)
CLO vintage (1.0/2.0/3.0)	**5.26** (0.15, 0.25, 18.31)	**5.55** (0.14, 0.31, 14.81)	**4.07** (0.11, 0.31, 10.74)
CLO rating (BB, B, Equity)	**2.41** (0.11, 0.27, 7.81)	**3.53** (0.14, 0.37, 8.42)	**15.05** (0.16, 0.39, 37.83)
log(CLO issue size)	**2.88** (0.12, 0.30, 8.46)	**2.89** (0.11, 0.28, 8.63)	**8.58** (0.14, 0.33, 22.41)
JPM LL spread	**3.65** (0.10, 0.27, 10.76)	**4.22** (0.13, 0.29, 12.10)	**6.11** (0.15, 0.35, 15.73)
Dealer CDS spread	**3.68** (0.09, 0.27, 10.69)	**4.41** (0.11, 0.31, 11.37)	**5.94** (0.17, 0.33, 16.70)

4.4 Discussion

TCI is a first attempt to utilize data on failed trades to better measure the cost of immediacy. In this subsection we discuss a number of ways that TCI can be extended. In our implementation, we use the seller's reserve price R as a proxy for the seller's outside-option valuation if the auction fails. In the optimal auction literature, reserve price is a strategic choice by the seller to illicit higher bids, which leads to inefficient auction failures. Hence, the seller is likely to strategically set her reservation value above her outside-option valuation. Measuring how far above her valuation the seller sets her reserve price would result in larger TCI estimates. Estimating this is challenging, as it involves estimating the full distribution of dealer valuations, which is difficult to reliably estimate in the data.

When an auction fails, the seller could potentially try to sell the CLO in a subsequent BWIC. In such a dynamic model, the seller would not set R below what she would expect to get if she tried to sell again. Table IA.1 in the Internet Appendix shows that for 5-10% of failed BWICs, the same CLO has another customer-sell OTC transaction the same day or the following day. less than 1% of them had another BWIC auction within the next day. In addition, given the reporting of failed BWICs, dealers are unlikely to bid above R in subsequent auctions for the same CLO that recently failed. Both of these dynamic effects suggest that sellers' outside-option valuations are below their reserve prices. Thus, a dynamic model is unlikely to yield smaller TCI estimates.

Our measure of TCI is defined as the difference between the proceeds to the seller and the ask price at which investors buy from the dealer. The end investor buys from the dealer in an OTC transaction in which the dealer is likely looking to reduce risk by selling a recently purchased CLO. In this case, the end investor is less likely to be demanding immediacy. An extreme case of this is a riskless principal trade where the dealer acts by brokering a trade between the initiating seller and the final buyer. Because the seller initiates the round-trip transaction, the ask price we measure is likely to be below the price at which an investor would pay when demanding immediacy to buy. Put another way, some of the compensation for providing immediacy to the seller accrues to the final buyer as opposed to entirely to the dealer. Adjusting the ask price upwards for this effect would increase TCI.

Another issue is that our definition of TCI treats seller i's reserve value, R_i, as being measurable in BWICs $i = 1, ..., I$. In Section 4.2, we show how to parametrize its estimation, $E[R_i|\boldsymbol{X}_i]$, as a function of observables, $\boldsymbol{X}_i$. However, R_i may also vary across sellers due to unobserved characteristics other than $\boldsymbol{X}_i$, $R_i = E[R_i|\boldsymbol{X}_i] + \varepsilon_{R,i}$, where $\varepsilon_{R,i}$ captures this variation by a random variable with zero conditional mean and variance $\sigma_\varepsilon^2 > 0$. When estimating TCI in the data, we pool BWICs across sellers. If sellers vary in their reservation values, the quantile regressions may be sensitive to some sellers having low reservation values. Thus $\varepsilon_{R,i}$ biases the estimate of R_i downwards and the expected failure costs and, therefore, TCI upwards. This bias implies that the expected reserve price is determined by a non-zero best-bid quantile, $\tau^* > 0$, in the empirical moment conditions (11) and (16). In Sections 4.2 and 4.3 we employ the fact that τ can be at most 50% when a symmetric noise term $\varepsilon_{R,i}$ generates all of the variation in $B^{1:N}$ and manually correct for this bias by using quantiles $\tau^* =$1%, 5%, 10% instead of $\tau =$0% in our estimation. This approach is the most flexible and least computationally demanding. Moreover, given that TCI estimates are similar using the 5% and 10% quantile, the TCI estimates do not appear sensitive to a small number of sellers having low reservation values.

Still, ideally, the "optimal" quantile rotation has to be performed endogenously. It is possible to estimate the optimal quantile rotation from the theoretical condition (10) using GMM but, unfortunately, it is not identified if only moments for the best-bid are used.[23] To make the GMM fully identified, we utilize data on the BWIC cover prices, $B^{2:N}$, to form the following additional moments

$$\Pr(B_i^{2:N} < R_i) = \mathbb{E}[\mathbb{1}(B_i^{2:N} < \alpha_R + \boldsymbol{\beta}'_R \boldsymbol{X}_i + \varepsilon_{R,i})|\boldsymbol{X}_i] = 0. \tag{21}$$

These moment conditions are motivated by the fact that $B^{2:N}$ is reported to market participants only when the seller would have accepted it if the transaction with the BWIC winner would have fallen through,[24] i.e., when $B_i^{2:N} \geq R_i$.[25] An important feature of the cover is that BWIC failure depends on the value of $B_i^{1:N}$, not $B_i^{2:N}$, relative to the value of R_i.

Having the unobserved $\varepsilon_{R,i}$ in moment conditions (10) and (21) implies that the rotation τ^* should depend on the probability of BWIC failure/success.[26] Assume the in-sample predicted probability of BWIC success equals $\Pr(\text{Trade}_i) = h(S_i) = h(\alpha_S + \boldsymbol{\beta_S}'\boldsymbol{X}_i)$. Then coefficients $(\alpha_S, \boldsymbol{\beta}_S)$ can be estimated from a first-stage probit regression ($h = \Phi$) to predict $\widehat{S}_i$ (see Table 5). Under a linearity assumption, $\tau^j(\widehat{S}_i) = \tau_0^j + \tau_1^j \widehat{S}_i$, with $j = 1$ and 2 indicating best bid and cover, respectively. Under these assumptions, moment conditions (10) and (21) take the form

$$\mathbb{E}[\tau_0^j + \tau_1^j \widehat{S}_i - \mathbb{1}(B_i^{j:N} < \alpha_R + \boldsymbol{\beta}'_R \boldsymbol{X}_i)|\boldsymbol{X}_i] = 0, \qquad j = 1, 2. \tag{22}$$

We estimate moments (22) using two GMM specifications named τ-GMM and $\tau(S)$-GMM,

[23] If the number of the explanatory variables, $\boldsymbol{X}$, is equal to K, we have K moments and $K + 2$ parameters due to τ and α_R.

[24] If the cover is reported when it is below the seller's reserve price then the GMM estimation of τ^* is biased upwards because of the additional variation in the cover.

[25] Krasnokutskaya (2011) pursues a similar approach in that the joint distribution of two bids is used to uniquely determine the underlying distribution.

[26] The unobserved $\varepsilon_{R,i}$ can arise from variation in reserve prices across sellers that is unrelated to dealer bids or from variation in reserve prices across sellers that is correlated with dealer bids.

respectively. Under τ-GMM specification, we rotate by a constant endogenous quantile, that is, we estimate $(\alpha_R, \boldsymbol{\beta}_R, \tau_0^1, \tau_0^2)$ and set $\tau_1^1 = \tau_1^2 = 0$. In the $\tau(S)$-GMM specification, we estimate $(\alpha_R, \boldsymbol{\beta}_R, \tau_0^1, \tau_1^1, \tau_0^2, \tau_1^2)$. The GMM approach has the limitation that it requires at least three control variables $\boldsymbol{X}$ for identification.[27]

Table IA.2 in the Internet Appendix summarizes the GMM parameter estimates for the reserve price determinants $(\alpha_R, \boldsymbol{\beta}_R)$, the quantile rotation of the best bid $B^{1:N}$, and the quantile rotation of the cover $B^{2:N}$.[28] Table 9 summarizes the TCI measured using the different empirical approaches. Throughout, the non-parametric estimates for TCI are more conservative than the GMM estimates for TCI, which suggests that our baseline τ-QR setting with the $\boldsymbol{X}$ controls and τ^* =5% is sufficient to control for unobserved variation in the reserve price across BWICs. Finally, estimates for τ^* using GMM approaches are $< 1\%$ for senior, $1 - 2\%$ for mezzanine, and 2% junior tranches, thus supporting the assumption that the variance of $\varepsilon_{R,i}$, σ_ε^2, is relatively small used to motivate the relation (19).

5 TCI during the 2020 Pandemic

In this section we investigate the behavior of the true costs of immediacy during the 2020 COVID-19 pandemic. Prior to the pandemic, there were debates about the potential dangers of the growing leveraged loan market largely held by CLOs. A lot of comparisons have been made with the CDO market decimated during the financial crisis of 2008. Some of these fears have been dispelled by Jerome Powell,[29] the chairman of the Federal Reserve, who said in a May 2019 speech that "Business debt has clearly reached a level that should give businesses and investors reason to pause and reflect. However, the parallels to the mortgage boom that led to the Global Financial Crisis are not fully convincing. Most importantly, the financial system today appears strong enough to handle potential business-sector losses, which was manifestly not the case a decade ago with subprime mortgages."

[27] When we have K control variables $\boldsymbol{X}$, the number of parameters is equal to $K+1$ in τ-GMM and $K+5$ in $\tau(S)$-GMM, and the number of moment conditions is equal to $2(K+1)$.

[28] In the empirical implementation, we convexify the indicator function by the smooth approximation $\mathbb{1}(x) \approx \Phi(\frac{x}{\sigma})$ (Horowitz (1998)). The approximation is more accurate the smaller $\sigma > 0$. With $\sigma = 0.2$, the approximation error is 2.867e-07/0.006/0.159/0.309 at $x = \pm 1/0.5/0.2/0.1$. With $\sigma = 0.1$, the approximation error is 7.620e-24/2.867e-7/0.023/0.159 at $x = \pm 1/0.5/0.2/0.1$. With $\sigma = 0.04$, the approximation error is 3.057e-138/3.732e-36/2.867e-07/0.006 at $x = \pm 1/0.5/0.2/0.1$. We report results for $\sigma = 0.1$.

[29] https://www.federalreserve.gov/newsevents/speech/powell20190520a.htm

Table 9: TCI: Alternative empirical approaches

The table reports TCI measured using different empirical approaches. In the first approach, we run non-parametric quantile regressions (τ-QR) on the best bid $B^{1:N}$ at quantiles τ =1%, 5%, and 10%. In the second approach, we determine the optimal quantile rotation endogenously using GMM applied jointly on $B^{1:N}$ and $B^{2:N}$. We either rotate by a constant quantile (τ-GMM) or by a conditional quantile ($\tau(S)$-GMM).

	TCI across BWICs						
	Mean	SD	5%	25%	50%	75%	95%
Panel A: Senior tranche (I = 8,525 BWICs)							
1%-QR on $B^{1:N}$	0.25	0.32	0.04	0.07	0.11	0.30	0.97
5%-QR on $B^{1:N}$	0.17	0.21	0.03	0.05	0.08	0.18	0.63
10%-QR on $B^{1:N}$	0.13	0.14	0.03	0.05	0.07	0.14	0.43
τ-GMM on $B^{1:N}$ and $B^{2:N}$	0.49	0.58	0.06	0.15	0.30	0.60	1.60
$\tau(S)$-GMM on $B^{1:N}$ and $B^{2:N}$	0.77	0.97	0.07	0.20	0.45	0.94	2.67
Panel B: Mezzanine tranche (I = 12,341 BWICs)							
1%-QR on $B^{1:N}$	2.00	1.74	0.22	0.62	1.45	2.96	5.64
5%-QR on $B^{1:N}$	1.02	0.92	0.16	0.36	0.68	1.36	2.93
10%-QR on $B^{1:N}$	0.77	0.72	0.13	0.28	0.49	0.99	2.25
τ-GMM on $B^{1:N}$ and $B^{2:N}$	1.70	1.27	0.31	0.83	1.38	2.19	4.41
$\tau(S)$-GMM on $B^{1:N}$ and $B^{2:N}$	1.70	1.28	0.30	0.82	1.37	2.18	4.43
Panel C: Junior tranche (I = 10,794 BWICs)							
1%-QR on $B^{1:N}$	7.22	8.31	1.03	2.20	3.66	8.25	26.93
5%-QR on $B^{1:N}$	4.61	5.42	0.41	1.22	2.29	5.64	17.08
10%-QR on $B^{1:N}$	3.64	4.40	0.27	0.94	1.86	4.11	13.97
τ-GMM on $B^{1:N}$ and $B^{2:N}$	6.92	6.87	1.27	2.52	4.37	7.95	22.93
$\tau(S)$-GMM on $B^{1:N}$ and $B^{2:N}$	7.22	7.00	1.49	2.83	4.46	8.26	23.43

Figure 8 zooms in on the first three months of 2020 to illustrate the effects of the COVID-19 pandemic on the CLO market and dealer funding conditions (Panel A), BWIC and trading intensities (Panel B), and trading volume (Panel C). The lightly shaded area indicates the early stage of the pandemic between weeks 8 and 11 (before the first US shelter-in-place orders), while the darker shaded area indicates the later stage of the pandemic between weeks 11 and 13, i.e., after the first US shelter-in-place orders have been implemented.

Both the primary and secondary markets of leveraged loans and CLOs were quite healthy in January and through most of February 2020. The leveraged loan spread (left plot in Panel A) was flat at around 4.5%. Dealers' health was generally good, as the average CDS spread of primary dealers (right plot in Panel A) was roughly flat at 45bps. Trading activity does not show any signs of distress during this period: the average numbers of weekly trades (dashed line in Panel B) were at around 25/40/50 which roughly translates to 325/520/650 trades per quarter for the

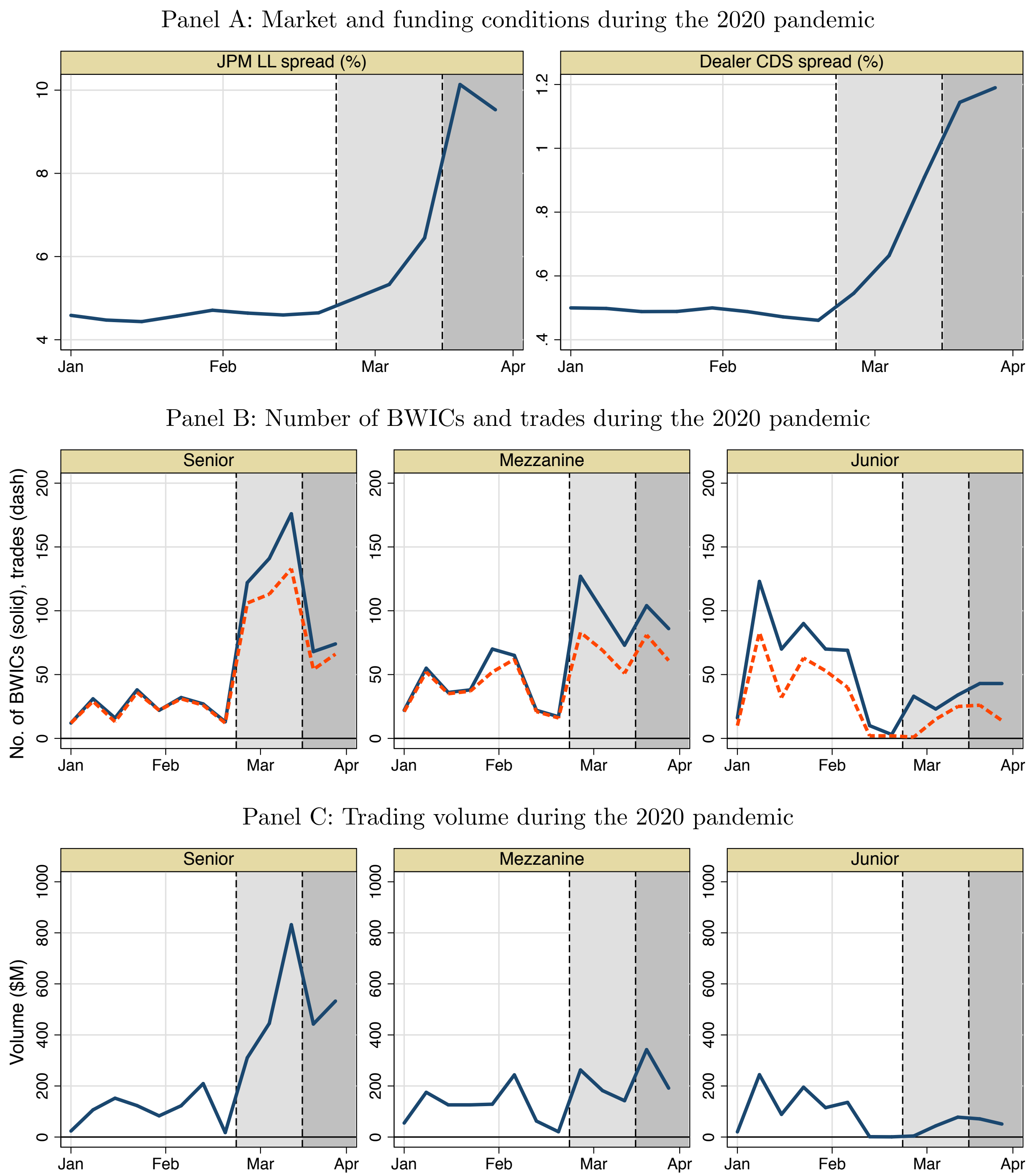


Figure 8: Economic conditions and CLO trading activity during the 2020 pandemic

This figure reports weekly economic conditions and CLO trading activity during the onset of the 2020 pandemic between January 2020 and March 2020. Panel A graphs left-to-right the leveraged loan spread and dealer CDS spread. Panels B documents the number of BWICs (solid line) and trades (dashed line). Panel C plots the trading volume. Panels B and C are split by tranche into the senior tranche rated AAA, mezzanine tranche rated AA–BBB, and junior tranche rated BB–equity. The lightly shaded area indicates early stages of the pandemic between 3rd week of February and 2nd week of March (before the first US shelter-in-place orders), while the darker shaded area indicates later stages of the pandemic between 2nd and 4th weeks of March, i.e., after first US shelter-in-place orders have been implemented.

senior/mezzanine/junior tranche, which were below the 2019 level, but above the 2018 level. The average weekly trading volume was around $180M for all three tranches. Finally, in February 2020 alone over thirty billion dollars in CLOs were issued.[30]

Figure 8 is complemented by Figure 9 which shows BWIC failure rates (Panel A), BWIC failure costs (Panel B), and TCI (Panel C). Pre-pandemic, January to mid-February 2020, BWIC failure rates were close to their full sample median values of 7%/16%/29%, while failure costs were on average at or below full sample means of 1.3%/4.8%/12.3% for the senior/mezzanine/junior tranche. Panel C of Figure 9 shows TCI (solid line) and bid-ask spread (dashed line). Pre-pandemic, bid-ask spreads were equal to 2bps/5bps/10bps for the senior/mezzanine/junior tranche. During this period, TCI for the senior tranche was just a couple of basis points larger than the bid ask spread due to low values of both BWIC failure rates and costs. TCI for the mezzanine tranche was hovering around 50bps, while TCI for the junior tranche was fluctuating between 4% and 8%.

As the pandemic hit the US, market conditions for leveraged loans and dealer funding conditions begin to deteriorate. In anticipation of the declining corporate earnings, credit-ratings agencies started to downgrade leveraged loans that underpin CLOs. Panel A of Figure 8 clearly shows that the leveraged loan spread starts to rise sharply in the 3rd week of February. At the same time, credit and funding risks of dealers who make OTC markets started to increase as indicated by the rising dealer CDS spread.

As the broader market volatility started to rise in late February, trading activities started to tick up in the CLO market as well. Panel B of Figure 8 shows that the number of both BWICs (solid line) and trades (dashed line) rises sharply in the 3rd week of February for the senior and mezzanine CLO tranches. The gap between the two lines represents BWICs that failed. The share of failed auction increased substantially for senior and Mezzanine tranches going into March. The number of BWICs and trades for junior tranches shows a milder increase, likely due to seller's anticipation of steep discounts and choosing to not fire-sale their risky holdings. The CLO trading volume plotted in Panel C shows similar patterns as the number of trades in Panel B.

Figure 9 illustrates how the bid-ask spread, TCI, and TCI's individual components behaved during the 2020 pandemic. Panel A shows that BWIC failure rates start to rise sharply in the 3rd week of February (week 8), well in advance of the rise in bid-ask spreads. Fails increased to

[30] https://dealogic.com/insight/loan-highlights-first-quarter-2020/

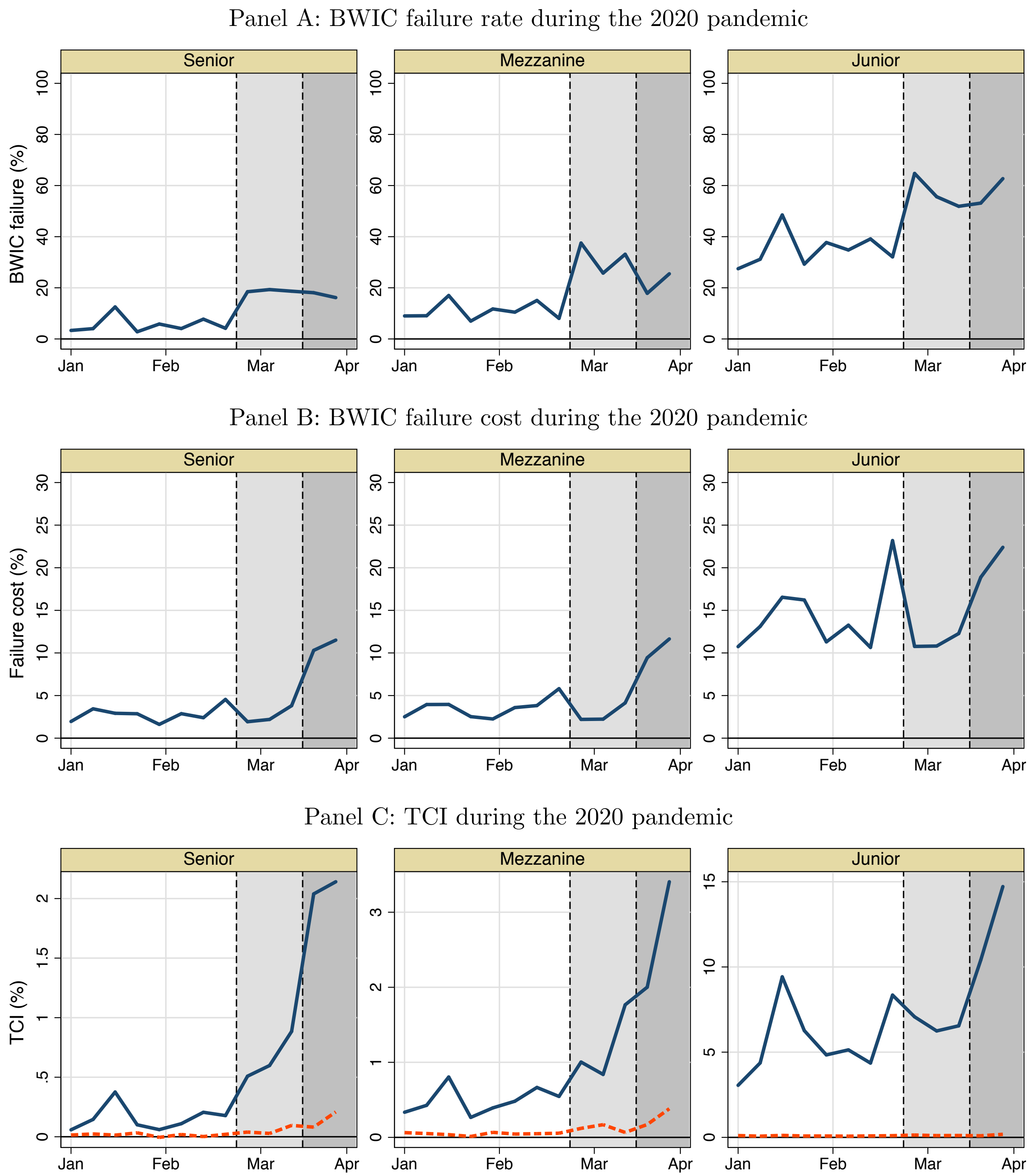


Figure 9: TCI during the 2020 pandemic

This figure reports weekly TCI and its individual components in the CLO market during the onset of the 2020 pandemic between January 2020 and March 2020, split by tranche into the senior tranche rated AAA, mezzanine tranche rated AA–BBB, and junior tranche rated BB–equity. Panels A and B of the figure document BWIC failure rate and failure cost, respectively. Panel C of the figure presents bid-ask spread (dashed line) and TCI (solid line). The lightly shaded area indicates early stages of the pandemic between 3rd week of February and 2nd week of March (before the first US shelter-in-place orders), while the darker shaded area indicates later stages of the pandemic between 2nd and 4th weeks of March, i.e., after first US shelter-in-place orders have been implemented.

20% and remained at this level through mid-March, and declined slightly in the wake of a series of broad-market actions taken by the Fed. For the mezzanine tranche, BWIC failure rates rise to 40% by early March, and fluctuated around 25% for the rest of the period. For the junior tranche, failure rates rise above 60% by early March and stayed above 50% throughout March. BWIC failure costs increase steadily during the pandemic reaching 10%/14%/24% for the senior/mezzanine/junior tranche by the end of March.

Panel C of Figure 9 juxtaposes the bid-ask spreads (dashed line) and TCI (solid line). Across all tranches, as the market stress deepens, TCI increases to levels that easily dwarfs that of the bid-ask spread. By the end of March, TCI rose to around 2%, 3% and 15% for the senior, mezzanine and junior tranches. Overall, TCI measure points to a substantial market deterioration during the worst part of the market stress in March.

Overall, these results highlight the extremely high costs of selling CLOs, particularly the riskiest mezzanine and junior tranches. Our estimates are orders of magnitude larger than what traditional liquidity measures, such as the effective bid-ask spread, would suggest.

Consistent with our results of extreme market illiquidity, structured credit funds, which are the major holders of the junior CLO tranche, accounted for a disproportionate share of hedge funds that suspended investor redemption in March 2020.[31] Perhaps not surprisingly, most of these funds cited market liquidity concerns as the primary reason to invoke such extreme measures.

6 Conclusion

This paper constructs the true cost of immediacy for securities that lack firm quotes and trade infrequently. A common way to measure transaction costs of infrequently-traded securities is through effective bid-ask spread, or realized returns to dealers, which calculates the difference between dealer buy prices and dealer sell prices. However, if investors choose not to trade when they are unable to obtain good prices, observed liquidity is biased upward. In this case, the true cost of immediacy must capture the opportunity cost to investors of failed attempts to trade.

[31] For instance, on March 31, EJF Capital suspended investor redemption from one of its structured credit funds after performance declined by more than 15% in March and investors requests for redemption reached 6% of assets that month. Medalist Partners also suspended cash withdrawals from its $700 million structured credit Harvest fund after it plummeted more than 50% in March. Prophet Capital Asset Management fund, which primarily held commercial mortgages and high-yield CLOs, also suspended investor redemption in late March.

Using data from 2012-2020 on bidding behavior in BWICs from the CLO market and whether or not the BWIC resulted in a trade enable us to incorporate the cost of failed attempts to trade into the cost of immediacy. We define the true cost of immediacy as the expected difference between the price at which an investor can buy the asset minus investors' expected payoff to selling. When a BWIC trades we observe the expected highest bid conditional on a trade. Using the reserve price to value the outside option, we show that the true cost of immediacy can be written as the expected bid-ask spread on observed trades plus the probability of BWIC failure times the cost of trade failure; where the cost of trade failure is the expected highest bid conditional on a trade minus the reserve price. The sellers' reserve price is the only component of the true cost that is not directly observable in the data. We estimate the reserve price using quantiles of the distribution of best bids.

Our estimates suggest that the true cost of immediacy in the CLO market is substantially higher than the effective bid-ask spread from successful BWICs only. We find that this cost gap is higher in lower-rated CLOs and in stressful market conditions when failure rates exceed 50%. Across our 2012-2020 sample period, for completed trades in senior CLOs, the expected cost is four bps while the true cost of immediacy is 13bps. In stressful periods, for junior tranches, the observed cost of trading increases from an average of 12bps to 25bps while the true cost of immediacy increases from less than 3% to over 10% of the face value of the asset.

This paper demonstrates the importance of having an unbiased measure of the costs of immediacy since the bias can be very large, especially during times of stress. Future studies should extend our approach to other fixed income securities, such as corporate and municipal bonds.

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Appendix

Appendix A Data Filters

The following table reports the steps to clean and filter the CLO BWIC data and the number of BWICs remaining after each step.

Step	Number of BWICs remaining
All auctions between 1.1.2012 and 3.31.2020	58,853
Keep only USD CLO	43,701
Keep only TRACE eligible CUSIPs	34,138
Keep only if seniority/rating information is not missing	33,408

The following table reports summary statistics on merging TRACE and Creditflux (CF). We report for each dealer-to-client, interdealer, and client-to-dealer trade out of the total how many are in TRACE only, how many are in both TRACE and CF, and how high is the match rate. In the table the statistic on 'In TRACE and CF' includes auctions with DNT flag or cover information that are nonstandard and cannot be translated into a decimal price.

	In TRACE only	In TRACE and CF	Total	Matched %
Dealer-to-client	88,573	13,093	101,666	13%
Interdealer	18,742	3,112	21,854	14%
Client-to-dealer	43,194	27,890	71,084	39%

Internet Appendix

This internet appendix provides additional analysis. Section A provides further evidence on the cost of BWIC failure. Section B documents the estimation results using the $\tau(S)$-GMM approach. Section C documents the link between TCI and dealers' bid shading in BWICs.

A Further Evidence on Cost of BWIC Failure

Table IA.1 provides evidence on the consequence of failed CLO auctions. It documents how often failed auctions are followed by an OTC trade over different time horizons, on the same day, within one day, and within 10 days of the failed auction.

Table IA.1: Probability of failed auction to be followed by an OTC trade (top panel) or another BWIC (bottom panel) on the same day, within a day or within 10 days of the auction.

	BWIC followed by OTC; any size			BWIC followed by OTC; matched size		
Seniority	Same day	$[t, t+1]$	$[t, t+10]$	Same day	$[t, t+1]$	$[t, t+10]$
All	0.052	0.080	0.149	0.030	0.043	0.072
AAA	0.042	0.073	0.215	0.032	0.036	0.067
AA	0.032	0.073	0.144	0.022	0.054	0.100
A	0.044	0.087	0.129	0.038	0.049	0.064
BBB	0.063	0.083	0.149	0.034	0.046	0.086
BB	0.062	0.091	0.163	0.033	0.045	0.077
B	0.040	0.062	0.104	0.025	0.040	0.066
EQUITY	0.043	0.061	0.102	0.016	0.030	0.038
	BWIC followed by BWIC; any size			**BWIC followed by BWIC; matched size**		
Seniority	Same day	$[t, t+1]$	$[t, t+10]$	Same day	$[t, t+1]$	$[t, t+10]$
All	0.000	0.005	0.039	0.000	0.001	0.008
AAA	0.000	0.012	0.090	0.000	0.000	0.012
AA	0.000	0.002	0.025	0.000	0.000	0.005
A	0.000	0.008	0.035	0.000	0.002	0.009
BBB	0.000	0.005	0.039	0.000	0.000	0.014
BB	0.000	0.005	0.044	0.000	0.001	0.009
B	0.000	0.000	0.012	0.000	0.000	0.000
EQUITY	0.000	0.001	0.009	0.000	0.000	0.001

B GMM Estimation Results

Table IA.2 reports the parameter estimates for the τ-GMM and $\tau(S)$-GMM specifications.

Table IA.2: Reserve price determinants

The table reports the parameter estimates for the τ-GMM and $\tau(S)$-GMM specifications. The reserve price in BWIC i is assumed to equal $R_i = \alpha_R + \boldsymbol{\beta}'_R \boldsymbol{X}_i + \xi_i$. The predicted probability of BWIC success equals $\Pr(\text{Success}_i) = h(S_i) = h(\alpha_S + \boldsymbol{\beta}'_S \boldsymbol{X}_i)$. The coefficients α_S and $\boldsymbol{\beta}_S$ are determined in a first-stage probit regression ($h = \Phi$). The moment conditions are derived from the restrictions (11) and (22). In the τ-GMM specification, we rotate by constant quantiles, that is, we estimate $(\alpha_R, \boldsymbol{\beta}_R, \tau_0^1, \tau_0^2)$ and set $\tau_1^1 = \tau_1^2 = 0$. In the $\tau(S)$-GMM specification, we estimate $(\alpha_R, \boldsymbol{\beta}_R, \tau_0^1, \tau_1^1, \tau_0^2, \tau_1^2)$. We convexify the indicator function by the smooth approximation $\mathbb{1}(x) \approx \Phi(\frac{x}{\sigma})$ with $\sigma = 0.1$ (Horowitz (1998)). Standard errors are robust to heteroskedasticity. Significance levels are indicated by * (10%), ** (5%), *** (1%).

	Senior tranche		Mezzanine tranche		Junior tranche	
	τ-GMM (1)	$\tau(S)$-GMM (2)	τ-GMM (1)	$\tau(S)$-GMM (2)	τ-GMM (1)	$\tau(S)$-GMM (2)
Reserve price determinants α_R and $\boldsymbol{\beta}_R$:						
logpar	0.13***	−0.58***	−0.21	−0.15	−0.61	0.41
	(0.03)	(0.02)	(0.20)	(1.00)	(0.58)	(1.49)
logoutstanding	0.63***	0.57***	−0.37***	−0.38	0.46	0.58
	(0.09)	(0.04)	(0.13)	(0.42)	(1.58)	(2.54)
CLO 2.0 vintage	1.73***	1.27***	−0.74	−0.46	−1.90	−0.51
	(0.23)	(0.09)	(0.76)	(2.42)	(1.78)	(2.49)
CLO 3.0 vintage	1.46***	0.59***	1.70***	1.75***	−0.41	−0.26
	(0.28)	(0.09)	(0.46)	(0.65)	(0.66)	(1.17)
A rating			−4.81***	−4.79		
			(1.64)	(5.06)		
BBB rating			−6.61***	−6.72***		
			(0.53)	(1.26)		
B rating					−13.49***	−11.53***
					(1.61)	(1.60)
Equity rating					−63.07***	−64.29***
					(1.93)	(3.41)
JPM LL spread	−0.08	−0.19***	−2.07***	−1.97***	−8.01***	−6.92***
	(0.10)	(0.02)	(0.17)	(0.36)	(0.67)	(1.00)
Dealer CDS spread	−17.46***	−25.68***	−16.85***	−17.39***	−27.40***	−34.03***
	(1.00)	(0.32)	(1.13)	(3.10)	(5.75)	(5.99)
Constant	101.75***	106.93***	114.19***	114.15***	131.59***	128.86***
	(0.58)	(0.00)	(0.95)	(1.00)	(5.99)	(9.17)
Quantile rotation τ^* for $B^{1:N}$:						
τ_1^1		−0.00***		−0.00		−0.02
		(0.00)		(0.05)		(0.01)
τ_0^1	0.00	0.00***	0.01***	0.02	0.02***	0.03***
	(0.00)	(0.00)	(0.00)	(0.05)	(0.00)	(0.01)
Quantile rotation τ^* for $B^{2:N}$:						
τ_1^2		0.00***		0.00		−0.02
		(0.00)		(0.06)		(0.01)
τ_0^2	0.00	0.00***	0.02***	0.01	0.02***	0.03***
	(0.00)	(0.00)	(0.00)	(0.05)	(0.00)	(0.01)
GMM statistics:						
GMM criterion	1.3463333	3.935e-09	28.748811	10.676783	297.15752	67.408569
Number of parameters	9	11	11	13	11	13
Number of moments	14		18		18	
N	7,486		9,360		6,390	

C CLO Buyer Valuations and Dealers' Strategic Bid Shading

This section explores the link between TCI and dealers' CLO valuations and bidding strategies. We start by discussing how to extract bidders' valuations from the BWIC data. In BWIC i, bidders $j = 1, ..., N$ value the CLO at V_{ij}. Below we show how to recover all V_{ij} from the best bid $B^{1:N}$ and the cover $B^{2:N}$ without knowledge of the number of bidders, N. The bidder's profit from bidding B_{ij} is equal to

$$\pi_{ij} = (V_{ij} - B_{ij}) \Pr(\text{Win}_{ij} | B_{ij}), \tag{IA1}$$

and $\Pr(\text{Win}_{ij}|B_{ij}) = \Pr(\max_{k \neq i} B_k \leq B_{ij}) = G^{1:N-1}(B_{ij}) = G(B_{ij})^{N-1}$. Bidder j chooses B_{ij} to maximize expression (IA1), which yields the condition

$$V_{ij} = B_{ij} + \underbrace{\frac{G^{1:N-1}(B_{ij})}{g^{1:N-1}(B_{ij})}}_{\text{Bid shading}>0}. \tag{IA2}$$

Condition (IA2) shows that the bidder shades the bid for two reasons. The number of bidders N may be low, creating little competition in the auction. Or, keeping N fixed the distribution of competing bids may be low. The distribution of bids and prices are related through the following identities:

$$\frac{G^{1:N-1}(B)}{g^{1:N-1}(B)} = \frac{G(B)}{(N-1)g(B)} = \frac{N}{N-1} \frac{G^{1:N}(B)}{g^{1:N}(B)} = \frac{G^{2:N}(B) - G^{1:N}(B)}{g^{2:N}(B)}. \tag{IA3}$$

So long as each bidder uses an upward-sloping bidding function $\beta(\cdot) : V \to B = \boldsymbol{\beta}(V)$, condition (IA3) yields that the bid function $B_{ij} = \boldsymbol{\beta}(V_{ij})$ is determined solely by the distribution of best and second-best bids. CLO values V can be identified from the distribution of best bids if N is known (Berman (1963); Guerre, Perrigne, and Vuong (1995); Athey and Haile (2002)). The number of bidders N is, however, not reported in our BWIC data.

The values that bidders assign to the CLO can, alternatively, be identified from the distribution of best bids and second-best bids without knowledge of the pool of potential bidders. Bidders' CLO valuations V_{ij} can be recovered from their bids B_{ij} and the distributions of both best bids and second-best bids:

$$V_{ij} = B_{ij} + \frac{G^{2:N}(B_{ij}) - G^{1:N}(B_{ij})}{g^{2:N}(B_{ij})}. \tag{IA4}$$

Given data on the best bids $b_i^{1:N}$ and cover $b_i^{2:N}$ in BWIC i and non-parametric estimates from Section 4.2 for the conditional distribution of best bids, $\widehat{G^{1:N}}(\cdot|\boldsymbol{X})$, and conditional distribution and density of second-best bids, $\widehat{G^{2:N}}(\cdot|\boldsymbol{X})$ and $\widehat{g^{2:N}}(\cdot|\boldsymbol{X})$, we use equation (IA4) to back out the valuation of the winner in the BWIC and the cover using expressions

$$\begin{aligned} \widehat{v_i^{1:N}} &= b_i^{1:N} + \underbrace{\frac{\widehat{G^{2:N}}(b_i^{1:N}|\boldsymbol{X}_i) - \widehat{G^{1:N}}(b_i^{1:N}|\boldsymbol{X}_i)}{\widehat{g^{2:N}}(b_i^{1:N}|\boldsymbol{X}_i)}}_{\text{Bid shading}>0}, \\ \widehat{v_i^{2:N}} &= b_i^{2:N} + \frac{\widehat{G^{2:N}}(b_i^{2:N}|\boldsymbol{X}_i) - \widehat{G^{1:N}}(b_i^{2:N}|\boldsymbol{X}_i)}{\widehat{g^{2:N}}(b_i^{2:N}|\boldsymbol{X}_i)}. \end{aligned} \tag{IA5}$$

Dealers' bid shading is estimated as a percentage of the CLO face value using relations (IA5) over the 2012–2020 sample period. Figure IA.1 graphs quarterly estimates split by tranche into the senior tranche rated AAA (left), mezzanine tranche rated AA–BBB (middle), and junior tranche rated BB–equity (right). Grey areas indicate periods of market stress: 2012 European debt crisis, 2015-16 credit stress, and 2020 COVID-19 pandemic.

Panel A juxtaposes dealers' valuations (solid line) and bids (dashed line), both as a percentage of the CLO face value. Several noteworthy observations stand out. First, valuations fall quite sharply during credit stress periods, with the size of the devaluation increasing with credit risk. For instance, dealer valuations fall by approximately 80bps/3%/8% of the CLO face value between 2015Q3 and 2016Q1 for the senior/mezzanine/junior tranche. In the case of junior tranche, dealers' valuation can be as low as 73% of the CLO face value in 2012Q1. Coming out of the crisis, valuations tend to recover as fast as they fall during crisis. For instance, dealer valuations rise by approximately 90bps/4%/10% between 2016Q1 and 2016Q3, reaching their highest values in 2017Q3. During all four quarters of 2017 dealers' valuation has been above the CLO face value for the senior and mezzanine tranches.

Second, Panel A reveals that dealers' valuations look different pre-2016Q1 than they look post-2016Q1 for the senior and mezzanine tranches. Pre-2016Q1 valuations are on average equal to 99%/97%, while they are equal to 100%/98% (excluding 2020 COVID-19 pandemic) post-2016Q1 for senior/mezzanine tranches. Pre-2016Q1 valuations are also more volatile than post-2016Q1 valuations for the senior and mezzanine tranches. This is largely due to the CLO market being dominated by CLO 1.0s and 2.0s pre-2016Q1, and by CLO 3.0s post-2016Q1. By way of contrast, the junior tranche valuations look quite alike pre-2016Q1 and post-2016Q1.

Panel B illustrates the dealer shading. Bid shading is higher pre-2016Q1 than post-2016Q1 for the senior tranche. Bid shading is quite high and volatile for most quarters in the case of the junior tranche. Bid shading increases quite sharply during credit stress periods. This is especially true for the mezzanine tranche for which bid shading increased dramatically during 2012 Euro debt crisis, 2015-2016 credit stress, and during 2020 COVID-19 pandemic with values reaching as high as 7.5% of the CLO face value in 2012Q1. For the senior tranche, bid shading increases in 2012 and 2020, but it remains low through 2015-2016 credit stress period. Outside crisis periods, dealers reduce their bid shading. For instance, dealers shaded their bids by only few bps between 2016Q3 and 2020Q1 for the senior and mezzanine tranches.

Next, we explore the determinants of the dealer CLO valuations using the same set of explanatory variables $\boldsymbol{X}$ as in Table 6. The benchmark specification (column 1) includes only CLO-specific characteristics such as the par value of trade, CLO vintage and the issue size. In Specification 2 (column 2) we also control for the fixed-income market conditions by adding the JPM leveraged loan spread to Specification 1. In Specification 3 (column 3) we add the dealer CDS spread and then use it jointly with the leveraged loan spread in Specification 4 (column 4). Specification 5 (column 5) reports results with all explanatory variables being included, as well as the quarter fixed effects. In addition, we use credit rating splits for the mezzanine and junior tranches.

Table IA.3 reports our findings split by senior/mezzanine/junior tranches in Panels A/B/C. It shows that dealer CLO valuation varies significantly with the CLO vintage for all CLO tranches across all five specifications. CLO 2.0s and 3.0s tend to have higher dealer valuations than CLO 1.0s for senior and mezzanine tranches. Interestingly, CLO

Table IA.3: Dealer CLO valuations

The table reports the determinants of dealers' CLO valuations. Panel A reports results for the senior tranche rated AAA, Panel B for the mezzanine tranche rated AA–BBB, and Panel C for the junior tranche rated BB–equity. Standard errors are robust to heteroskedasticity. Significance levels are indicated by * (10%), ** (5%), *** (1%).

	Implied dealer valuations (% par value)				
	(1)	(2)	(3)	(4)	(5)
Panel A: Senior tranche (I = 3,977 BWICs)					
log(Par value of trade)	−0.01	−0.01*	0.00	−0.01	0.00
CLO 2.0 vintage	0.73***	0.74***	0.56***	0.61***	0.49***
CLO 3.0 vintage	1.10***	1.14***	0.79***	0.90***	0.83***
log(CLO issue size)	−0.04***	−0.05***	−0.02	−0.03**	−0.02
CLO issue size missing	0.16	0.21**	0.10	0.15	0.26***
JPM LL spread		−0.29***		−0.22***	−0.42***
Dealer CDS spread			−1.47***	−1.09***	−0.79***
Quarter FE	No	No	No	No	Yes
R^2	0.266	0.361	0.363	0.408	0.498
Panel B: Mezzanine tranche (I = 5,005 BWICs)					
log(Par value of trade)	−0.11***	−0.09**	−0.04	−0.05	0.01
CLO 2.0 vintage	1.51***	1.36***	0.90***	1.00***	0.88***
CLO 3.0 vintage	1.87***	1.98***	0.60***	1.12***	0.00
log(CLO issue size)	−0.01	0.03	−0.01	0.02	−0.03
CLO issue size missing	0.14	−0.02	−0.26	−0.23	−0.64***
A rating	−0.83***	−0.85***	−0.83***	−0.84***	−0.80***
BBB rating	−1.55***	−1.62***	−1.65***	−1.66***	−1.60***
JPM LL spread		−1.48***		−1.06***	−1.44***
Dealer CDS spread			−5.22***	−3.42***	−4.86***
Quarter FE	No	No	No	No	Yes
R^2	0.116	0.243	0.231	0.282	0.408
Panel C: Junior tranche (I = 3,372 BWICs)					
log(Par value of trade)	−0.10	−0.23	0.04	−0.14	−0.25
CLO 2.0 vintage	−0.57	−1.27*	−3.31***	−2.46***	−0.30
CLO 3.0 vintage	0.14	0.55	−4.60***	−1.78**	−0.76
log(CLO issue size)	0.00	0.09	0.07	0.11	0.26
CLO issue size missing	−0.14	0.45	−2.03**	−0.55	−1.37*
B rating	−4.97***	−5.73***	−5.07***	−5.65***	−5.64***
Equity rating	−24.34***	−25.19***	−24.68***	−25.22***	−25.76***
JPM LL spread		−6.46***		−5.38***	−4.67***
Dealer CDS spread			−20.06***	−9.58***	−11.56***
Quarter FE	No	No	No	No	Yes
R^2	0.478	0.581	0.535	0.591	0.671

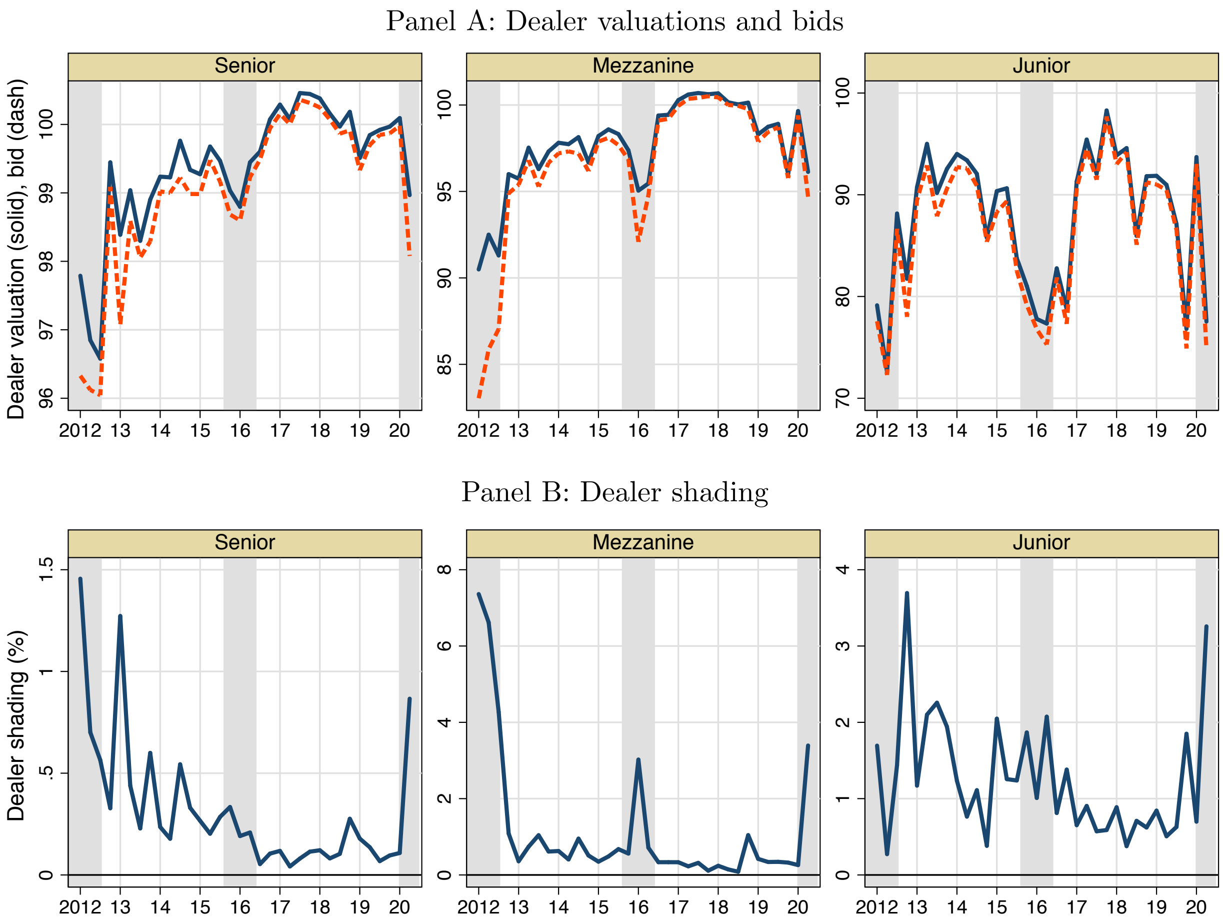

Figure IA.1: Dealer shading

The figure documents the quarterly amount of dealer bid shading in the CLO market over the sample period 2012–2020, split by tranche into the senior tranche rated AAA (left), mezzanine tranche rated AA–BBB (middle), and junior tranche rated BB–equity (right). Grey areas indicate periods of market stress: 2012 European debt crisis, 2015-16 credit stress, and 2020 COVID-19 pandemic.

1.0s tend to have higher dealer valuations than CLO 2.0s and 3.0s in the case of the junior tranche, consistent with the pre-crisis vintage having lower level of subordination, benefiting holders of junior tranches. Table 6 shows that higher valuations translate into higher best bids for the senior and mezzanine tranches of CLO 2.0s and 3.0s. Specification 1 has R^2 of 26.6%/11.6%/47.8% for senior/mezzanine/junior tranches. For mezzanine and junior tranches dealer valuations decline with the CLO credit rating for all five specifications.

Dealer's CLO valuation declines with the JPM leveraged loan spread for all CLO tranches in all five specifications. The economic magnitude of the effect is largest/smallest for the junior/senior tranche. Specifications 3 suggests that dealers with higher credit risk tend to value CLOs lower than dealers with low credit risk. The effect is even stronger for riskier tranches.

Finally, we explore the determinants of the dealer bid shading. Table IA.4 utilizes the same layout as in Table IA.3

Table IA.4: TCI due to dealer shading

The table reports the determinants of dealers' bid shading. Panel A reports results for the senior tranche rated AAA, Panel B for the mezzanine tranche rated AA–BBB, and Panel C for the junior tranche rated BB–equity. Standard errors are robust to heteroskedasticity. Significance levels are indicated by * (10%), ** (5%), *** (1%).

	Dealer shading (% of par value)				
	(1)	(2)	(3)	(4)	(5)
	Panel A: Senior tranche (I = 3,977 BWICs)				
log(Par value of trade)	−0.01*	−0.01*	−0.01**	−0.01**	−0.02***
CLO 2.0 vintage	−0.25***	−0.25***	−0.21***	−0.20***	−0.13***
CLO 3.0 vintage	−0.33***	−0.33***	−0.26***	−0.25***	−0.18***
log(CLO issue size)	−0.03***	−0.03***	−0.03***	−0.04***	−0.03***
CLO issue size missing	−0.16***	−0.16***	−0.15***	−0.14***	−0.17***
JPM LL spread		0.01		−0.02	0.00
Dealer CDS spread			0.33***	0.36***	0.17
Quarter FE	No	No	No	No	Yes
R^2	0.076	0.076	0.088	0.089	0.162
	Panel B: Mezzanine tranche (I = 5,005 BWICs)				
log(Par value of trade)	−0.01	−0.01	−0.05**	−0.05**	−0.02
CLO 2.0 vintage	−0.41***	−0.36***	−0.03	−0.04	0.04
CLO 3.0 vintage	−0.60***	−0.64***	0.18**	0.14*	0.16**
log(CLO issue size)	0.02	0.01	0.02	0.02	0.04
CLO issue size missing	−0.27***	−0.21***	−0.02	−0.02	−0.02
A rating	0.13**	0.13**	0.13**	0.13**	0.15***
BBB rating	0.10	0.12*	0.16***	0.16***	0.16***
JPM LL spread		0.48***		0.10	0.98***
Dealer CDS spread			3.22***	3.06***	2.08**
Quarter FE	No	No	No	No	Yes
R^2	0.023	0.067	0.168	0.170	0.300
	Panel C: Junior tranche (I = 3,372 BWICs)				
log(Par value of trade)	0.04	0.04	0.03	0.03	0.05
CLO 2.0 vintage	−0.33*	−0.30*	−0.16	−0.19	−0.33*
CLO 3.0 vintage	−0.88***	−0.90***	−0.59***	−0.70***	−0.60***
log(CLO issue size)	0.05	0.04	0.04	0.04	0.02
CLO issue size missing	−0.40**	−0.43***	−0.28*	−0.34**	−0.13
B rating	0.26*	0.30**	0.27*	0.29**	0.28*
Equity rating	0.51***	0.55***	0.53***	0.55***	0.62***
JPM LL spread		0.31***		0.21***	0.41
Dealer CDS spread			1.24***	0.83**	−0.36
Quarter FE	No	No	No	No	Yes
R^2	0.034	0.044	0.044	0.048	0.094

to report our findings. Independent of the specification, bid shading is the lowest for CLO 3.0s, next lowest for CLO 2.0s . In fact, only CLO vintage has the explanatory power for the senior tranche in the Specification 5. Trade size and the CLO amount outstanding have no explanatory power in any of the specifications. Dealers shade a lot when bidding for the equity-rated CLO tranches. Market conditions matter only for the mezzanine tranche; dealers underbid more when the dealer CDS spread is higher, and shade bids less when the loan spread is higher.