Enhanced Resiliency in Corporate Bond Liquidity: A Tradeoff in OTC Markets *

Botao Wu
CUHK

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Abstract

I argue post-financial crisis regulations create a tradeoff between immediacy and resiliency in corporate bond market liquidity. While existing studies have documented that stricter capital requirements reduced dealer inventories, leading to longer trading delays in normal times, this paper highlights the intended benefits of these regulations: enhanced market resiliency during crises. Using data from the Great Financial Crisis (2008) and the COVID-19 pandemic (2020), I show that better-capitalized dealers have more balance sheet flexibility to absorb systemic selling pressures by "leaning against the wind", stabilizing prices and accelerating recovery. High-yield bonds, which experience disproportionately larger declines in immediacy compared to investment grade bonds, exhibit the most significant improvements in resiliency, driven by dealers' increased balance sheet capacity. I develop a stylized over-the-counter (OTC) model that formalizes this tradeoff, linking lower dealer inventories in normal times to greater balance sheet capacity available during crises. By bridging the immediacy costs and resiliency benefits, I offer a balanced framework for assessing the welfare implications of post-GFC regulations on market liquidity.

Keywords: Corporate Bond Liquidity, Resiliency, Regulations, Welfare

JEL classification: G10, G12, G18, G20

*Contact: botaowu@cuhk.edu.hk. I appreciate conversations with Farshid Abdi, Jaewon Choi, Peter Feldhütter, Matthew Pritsker, Chaojun Wang, and participants at the IOSCO/OECD Conference on Corporate Bond Markets and CUHK junior workshop. I am grateful to the research support by the Early Career Scheme from the Hong Kong SAR government.

1 Introduction

Corporate bond market liquidity has been a subject of heated debates since the great financial crisis (GFC). Post-GFC banking regulations introduced stricter capital requirements for dealer banks. It is well documented that these regulations have introduced unintended costs for corporate bond market liquidity, as they stipulate stringent limits on the amount of dealer capital that can be committed to trading during normal times. These regulations therefore reduce dealer banks' inventory holdings, and their provision of immediacy during normal times. Investors now need to spend more time waiting to fully execute their trades.[1]

Contrary to the common belief that corporate bond liquidity worsened to a great extent during the COVID crisis because of the bid-ask spread spikes or the elevations in the yields, I argue the right angle to look at liquidity during the crisis times is through its resiliency, namely, how soon prices can recover from a systemic liquidity shock. When a liquidity shock creates selling pressure and rising liquidity demand, it is natural that price will fall and bid-ask spread will rise. What really matters is how long it will last, and how disruptive prices can be. From this perspective, I show that resilience of the corporate bond liquidity has actually improved in recent years. Post-GFC regulations make dealer banks better capitalized. They do not need to cut back capital and sell the bonds as they used to do during the great financial crisis. Instead, better capitalized dealer banks are able to "lean against the wind", absorbing the strong selling pressure by buying during the crisis and selling them back afterwards, thereby stabilizing the prices and contributing to a faster recovery. Such improved resiliency, I believe, is one of the intended benefits of the post-GFC regulations on the OTC market liquidity.

I document that the resilience dimension of corporate bond liquidity has actually improved after the great financial crisis. I measure the liquidity resiliency as the elevation in credit spreads in response to a liquidity shock as well as the time duration for the credit spread to fully absorb the liquidity shock. I find that while it used to take 10 weeks before the great financial crisis for liquidity shocks to be fully absorbed by the credit spread, after the great financial crisis such absorption becomes instantaneous. I also look at alternative definitions of resiliency, such as the

[1] Goldman Sachs Global Investment Research: *"it isn't that they can't get trades done; it's that they can't get trades done as quickly [...] [T]rade that historically may have taken a day to get done now needs to [...] take a week or two to execute."* Source: https://www.goldmansachs.com/insights/pages/macroeconomic-insights-folder/liquidy-top-of-mind/pdf.pdf.

price impact of demand shocks from trade imbalances or mutual fund flows, or the mean-reverting rates of the yields. All of them point out to the improved resiliency in corporate bond markets liquidity after the great financial crisis.

Greater resiliency comes from dealers' greater capability of using their balance sheet capacity to lean against the wind and accommodate strong selling pressures. Indeed, I document that during the great financial crisis, dealers were trading in the same direction as the selling pressure as they were dumping the bonds, exacerbating the instability of the market. During the COVID pandemic on the other hand, dealers were trading against the selling pressure as they were buying bonds in response to liquidity shocks, contributing to a faster recovery of the market.

To understand the underlying cause of such improved resiliency, I separate the sample into investment grade bonds and speculative high yield bonds. I find that the improved resiliency after the great financial crisis primarily comes from the high yield bond sample. The credit spread response to liquidity shocks has only been less elevated for high yield bonds after the great financial crisis, while for the highly rated investment grade bonds the credit spread response to liquidity shocks has not changed. Similarly, I find that while dealers dump both the investment grade bonds and high yield bonds during the great financial crisis, resulting in a negative dealer trading imbalance, dealers have actually increased purchases of high yield bonds in 2020, resulting in a positive trading imbalance. In other words, dealers' leaning against wind is more visible for high yield bonds.

It is important to look at the improved resiliency together with the reduced immediacy that has been documented extensively in the literature. High yield bonds suffered more from the reduced immediacy following the introduction of the post-GFC regulations. It is therefore not surprising to see that high yield bonds benefit more from the improved resiliency due to the same regulations. To add some identification, I separate the sample into the bonds whose trades are mostly done by the top 10 biggest dealers, and bonds whose trades not done by the big dealers. Identification is through the assumption that big dealers tend to be banks that are subject to regulations. As can be expected, only bonds that are done by the big dealers enjoy an improved resiliency during the 2020 pandemic period, compared to those bonds that are not. Such a difference does not exist during the 2008 great financial crisis period, as both bonds suffer from a lack of resiliency.

To rationalize my empirical findings, I build a stylized OTC market in the spirit of Lagos and Rocheteau (2007) to which I introduce two aggregate states of the economy: the normal times and the crisis times. One novelty of the model is that I link regulations to the resiliency and immediacy of the OTC market via the dealer inventory level and balance sheet capacity. In normal times regulations reduce the dealer inventory level, delaying the search time between the customers and dealers and therefore harming the immediacy dimension of the OTC liquidity. In times of crisis, dealers now have a higher balance sheet capacity,[2] and so prices recovers faster and market becomes more resilient. As such, a tradeoff between immediacy and resiliency in the OTC market is established. The model is able to generate rising trading delays and liquidity premium in normal times as well as less severe price drops and faster recovery in crisis times, when dealer's inventory level is being reduced, all of which are consistent with the empirical patterns documented in this paper and in previous studies (e.g., Wu 2020).[3] I then use the model to look at several policy recommendations by regulators to address the bond market liquidity concerns. I show that while electronic trading may improve immediacy and mitigate the magnitude of price crashes when a crisis hits, it cannot shorten the recovery time for liquidity shocks to be fully absorbed. Moreover, electronic trading increases the volatility of the market, which may not be desirable given that fixed income investors typically prefer stable cash flows.

One key advantage of the model is that it allows me to do a welfare analysis of the post-crisis regulations on the OTC market liquidity. Existing studies solely address the costs of the regulations without taking into account the potential benefits of these regulations. Therefore, the optimal dealer inventory level in these studies should be 100% of the total balance sheet capacity. However, full balance sheet capacity usage in normal times actually harm the resilience of the market in times of crisis, as dealers would have no additional balance sheet capacity to lean against the wind and have to dump their bond holdings in response to selling pressures, exacerbating the market crash. I derive an analytical formula of the welfare function which trades off the improved resiliency in crisis times against the reduced immediacy in normal times. A preliminary calibration shows that the optimal dealer inventory level is 20% of the total balance sheet capacity, which is broadly in line with the reduction in the corporate bond primary dealer inventory level since the

[2] Assume dealer's total capacity is fixed. A lower inventory level is equivalent to a higher balance sheet capacity which is equal to the fixed total capacity minus the inventory level.

[3] See the reduction in corporate bond dealer inventory level in Appendix Figure A5.

great financial crisis in the data.

This paper contributes to the following strands of literature. First, this is one of the first papers that document the improved resiliency in corporate bond liquidity after the great financial crisis. Doing so I complement the work by Becker and Benmelech (2021) who show that bond issuance is more resilient than loan issuance in crisis. My results suggests that the faster recovery for corporate bond yields to absorb liquidity shocks may help encourage bond issuance in times of crisis. O'Hara, Rapp, and Zhou (2021) show that insurance companies help support the resilience of investment grade bonds during the COVID crisis. I complement their work by showing that high yield bonds enjoy more improvement in the resilience dimension of liquidity and better capitalized dealers are more likely to be the main contributors because insurance companies do not trade or own high yield bonds due to their investment mandates. More broadly, I add to the literature on fixed income market in crisis periods (i.e., Haddad, Moreira, and Muir 2021, Ma, Xiao, and Zeng 2022). These papers document that mutual funds sell liquid and good quality bonds first during the onset of the COVID pandemic, resulting in the elevated yields and strong selling pressures of the investment grade bonds. My paper suggests that part of the reason why high yield bond yields can on the other hand recover faster during COVID is because dealers are better capitalized thanks to the post-GFC regulations which impose more stringent capital requirement on high yield bonds. Mutual funds cannot be the sole reason for the resilience differential between investment grade and high yield bonds as I show that such difference only exists in the post-GFC period. During the great financial crisis, both investment grade and high yield bonds suffer from a lack of liquidity resiliency. I show that dealers become net purchasers of high yield bonds during the COVID crisis, and they trade against mutual fund outflows in response to fallen angel bonds only during the post-GFC period.

Second, my paper contributes to a more comprehensive understanding of the impact of the post-GFC regulations on bond liquidity. Existing studies have mostly focused on the costs of these regulations, namely the reduced immediacy. Dick-Nielsen and Rossi (2018) and Bao, O'Hara, and Zhou (2018) show that dealers charge higher costs of immediacy following bond downgrades. Bessembinder et al. (2018) show that dealers commit less capital to trading in normal times in the post-GFC period. Wu (2020) uses a structural model to estimate trading delays and shows that regulations have increased corporate bond trading delays from less than 1 day to a over week.

My paper is one of the first that studies the potential benefits of these regulations in corporate bond markets, namely the improved resiliency during crisis times. I show that bonds that are more penalized by regulations in normal times (i.e., high yield bonds) actually enjoy more improvement in resiliency in times of crisis. It should be noted that I am not arguing against the existing conclusions of the worsened immediacy due to regulations such as the Volcker rule. Instead, I am pointing out such loss of immediacy is the necessary costs for the improved resiliency, which is what the regulators have intended in the first place. My paper suggests that regulators should always pay attention to market conditions and be ready to relax the capital requirement whenever necessary. In other words, dealer balance sheets should function like a reservoir and liquidity stored in normal times should be ready to be unleased in times of crisis when it is needed the most. When regulators fail to do so, we end up in the worse of both worlds: a worsened immediacy in normal times and a lack of resiliency in times of crisis, which should be the true concerns shared by regulators and practitioners.

Finally, my paper contributes to modeling the OTC market in a search framework following the seminal work by Duffie, Gârleanu, and Pedersen (2005). Broadly two types of such models exist in characterizing the OTC market. Duffie, Gârleanu, and Pedersen (2005), Lagos and Rocheteau (2009) study the steady states and show that slower trading speed reduces the asset price relative to the fundamental value. Weill (2007), Lagos, Rocheteau, and Weill (2011) study the transitional dynamics out of steady states and characterize price crash and recovery in response to an aggregate liquidity shock. My model is one of the first in the literature that points out the potential linkage between these two types of models, namely the longer trading delays in normal times and the faster recovery following a crisis via dealers' inventory holding and balance sheet capacity. By introducing two aggregate states to a stylized OTC model, I characterize the tradeoff between immediacy in normal times and resiliency in crisis times in the OTC market. The two aggregate-state feature is indispensable in establishing such a tradeoff because in absence of transitions between the aggregate states, longer trading delays will lengthen the recovery time following market crashes (Duffie, Gârleanu, and Pedersen 2007). My model suggests that transition intensities between the crisis state and the normal market state should be of first order importance in characterizing the resilience dimension of the OTC market liquidity than the meeting intensities between customers and dealers.

The tractability of the model also allows me to conduct a comprehensive cost-benefit analysis of the post-GFC regulations on the OTC market while existing models only feature the cost component. The tradeoff between immediacy and resiliency is also in part supported by the empirical findings in U.S. treasury market. Duffie et al. (2023), He, Nagel, and Song 2022 observe that regulations have made treasury market less resilient during the COVID crisis. The impact of regulations on the treasury market can be seen as the exact opposite of what happens to the corporate bond market: dealers' treasury inventory has actually increased in normal times after the great financial crisis (Adrian et al. 2017, Du, Hébert, and Li 2023), shrinking the balance sheet capacity for crisis times and resulting in elevated treasury yields and disruptions during the pandemic.

The rest of the paper is organized as follows. In Section 2 I outline an OTC model that features the tradeoff between the immediacy in normal times and resiliency in crisis time via dealer inventory and balance sheet capacity. In Section 3 I empirically document the improvement in the resilience dimension of corporate bond liquidity and point out that regulations are the potential cause. In Section 4 I use my model to conduct a welfare analysis of the post-GFC regulations on corporate bond liquidity and back out the optimal dealer inventory level. Section 5 concludes.

2 OTC Model of Immediacy vs. Resiliency

To demonstrate the tradeoff between the immediacy and resiliency dimensions of liquidity as regulations increase the capital requirement of dealer banks, I build an OTC model following Lagos and Rocheteau (2007) and Lagos, Rocheteau, and Weill (2011) with aggregate shocks. Time is continuous with discount rate r and there is a bond with fixed supply of A. There are two types of customers: H(igh) and L(ow). There is a liquidity shock that happens at the Poisson rate of δ. Conditional on the shock, customer i switches to type j with probability π_j or remains at type i with probability $\pi_i = 1 - \pi_j$. There is a competitive asset market. Customers can trade in the asset market by contacting dealers at the Poisson rate of α. Upon contact, customers and dealers will negotiate trade quantities and an intermediation fee ϕ. Moreover, There is an aggregate normal state (N), and a crisis or liquidity distress state (C). The normal state switches to the crisis state at the poisson rate of λ^N, and the crisis state switches to the normal state at

the poisson rate of λ^C. Customer of type i in the aggregate state s with bond holding a has a linear utility function $z^s\epsilon_i a$ with $\epsilon_L < \epsilon_H$ and $z^N > z^C$. One can think of ϵ_H as the cashflow of a bond. So while the investors receive the idiosyncratic preference shocks at some probability, the aggregate shocks change all investors' valuations.

Consider a stochastic stationary equilibrium. The value function of customer $i \in \{H, L\}$ in the aggregate state $s \in \{N, C\}$ with asset holding a satisfies the following Hamilton-Jacobi-Bellman (HJB) equation:

$$rV_i^s(a) = z^s\epsilon_i a + \lambda^s(V_i^{s'}(a) - V_i^s(a)) + \delta\pi_j(V_j^s(a) - V_i^s(a)) + \alpha(V_i^s(a_i) - V_i^s(a) - p(a_i - a) - \phi_i(a)) \quad (1)$$

This equation is intuitive. At some poisson rate λ^s, customers in the aggregate state s switches to the other aggregate state s'. At the poisson rate δ, customers of type i changes to type j with probability π_j. And finally, customers meet with dealers at the rate of α.

I model the impact of regulations through the following two ways. First, the speed at which customers meet with dealers increase with the the level of inventory $I < \bar{I}$ where $\bar{I}$ is the total balance sheet capacity: $\alpha(I)$ increases in I. Second, the rate at which the aggregate state recovers from a crisis (C) to a normal state (N) increases in the additional dealer balance sheet capacity $\bar{I} - I$: $\lambda^C(\bar{I} - I)$ decreases in I. This two assumptions, though seem *ad hoc*, captures well the notions of loss of immediacy and price recovery. The amount of dealer inventory directly affects the trading speed. Lagos and Rocheteau (2007) endogenize this assumption through dealer entry problems affected by the dealer inventory cost. In reality during normal times, buy and sell orders are more or less balanced at a weekly or monthly basis, so large dealer inventory holdings facilitate dealers' trading with customers. During a crisis, strong selling pressure creates a one-sided market, and requires the dealer to expand their inventory position and lean against the wind. However, this requires dealers to have enough balance sheet capacity $\bar{I} - I$ to absorb the additional selling pressure. So a higher balance sheet capacity $\bar{I} - I$ makes the market more resilient to the aggregate liquidity shocks, and recover faster (large λ^C). Consider the case when $\alpha(\cdot)$ and $\lambda^C(\cdot)$ are both linear in I. A reduction in the dealer inventory holding in normal times from $I = 80\%\bar{I}$ to $I = 20\%\bar{I}$ implies that trading delays in normal times increases by 4 times, while price recovers from the aggregate

liquidity shock 4 times faster during the stress times. In Appendix A.1, I micro found these two assumptions using a Duffie, Gârleanu, and Pedersen (2005) type of model that features both longer trading delays in the steady states as well as the faster price recovery in the transition dynamics.

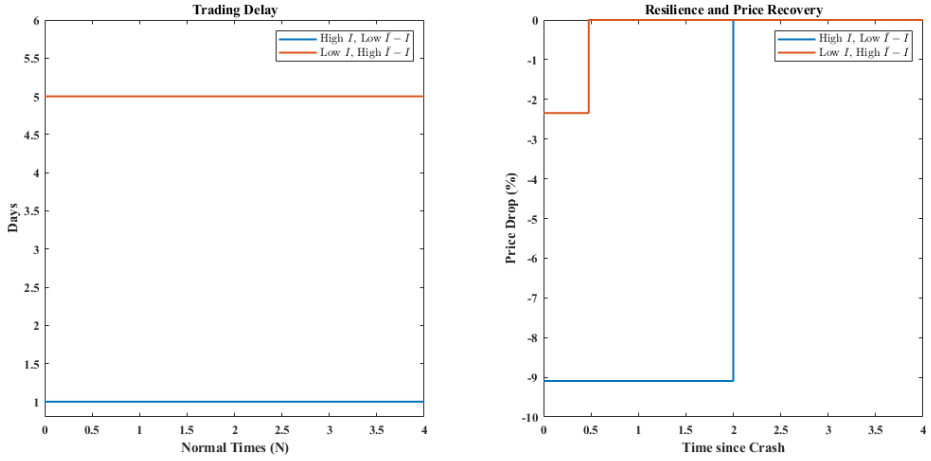
As is shown in Lagos and Rocheteau (2007), price in the aggregate state s satisfies the following equation:

$$p^s = \frac{\bar{\epsilon}_H^s}{r} - \frac{\kappa\lambda^s}{r(r+\kappa)(r+\lambda^C+\lambda^N)}(\bar{\epsilon}_H^s - \bar{\epsilon}_H^{s'}) \tag{2}$$

where $\bar{\epsilon}_H^s = \frac{(r+\kappa+\lambda^{s'})z^s+\lambda^s z^{s'}}{r+\kappa+\lambda^C+\lambda^N}\bar{\epsilon} + \frac{r+\kappa}{r+\kappa+\delta}\frac{(r+\kappa+\delta+\lambda^{s'})z^s+\lambda^s z^{s'}}{r+\kappa+\delta+\lambda^C+\lambda^N}(\epsilon_H - \bar{\epsilon})$ and $\kappa = \alpha(I)(1-\eta)$. In Figure 1 I plot the trading delays $\frac{1}{\alpha(I)}$ in normal times (N), and percentage drop in price $\frac{p^C-p^N}{p^N}$ and recovery in the stressful times (C) when regulations reduces inventory I from $100\%\bar{I}$ to $20\%\bar{I}$. This is broadly on par with the decline in corporate bond primary dealer inventory from 2006 to 2017-2018 before the market gets disrupted by COVID (Figure A5). We see that a lower inventory level reduces the immediacy dimension of liquidity and trading delays rise in normal times from 1 day to 5 days (Wu 2020). However, a lower level of inventory in normal times means that when the aggregate liquidity shock hits, dealers will have more balance sheet capacity $\bar{I} - I$ to lean against with wind, which makes market more resilient to the aggregate shocks in stressful times. We see from the right panel that low inventory during normal times makes the price crash less severe compared to high inventory in normal times (-2.5% vs -9%). The market recovers faster too. In the low inventory $I = 20\%\bar{I}$ and high balance sheet capacity $\bar{I} - I$ regime, price recovers in an average of 0.5 years, compared to the average recovery time of 2 years in the high inventory $I = 100\%\bar{I}$ and low balance sheet capacity $\bar{I} - I$ regime.

The model suggests that the loss of immediacy and longer trading delays in normal times are the necessary costs in order to have better resiliency in terms of a higher balance sheet capacity $(\bar{I} - I)$ to accommodate additional selling pressures in times of stress. The policy recommendation from my model is for corporate bond dealers to remain vigilant and stay ready to use their additional capacity $\bar{I} - I$ to lean against the wind whenever the aggregate liquidity shock hits the market. To do so regulators must be ready to loosen the inventory constraint by the dealers whenever necessary. I now use this model to evaluate several policy recommendations put forward by the regulators.

Figure 1: Immediacy vs. Resiliency



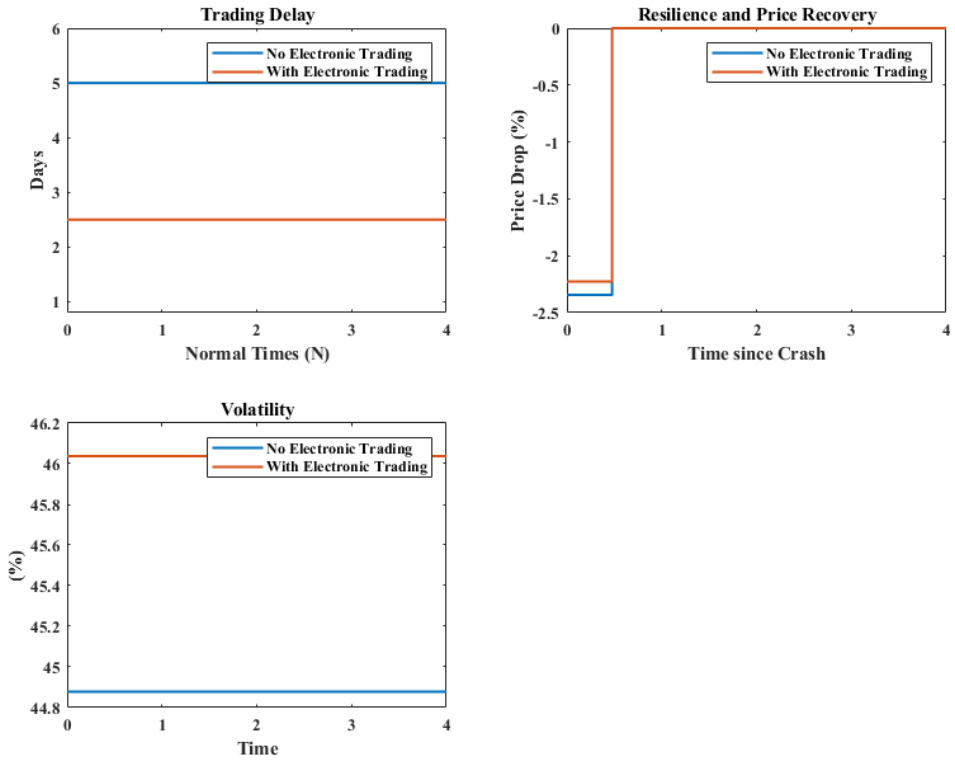
Notes: The left panel shows the average trading delays (immediacy) in the high inventory $I = \bar{I}$ and low balance sheet capacity $\bar{I} - I = 0$ case (red line, pre-crisis) vs. low inventory $I = 0.2\bar{I}$ and high balance sheet capacity $\bar{I} - I = 0.8\bar{I}$ case (blue line, post-crisis). The right panel shows the price recovery (resiliency) in the high inventory $I = \bar{I}$ and low capacity $\bar{I} - I = 0$ case (red line, pre-crisis) vs. low inventory $I = 0.2\bar{I}$ and high balance sheet capacity $\bar{I} - I = 0.8\bar{I}$ case (blue line, post-crisis).

2.1 Policy Implication: Electronic Trading

One of the heated debates in IOSCO (2022) is the emergence of electronic trading in the corporate bond market. Industry practitioners considers electronic trading as a solution to the illiquidity brought by regulations in the corporate bond market. To model the effect of electronic trading, I follow Wu (2020) and introduce a separate trading channel β through which the customers can trade with each other. Below I plot the trading delays, price recovery, and volatility of the prices when the share of electronic trading, $\frac{\beta}{\alpha(I)+\beta}$, increases from 0 to 50%, under the context that regulations force dealers to reduce inventory to be 20% of the total balance sheet capacity $\bar{I}$. This is broadly in line with the share of electronic trading in the investment grade bonds. We see that electronic trading improves immediacy, reducing trading delays, from 5 days to less than 3 days. The initial drop in price upon the aggregate liquidity shock is also further mitigated. However, resiliency is not improved substantially because improved immediacy from electronic trading cannot shorten the amount of time during which prices recovers to the normal condition, which still takes 0.5 years. The recovery time depends on the dealer capacity $\bar{I} - I$, which is not directly affected by electronic trading β. Moreover, rising shares of electronic trading increases the volatility of the market $\frac{\sqrt{\lambda^N \lambda^C}}{\lambda^N + \lambda^C}(p^N - p^C)$, as one can see from the bottom panel. Therefore, while industry

practitioners are correct that electronic trading can improve immediacy worsened by regulations, resiliency remains intact as price recovers at the same speed. Moreover, electronic trading comes at a cost of rising volatility of the market, which may not be desirable to the fixed income investors.

Figure 2: Impact of Electronic Trading



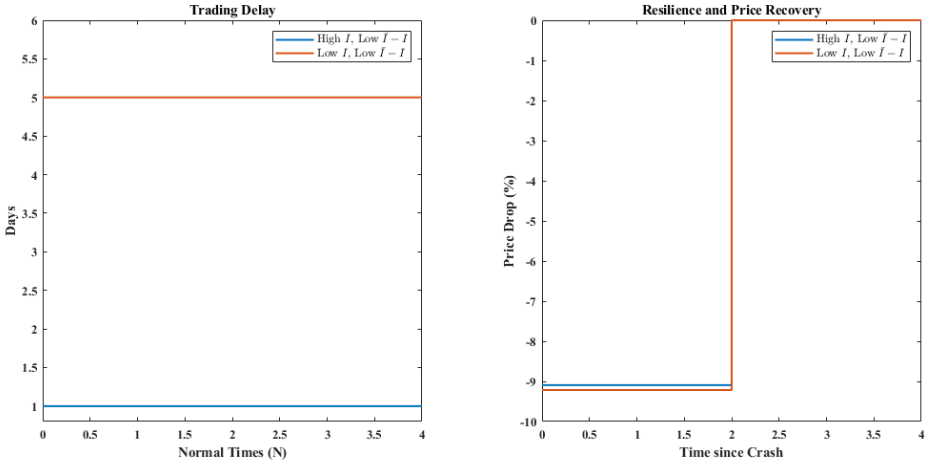
Notes: I plot the trading delays, price discovery, and volatility when the shares of electronic trading increases from 0 to 50%. Everything is under the context that regulations reduces dealer inventory to 20% of the total capacity $\bar{I}$.

2.2 Policy Implication: the Volcker Rule and Draconian Regulators

Finally, I consider the case that most people have in mind when thinking about the impact of regulations on dealers' market making. That is, dealers and regulators may fail to use the additional balance sheet capacity $\bar{I} - I$ to accommodate the strong selling pressure, even if they have the capacity to do so now that the inventory level is much lower than the capacity constraint: $I << \bar{I}$. This concern is legitimate, because a reduced level of dealer inventory I comes about primarily due to the harsh regulations imposed by the regulators. If regulators fail to lift the constraint in times of a liquidity crisis, or if dealers become unwilling to expand their inventory level using their

additional balance sheet capacity, then we end up with the worst of the both worlds. On the one hand, we have a reduced immediacy in normal times due to the low inventory level (I). On the other hand, we also end up with a worse recovery because dealers fail to use their additional balance sheet capacity $\bar{I} - I$ to accommodate the strong selling pressure. In Figure 3 I plot this scenario where dealer inventory is reduced to 20% $\bar{I}$, and dealers fail to use the additional capacity in times of crisis: $\bar{I} - I = 0$

Figure 3: Immediacy vs. Resiliency when Inventory and Balance Sheet Capacity are Both Low.



Notes: This figure plots the trading delays and price recovery when both the inventory is low $I = 0.2\bar{I}$, and dealers fail to use the additional balance sheet capacity in times of stress $\bar{I} - I = 0$.

We see that first, immediacy during normal times is worsened as trading delays increase from 1 day to 5 days. Second, resiliency is worsened as well, as dealers fail to use the additional balance sheet capacity to accommodate the strong selling pressure. We see that price drops more in this case upon the aggregate liquidity shock, as customers now trade more slowly with dealers. Moreover, prices do not recover faster even if dealers now have the additional balance sheet capacity to do so. This is the potential consequence of the Volcker Rule, which forbids any market making business of the dealers. One can interpret the market making business during a crisis as using the additional $\bar{I} - I$ to buy the bonds offloaded by the sellers, and then sell them back when the price recovers. If such business is prohibited under any circumstance, then dealers' hands are tied in times of crisis when the strong selling pressure disrupts the market. The implication for resiliency is ironically the same as the case when dealers are using all their capacity in normal times $I = \bar{I}$. In both cases dealers do not have the capacity to accommodate the additional selling pressure in the stress times.

What is worse, in this case investors do not enjoy the benefits of a higher dealer inventory I in normal times either, which could have improved the trading speed in normal times. This is indeed the worst of the both worlds!

3 Empirical Corporate Bond Resiliency

3.1 Data

I use the ICE Bank of America option-Adjusted Spread from the FRED as the aggregate corporate bond yield spread indices. Individual corporate bond transaction information is from the Academic version of the U.S. corporate bond transaction-level TRACE data. Compared to the standard TRACE, the data includes reporting dealers with unique masked identifiers. It also offers uncensored trading volume in addition to the masked dealer identifiers. I use eMAXX bond holding data which includes the bond holding information for institutional investors such as insurance companies, mutual funds, and pension funds. Finally, bond characteristics are from the Mergent Fixed Income Securities Database (FISD).

3.2 Improved Resiliency

I measure corporate bond resilience through the following regression on a weekly basis:

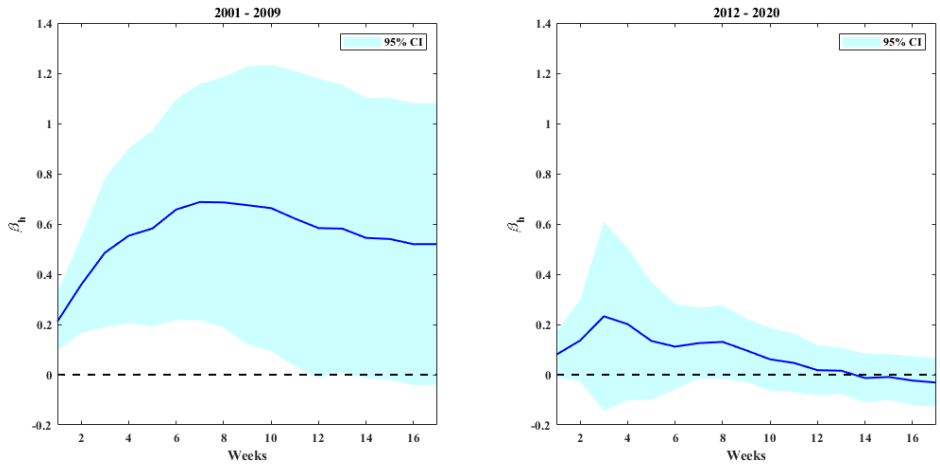
$$\textit{Credit-Spread}_{t+h} - \textit{Credit-Spread}_t = \alpha_h + \beta_h \text{LiqShock} + \textit{Lagged Credit-Spread} + \epsilon_{t+h} \qquad (3)$$

where LiqShock measures the aggregate liquidity shocks in the corporate bond market. This regression is motivated by my theoretical model as well as the OTC framework in Weill (2007) and Lagos, Rocheteau, and Weill (2011), which study the response of prices to a liquidity shock and selling pressures in the OTC market. In the theoretical framework, aggregate liquidity shocks lower all investor preference types, causing patient bond holders to become impatient and want to sell the asset in hand. Changes in the VIX index naturally measures this liquidity shock, as VIX is the fear index and is closely related to the aggregate corporate bond liquidity (Bao, Pan, and Wang 2011, Goldstein, Jiang, and Ng 2017) as well as the bond fund flows (Feroli et al. 2014).

Spikes in VIX are often associated with greater selling pressure.

I am interested in the evolutions of β^h, which measures the responsiveness of the cumulative credit spread changes to the liquidity shocks as we increase the horizons. A more resilient market means that β^h is insignificant from 0 and converges to 0 at a faster speed. I first conduct my analysis on the aggregate credit spread indices. Figure 4 shows the result. We see that corporate

Figure 4: Corporate Bond Resiliency: Aggregate Indices



Notes: This figure shows the β^h from Equation 3, as well as the 95% of the confidence intervals using theNewey and West (1987) type of standard errors.

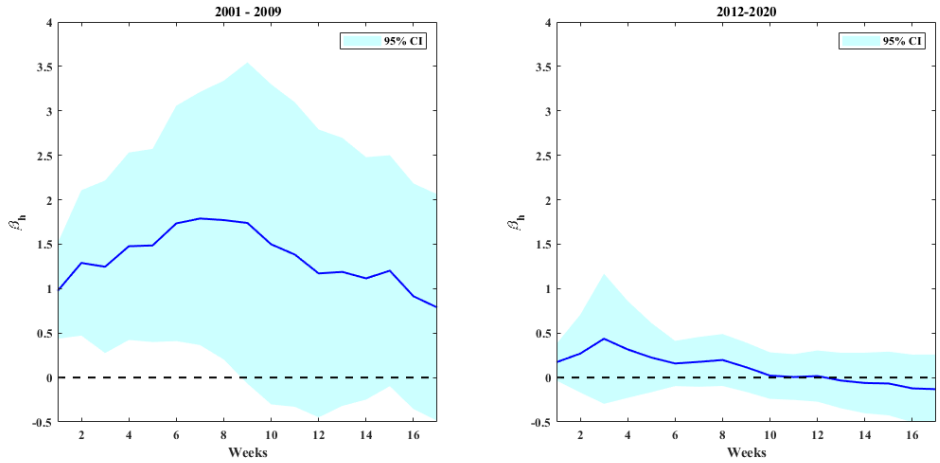
bond resiliency has improved after 2012 compared to the pre-GFC period. During the pre-GFC period, 1% increase in the weekly VIX leads to more than 0.6% increase the cumulative credit spread. The impact is long-lasting and remains significant even after 10 weeks. During the post-GFC period, on the other hand, 1% increase in VIX only temporarily increases the credit spread, and the impact is not statistically significant from zero.[4] In Appendix Figure A3, I plot the 5-week total credit spread response β^5 to liquidity shocks on a rolling window basis. We see that β^5 is significantly positive before the great financial crisis, and drops to zero after layers of capital regulations take into effect. Finally, o see whether the same patterns show up in the panel of bonds, I next run the following panel regression:

$$\textit{Credit-Yield}_{i,t+h} - \textit{Credit-Yield}_{i,t} = \alpha_i^h + \beta^h \times \text{LiqShock}_t + \textit{Lagged Credit-Yield} + \epsilon_{i,t+h}, \quad (4)$$

[4]The results are driven by the liquidity component of credit spreads instead of the credit component as CDS does not exhibit strong response to changes in VIX.

where again I use percentage change in VIX as a proxy to the aggregate liquidity shock. I include bond fixed effects, and use the Driscoll and Kraay (1998) type of standard errors. Figure 5 shows the results when I run the panel regression. We see similar patterns as in the aggregate bond

Figure 5: Corporate Bond Resiliency: Panel Regression



Notes: This figure shows the β^h from Equation 4, as well as the 95% of the confidence intervals using the Driscoll and Kraay (1998) type of standard errors with bond fixed effect.

indices. For a panel of bonds, the response to 1% increase in weekly VIX leads to more than 1% increase in the average bond yields in the pre-GFC period, while the average response is much muted after the GFC.

Our preferred way of measuring resiliency is through this macro angle by looking at how an aggregate liquidity shock is absorbed into prices and how fast price will recover after the shock. There are alternative ways of measuring resiliency. Bessembinder et al. (2016) study resiliency through a more microstructure perspective by looking at the persistent impact of trades on price.[5] For a similar exercise, I run the following price impact regression on a weekly basis:

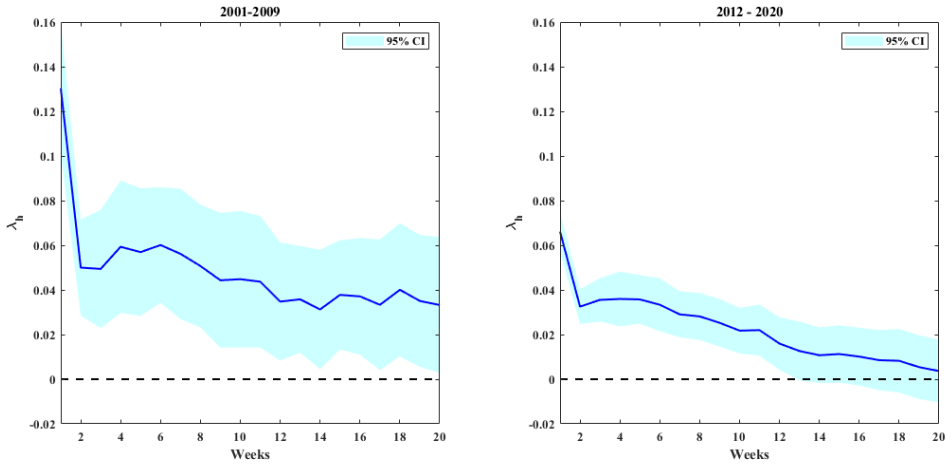
$$\textit{Credit-Yield}_{i,t+h-1} - \textit{Credit-Yield}_{i,t-1} = c_i^h + \lambda_h(-\text{Imbalance}_{i,t}) + \textit{Lagged Imbalance \& Credit-Yield}_i + \epsilon_{i,t+h}. \tag{5}$$

Figure 6 shows the evolution of λ_h. We see a declined impact of the yield response upon the trades in the post crisis period (0.13 vs 0.07). Moreover, Trade continues to impact prices significantly after 20 weeks in the pre-GFC period, while the impact generally dies away after 10 weeks in the

[5]This approach can be unified into the previous framework as trade imbalances can be seen as a proxy for demand shocks Li and Lin (2022)

post-GFC period. Another way of capturing resiliency is by looking at the mean-reversion rate in

Figure 6: Corporate Bond Resiliency: Alternative Measure I



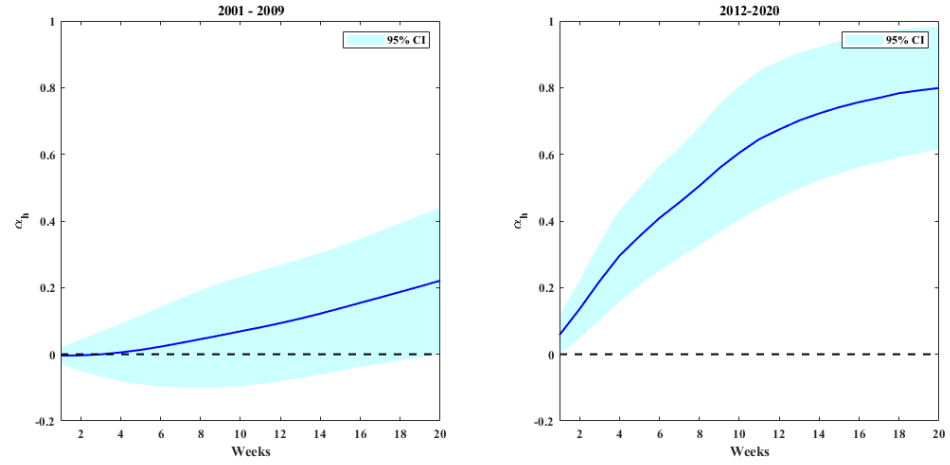
Notes: This figure shows the λ^h from Equation 5, as well as the 95% of the confidence intervals with Driscoll and Kraay (1998) type of standard errors with bond fixed effect.

the yields (Dong, Kempf, and Yadav 2007):

$$\textit{Credit-Spread}_{t+h} - \textit{Credit-Spread}_t = c_h + \alpha_h(-\textit{Credit-Spread}_t) + \epsilon_{t+h}. \tag{6}$$

We see that after the great financial crisis, corporate bond market have become more resilient

Figure 7: Corporate Bond Resiliency: Alternative Measure II



Notes: his figure shows the α^h from Equation 6, as well as the 95% of the confidence intervals with Newey and West (1987) type of standard errors with bond fixed effect.

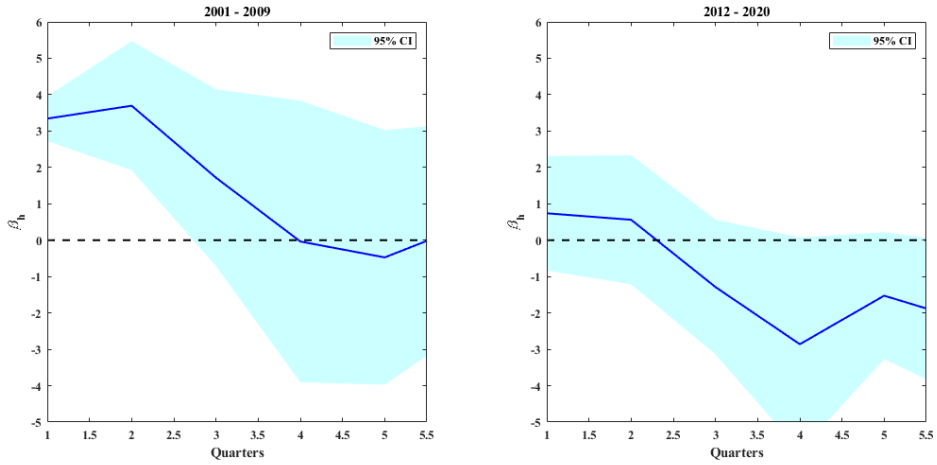
as the yields mean revert more quickly compared to the pre-GFC period. Finally, to address the

concern that VIX perhaps may not capture well the sudden liquidity shock, I use the corporate bond mutual fund flow-driven demand shocks (Lou 2012, Chaudhary, Fu, and Li 2022) and look at whether bond yields are able to absorb these demand shocks. Aggregate liquidity shocks trigger fund outflows which lead to price drops and subsequent recovery. I first construct the quarterly demand shocks at the bond level following Chaudhary, Fu, and Li (2022) and run the following panel regression:

$$\textit{Credit-Spread}_{i,t+h-1} - \textit{Credit-Spread}_{i,t-1} = c_i^h + \beta_h(-\text{DemandShock}_{i,t}) + \epsilon_{i,t+h}. \tag{7}$$

We see similar patterns of improved resiliency after the great financial crisis. Prior to the great

Figure 8: Corporate Bond Resiliency: Demand Shocks



Notes: This figure shows the β_h estimates from Equation 7. as well as the 95% of the confidence intervals with Driscoll and Kraay (1998) type of standard errors with bond fixed effect.

financial crisis, it took more than 2 quarters for bond yields to fully absorb the liquidity shocks driven by demand, while such absorption happens much faster and the price impact disappears after the great financial crisis.

For the rest of the paper, I will stick to the original definition of the resiliency for two reasons. First, it captures the resiliency both in terms of the magnitude of price drop (yield increase), and in terms of the time duration it takes for the price (yield) to recover in response to a liquidity shock. Second, it allows us to capture a more macro notion of liquidity compared to the more microstructure angle through trades and price impacts. This proves crucial when we later examine

the welfare implications of the post-GFC regulations on bond liquidity where we show that investor welfare ultimately depends on the time it takes to trade in normal times and the time it takes for prices to recover after a crash.

3.3 Regulations, Dealer Balance Sheet Capacity, and Resiliency

My model suggests that regulations are the key driver of the improved resiliency in stressful times. This comes at the cost in terms of the worsened immediacy in normal times. Previous studies show that in normal times high yield bond immediacy has been deteriorated more due to the more stringent regulations compared to the investment grade bond immediacy (Bao, O'Hara, and Zhou 2018, Wu 2020 etc.). It is therefore natural to expect that high yield bonds have better resiliency compared to the pre-GFC period than investment grade bonds in times of stress. To study how resilience evolves through different time periods and varies across different ratings of bonds, I use the following regression:

$$\textit{Credit-Spread}_{t+h} - \textit{Credit-Spread}_t = \sum_j \left(c_j^h + \beta_j^h \times \text{LiqShock}_t + \epsilon_{j,t}^h \right) \times \mathbb{1}_{t \in j}, \tag{8}$$

where j is either "pre-GFC" (January 2004 - June 2007), "GFC" period (July 2007 - April 2009), "post-GFC" (May 2009 - May 2012), "Regulatory" (June 2012 -) I separately run the regression for the indices of bonds with different ratings, and test the differences in $\beta's$ between different time periods. Table 1 presents the result. We see that the resilience of speculative high yield bonds improve the most compared to the pre-GFC level. The difference in the $\beta's$ are statistically significant for both the short horizon $h = 1$ and the long horizon $h = 10$. For the high quality bonds, we do not see such improvement in their liquidity resiliency. For the AA-rated bonds, the $\beta's$ between the pre-GFC period and the regulatory period do not differ significantly, although the magnitudes are at least 50% lower. The fact that high yield bonds now have improved level of resilience is just the other side of the worsened immediacy of these bonds according to the immediacy-resiliency tradeoff in the OTC market.

Greater resilience, in the context of our model, comes from the greater balance sheet capability of dealers ($\bar{I} - I$) to lean against the wind in times of crisis. In the pre-GFC period, dealers face low

Table 1: β^h of Different Bond Indices

	AA-rated			...	High Yield		
Horizons	β_1	β_5	β_{10}		β_1	β_5	β_{10}
Pre-GFC 2001.1 - 2007.6	0.046**	0.117***	0.110*	...	0.384**	0.927***	0.830**
	(2.15)	(2.81)	(1.83)		(2.46)	(2.78)	(2.13)
GFC 2007.7 - 2009.4	0.337**	0.764*	0.667	...	1.093**	3.601*	4.442
	(2.35)	(1.89)	(1.19))		(2.17)	(1.89)	(1.30)
Post-GFC 2009.5 - 2012.5	0.049	0.194*	0.069	...	0.207	0.290	0.196
	(1.14)	(1.81)	(0.47)		(1.16)	(0.81)	(0.45)
Regulatory 2012.6 -	0.022***	0.027	0.021	...	0.031	-0.121	-0.139
	(2.84)	(1.36)	(0.87)		(0.42)	(-0.80)	(-0.78)
$\beta^{Precrisis} - \beta^{Regulatory}$	0.02	0.09*	0.09	...	0.35**	1.05***	0.97**
	(-1.09)	(-1.94)	(0.438)		(-1.37)	(-2.86)	(-2.26)

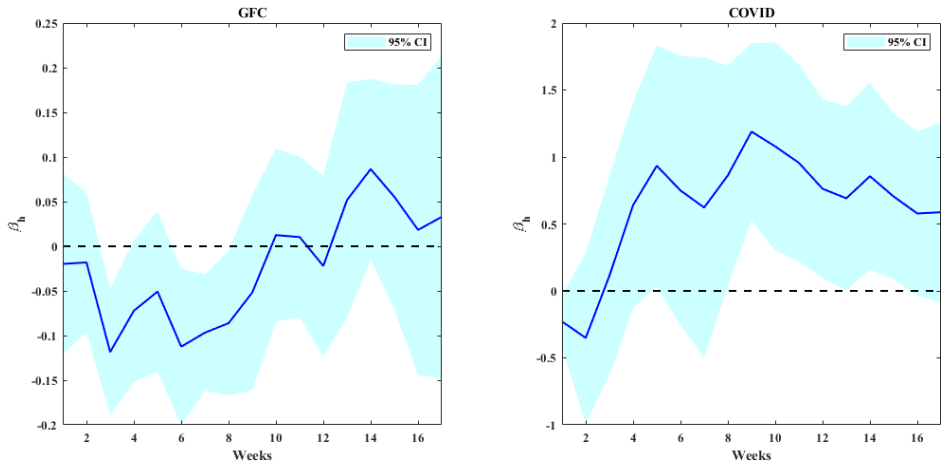
Notes: This table presents $\beta's$ from regression 3 run on the AA-rated and the high yield bond indices separately. T-statistics based on Newey and West (1987) types of standard errors are presented in parentheses. *** (**) [*] denotes statistical significance at 1% (5%) [10%] level.

capital requirements. They build up inventory level to facilitate trading and compete for market shares in a high immediacy environment (An 2022). After the great financial crisis, regulations have made dealers subject to more stringent capital requirement, and dealers therefore hold low inventory level during normal times. However, as dealers are now better capitalized, they are more able to provide liquidity to accommodate strong selling pressures when liquidity is needed the most during the stressful period. To see how dealers manage their inventory in response to the aggregate liquidity shock, I run the following regression:

$$\log(Inventory_{t+h}) - \log(Inventory_t) = c^h + \beta^h \times \text{LiqShock}_t + \epsilon_t^h \tag{9}$$

where I use the aggregate corporate bond primary dealer inventory statistics from the New York Federal Reserve. We see striking evidence that at the start of the great financial crisis, the primary

Figure 9: Corporate Bond Resiliency: Dealer Inventory



Notes: This figure shows β^h from Equation 9 as well as the 95% confidence interval with Newey and West (1987) types of standard errors.

corporate bond dealers were not able to lean against the wind. In fact, they were doing exactly the opposite, offloading corporate bonds in response to the aggregate liquidity shock, contributing to greater instability in the financial market. This is not the case during the recent COVID pandemic, where we see that corporate bond primary dealers were able to expand their inventory and increase their corporate bond holdings in response to aggregate liquidity shocks. This piece of evidence is consistent with our model. Before the great financial crisis, dealers hold large amount of inventory,

and so they cannot expand their balance sheets further ($I = \bar{I}$). They have to offload some bonds first in order to expand their inventory capacity again (Choi, Shachar, and Shin 2019,Randall 2015). After the great financial crisis, regulations impose a lower inventory level I, which means that dealers now have more balance sheet capacity $\bar{I} - I$ to lean against the wind, precisely when liquidity is needed the most in times of crisis. In response to the strong selling pressure during the COVID pandemic, they were able to use their additional balance sheet capacity to accumulate more inventory.

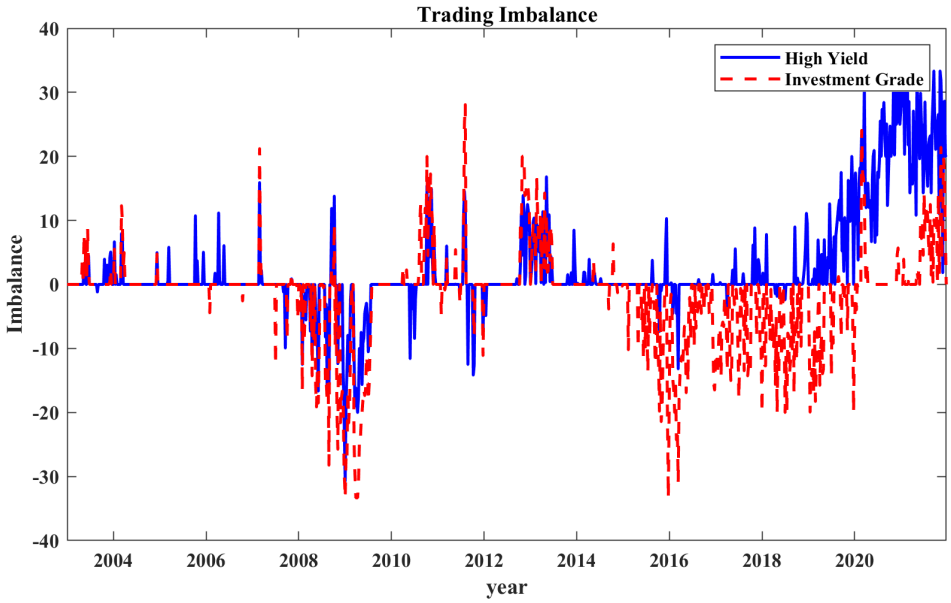
If high yield bonds show greater liquidity resiliency after great financial crisis, it must mean that the dealers now have greater flexibility to expand their balance sheets for the high yield bonds in times of crisis. For this purpose, I look at the corporate bond dealer trade imbalance in a similar spirit to (Duffie et al. 2023). I show that for the high yield bonds, corporate bond dealers utilize their rising balance sheet capacity ($\bar{I} - I$) to lean against the wind in times of crisis, absorbing the selling pressures. To measure the dealer trade imbalance, I use the Academic version of TRACE that includes the masked dealer identities. For each dealer (d) and each bond (i), I first compute its trade imbalance using dealer-customer trades at the weekly frequency. I then take the average across different dealers of the same bond to get the trade imbalance at the bond level:

$$Imbalance_{i,t} = \frac{1}{D} \sum_{d \in D} \frac{BuyVol_{d,i,t} - SellVol_{d,i,t}}{BuyVol_{d,i,t} + SellVol_{d,i,t}} \tag{10}$$

In figure 10, I plot the time series of the median trade imbalances for investment grade (IG) and high yield (HY) bonds. We see that in normal times, corporate bond dealers maintain a net zero imbalance, reflecting the equal buy or sell requests from the customers in normal times. During the great financial crisis, corporate bond dealers are dumping their bond holdings, resulting in a negative 30% imbalance for both investment grade and high yield bonds. However, such trends have been reversed during COVID. For high yield bonds, dealers become net buyers and are able to maintain a positive 30% imbalance to absorb the selling pressures during the COVID period.

In Table 2, I compute the average trade imbalances for the investment grade and the high yield bonds in different time periods. We see the differences in trade imbalances between investment grade and high yield bonds only become significant after the regulation period. The net trade

Figure 10: Corporate Bond Resiliency: Trade Imbalance



Notes: This figure shows the median of the trade imbalances of investment grade and high yield bonds. Trade imbalance at the dealer-bond-week level is computed from Equation (10). I take average imbalance across different dealers to get the imbalance at the bond-week level, and then plot the cross-sectional median.

imbalance is -4 to -6% during the great financial crisis for both investment grade and high yield bonds, suggesting that dealers were heavily selling them during the great financial crisis. Since the COVID pandemic on the other hand, dealers were able to maintain on average a 25% trade imbalance for high yield bonds, which is more than 20 percentage points increase compared to the pre-GFC period, while such difference is not statistically significant for investment grade bonds. The results suggest that dealers now have greater flexibility to expand their balance sheet to purchase high yield bonds in times of crisis.

Having established that dealers are now able to expand their balance sheets more flexibly for high yield bonds, which results in improved resiliency for high yield bond liqudity, it remains to show that regulations are the potential cause of such increased resiliency. It is a natural hypothesis as my model suggests that regulations create a tradeoff between immediacy and resiliency in the OTC market. As many papers have suggested that the post-GFC regulations worsened the bond market immediacy in normal times, we seek to understand the role of these regulations in improving the bond liquidity resiliency in times of crisis.

Li and Schürhoff (2019) suggest that the very few large dealers conduct majority of the trades in

Table 2: Dealer Trade Imbalance

	Investment Grade (IG)	High Yield (HY)	HY - IG
Pre-GFC: Jan 2003 - Jun 2007			
	2.525	3.353	0.83*
			(1.72)
GFC: Jul 2007 - Apr 2009			
	-6.340	-4.337	2.00
			(1.30)
Post-GFC: May 2009 - May 2012			
	0.189	1.285	1.10
			(1.18)
Regulation: Jun 2012 - Dec 2020			
	-4.053	5.630	9.68***
			(9.43)
COVID: Jan 2020 - Dec 2021			
	3.563	25.326	21.76***
			(10.14)
Difference			
COVID − Pre-GFC	1.04	21.97***	
	(0.73)	(13.64)	

Notes: This table presents the average trade imbalance of investment grade and high yield bonds. T-statistics based on Driscoll and Kraay (1998) with 16 lags are presented in parentheses. *** (**) [*] denotes statistical significance at 1% (5%) [10%] level.

the OTC fixed income market. Assume that those large dealers are the banks subject to stringent regulations, we conjecture that bonds whose trades go through large dealers experience greater improvement in their liquidity resilience. Formally, I test the following:

$$\Delta \textit{Credit-Spread}_{i,t+5} = c_i + \beta \times \text{LiqShock}_t + \eta \times \text{LiqShock}_t \times \mathbb{1}_{i,t\in\text{Regulated Dealer}} + \epsilon_{i,t}, \tag{11}$$

where $\mathbb{1}_{i,t\in\text{Regulated Dealers}} = 1$ if over 90% of bond i's trades in week t are done by the top 10 dealers (ranked by the total trading volume in the sample), and $\mathbb{1}_{i,t\in\text{Regulated Dealers}} = 0$ if less than 10% of bond i's trades in week t are done by the top 50 dealers.[6] In other words, I test whether bonds traded by large dealers experience an increase in their liquidity resilience. Table 3 shows that results.

Table 3: Resiliency: Regulated Dealers vs. Non-regulated Dealers

	2008 GFC	2020 COVID	2020 - 2008
Regulated			
	2.225**	-0.239	-2.46***
	(2.38)	(-1.27)	(2.66)
Non-Regulated			
	2.426***	3.193**	0.77
	(3.84)	(2.22)	(0.50)
Difference			
Regulated − Non-Regulated	-0.20	-3.44**	
	(-0.26)	(-2.52)	

Notes: This table presents β from Regression 11 run on the regulated dealer sample and the non-regulated dealer sample in both 2008 and in 2020 separately. T-statistics based on the Driscoll and Kraay (1998) types of standard errors are presented in parentheses. *** (**) [*] denotes statistical significance at 1(5%) [10%] level.

We see that the improved liquidity resilience entirely comes from bonds with a majority of trades done by the top 10 dealers. In 2008 during the great financial crisis, one percent increase in the liquidity shock in terms of VIX increases the 5-week total credit spread response by more than 2 percent for both the regulated dealer sample and the non-regulated dealer sample. During the 2020 pandemic period however, we see that while the response of those bonds done by the non-regulated dealers remains elevated at 2-3 percent, the resilience of the bonds done by the regulated dealers

[6] I focus on the top 50 dealers here to create roughly equal number of observations in the regulated dealer sample and the non-regulated dealer sample. Results are robust if I use the top 10 dealers for the non-regulated dealer sample

has improved significantly. The 5-week response to a one percent liquidity shock of these bonds have essentially become null.

3.4 Alternative Explanation

We now explore some alternative explanations on the improved liquidity resiliency in the US corporate bond market. One of the consequences of the post-GFC dealer regulations is the changing demographics of the bond market participants. While dealers provide less liquidity in normal times, other market participants such as insurance companies or mutual funds take up the role. O'Hara, Rapp, and Zhou (2021) show that insurance companies support the investment grade bond resiliency during COVID. However, insurance companies do not trade or own many high yield bonds due to their regulatory mandates. It is therefore hard to attribute the increased liquidity resiliency in high yield bonds documented in thi paper to insurance companies. To test whether mutual funds contribute to the improved resiliency in the bond market, I use the institutional investor holdings data from eMAXX and look at how mutual funds and dealers change their holdings when bond ratings are downgraded or bond ratings change from investment grade to speculative high yield grade (fallen angels). This can be seen as another proxy for liquidity shocks as insurance companies cannot hold speculative bonds and therefore are likely to trigger a strong selling pressure of these bonds when their ratings deteriorate (Dick-Nielsen and Rossi 2018). Specifically, I follow He, Khorrami, and Song (2019) and run the following regression:

$$\Delta(Holding)_{i,t} = c + \beta \times \text{Downgrades/Fallen Angel}_{i,t} + +\gamma Controls_{i,t} + \text{Fixed Effect} + \epsilon_{i,t}, \quad (12)$$

where $Downgrade/FallenAngel = 1$ if bond i is downgraded or becomes a speculative high yield bond from investment grade ratings. We compare holding response for both mutual funds and dealers. Table 4 presents the results.

We see that when a bond is downgraded or becomes a fallen angel (which is likely to trigger selling pressures from the insurers), mutual funds are actually dumping their holdings of these downgraded bonds. Dealers on the other hand, do not change their holdings of these bonds before the 2008 great financial crisis in the high inventory regime (high I). However, after 2012 during the

Table 4: Market Participant Response to Bond Downgrades

	Mutual Fund	Dealer Pre-2008	Dealer Post-2012	Mutual Fund	Dealer Pre-2008	Dealer Post-2012
Downgrade	-0.052***	0.022	0.0034***			
	(-16.57)	(0.90)	(2.67)			
Fallen Angel				-0.080***	0.037	0.148***
				(-6.73)	(0.58)	(2.86)
Bond Controls	Y	Y	Y	Y	Y	Y
Time Fixed Effect	Y	Y	Y	Y	Y	Y
No. Observations	937,467	37,742	130,380	937,467	37,742	130,380
R-squared	0.014	0.008	0.001	0.014	0.008	0.001

Notes: This table presents the response of mutual fund and dealer inventory holdings in response to bond downgrades or fallen angel changes in equation (12). T-statistics based on standard errors clustered at the bond level and time fixed effects are presented in parentheses. *** (**) [*] denotes statistical significance at 1% (5%) [10%] level.

regulatory period when dealer inventory become low and therefore balance sheet capacity is high (high $\bar{I} - I$), dealers actually increased their holdings of the downgraded or the fallen angel bonds. The magnitudes are comparable to and offset the dumping from the mutual funds. Taking all the evidence together, it is unlikely that mutual funds improved the bond liquidity resiliency in times of crisis when there is a strong selling pressure because these funds tend to trade in the same direction as the selling pressure. It is the dealers on the other hand, especially after the regulatory period, that lean against the wind and improve the liquidity resiliency of the corporate bond market.

4 Welfare Implication

Having established that corporate bond market liquidity now exhibits stronger resiliency and that post-GFC regulations are potential causes, I now use my model to evaluate the welfare implications of regulations on the OTC market liquidity. Such analysis is not possible in the existing OTC models with a single aggregate state because these models can only feature the costs of regulation, namely the deteriorating immediacy in normal times. To be more specific, the welfare criterion is the

average utilities of the customers in normal times and in crisis:

$$U = \frac{\lambda^C}{\lambda^C + \lambda^N} V^N + \frac{\lambda^N}{\lambda^C + \lambda^N} V^C. \tag{13}$$

where

$$V^N = \mathbb{E}\Big\{ \int_0^{T^N} \big(n_{HH} z^N \epsilon_H a_H^N + n_{HL} z^N \epsilon_L a_H^N\big) e^{-rt} dt + e^{-rT^N} V^C \Big\}$$

and

$$V^C = \mathbb{E}\Big\{ \int_0^{T^C} \big(n_{HH} z^C \epsilon_H a_H^C + n_{HL} z^C \epsilon_L a_H^C\big) e^{-rt} dt + e^{-rT^C} V^N \Big\}.$$

Here the expectation $\mathbb{E}$ is with respect to T^C and T^N, which are exponentially distribution with λ^C and λ^N. Some calculations leads to the exact formula of the customer welfare (per unit of bond supply A):

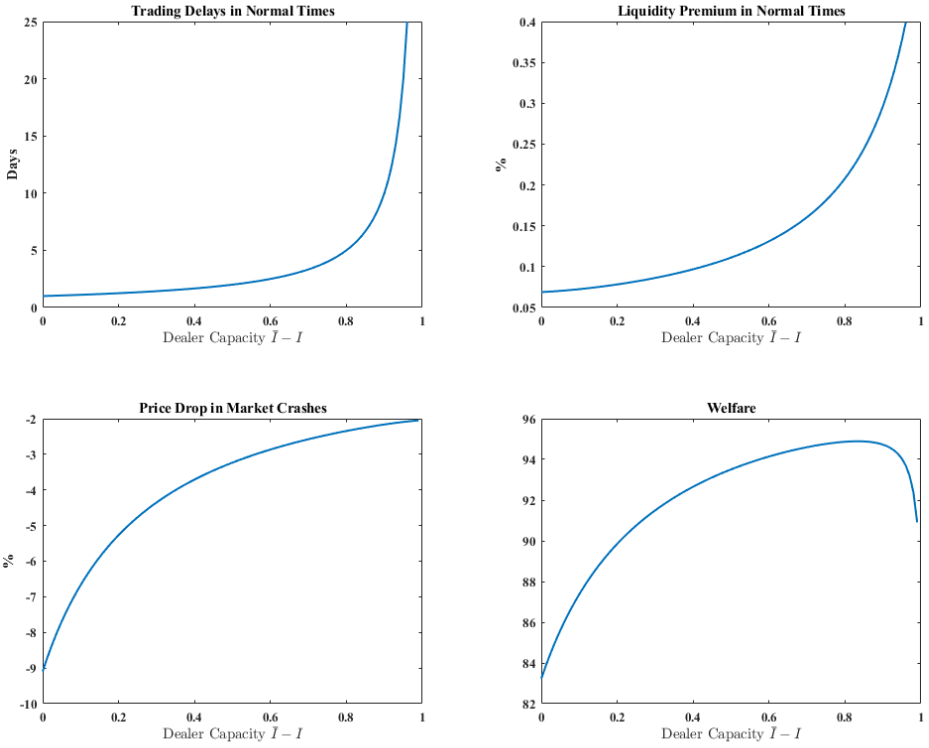
$$\begin{aligned} \frac{U}{A} &= \frac{\lambda^C(\bar{I} - I) z^N + \lambda^N z^C}{\lambda^C(\bar{I} - I) + \lambda^N} \frac{1}{r} \Big\{ \frac{\delta \pi_H + \alpha(I)}{\alpha(I) + \delta} \epsilon_H + \frac{\delta \pi_L}{\alpha(I) + \delta} \epsilon_L \Big\} \\ &= \frac{1}{r} \mathbb{E}[z^s] \mathbb{E}[\epsilon_i]. \end{aligned} \tag{14}$$

We see that $\frac{\lambda^C(\bar{I}-I)z^N + \lambda^N z^C}{\lambda^C(\bar{I}-I)+\lambda^N}$ captures the benefit of regulations in terms of improved resiliency in crisis times as this term increases in dealer balance sheet capacity $\bar{I} - I$, while the term $\frac{\delta\pi_H + \alpha(I)}{\alpha(I)+\delta}\epsilon_H + \frac{\delta\pi_L}{\alpha(I)+\delta}\epsilon_L$ captures cost of regulations in terms of reduced immediacy in normal times as this term decreases in the dealer inventory level I. The optimal inventory level therefore trades off the benefit of increased resiliency in times of crisis against the cost of reduced immediacy in normal times.

Figure 11 plots the trading delay in normal times $\frac{1}{\alpha(I)}$, the liquidity premium in normal times $\frac{z^H \epsilon_H}{p^N}$, price drop in times of crisis $\frac{p^C - p^N}{p^N}$, as well as the welfare in equation (14) as a function of the dealer balance sheet capacity $\bar{I} - I$. I calibrate the parameters so the model implied liquidity premium, turnover, trading delays fit the empirical moments reported in Wu (2020) and Feldhütter (2012). Specifically, I reduce dealer inventory level (I) from 100% of the total capacity ($\bar{I}$) to 20%, or equivalently dealer balance sheet capacity ($\bar{I} - I$) from 0 to 80% of the total capacity, which broadly corresponds to the reduction in the primary corporate bond dealer inventory level in Figure

A5. We see that trading delays increase from 1 day to 5 days, and the liquidity premium in normal times increase from less than 10 basis points to over 20 basis points, both in line with the empirical statistics reported in Wu (2020). Interestingly, we see that the benefit of regulations outweighs the costs as the welfare function increases except for very large unused balance sheet capacity (i.e., low inventory levels). The optimal dealer balance sheet capacity is around 80%, or equivalently dealer optimal inventory level at 20% of the total capacity, which is again in line with the post-GFC primary dealer inventory level in the data.

Figure 11: Welfare



Notes: This figure plots the trading delay in normal times, the liquidity premium in normal times, price drop in times of crisis, as well as the welfare in equation (14) as a function of the dealer balance sheet capacity $\bar{I} - I$.

5 Conclusion

Post-GFC regulations on corporate bond dealers create a tradeoff between immediacy in normal times and resiliency in times of crisis. Reduced immediacy and dealer inventory in normal times are

the necessary costs of the enhanced market resiliency in times of stress. In this paper, I show that better-capitalized dealers are able to "lean against the wind", absorbing systemic liquidity shocks and stabilizing prices, which lead to a faster recovery. This effect is particularly pronounced for high-yield bonds, which have experienced the largest declines in immediacy but also the greatest improvements in resiliency, driven by dealers' increased balance sheet capacity. These findings challenge the prevailing narrative that post-GFC regulations have unambiguously harmed market liquidity. Rather, these regulations have created a necessary balance, trading off some immediacy in normal times for greater resiliency during crises.

I developed a stylized OTC model that links lower dealer inventories in normal times to greater balance sheet capacity during crises. This framework allows one to conduct a comprehensive welfare analysis to evaluate the impact of post-GFC regulations on market liquidity. Overall, my findings underscore the importance of maintaining flexibility in regulatory frameworks, allowing dealers to utilize their balance sheet capacity effectively when liquidity is needed the most. These insights are particularly relevant for policymakers aiming to enhance market stability and investor welfare. Future studies could further explore the dynamic interactions between regulatory constraints, dealer behavior, and market outcomes, providing additional guidance for designing resilient financial systems.

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APPENDIX

A Appendix

A.1 Micro-Foundation of OTC Model in 2

To micro found the model, I build an OTC model following Weill (2007) and Lagos, Rocheteau, and Weill (2011) which feature both the steady states and a transition dynamics. In the model, there are three types of agents: buyers (B), owners (O) and sellers (S). Buyers and owners have high valuations of the bond. There is a liquidity shock that happens at the Poisson rate of κ, upon which the owner of the bond wants to sell it, and the buyer of the bond leaves the market. Trades happen when buyers and sellers meet at the Poisson rate of λ. Finally, buyers enter the market with some amount $I(t)$ each time. In this model we take the perspective of a potential seller. This is a natural assumption as during a distress, a seller typically suffers more from illiquidity when they cannot find potential buyers. Naturally, one could interpret the buyer agent (B) as the dealer of the market and $I(t)$ as the amount of capital they commit to trading. As before, we assume that there is a maximum capital capacity $I(t) < \bar{I}$. In the model, we assume that capital $I(t)$ is controlled by regulators and therefore abstract from individual dealer maximization problem. The agents distribution therefore satisfy the following:

$$\begin{aligned} \dot{u_B} &= -\lambda u_B u_S - \kappa u_B + I(t) \\ \dot{u_S} &= -\lambda u_B u_S + \kappa u_O \\ \dot{u_O} &= \lambda u_B u_S - \kappa u_O \end{aligned} \tag{15}$$

Finally, total bond supply is s and market clears: $u_S + u_O = s$. These equations are intuitive. Each time a buyer enters the market with some capital $I(t) < \bar{I}$. He trades with a seller at rate λ, upon which he becomes an owner of the bond and leaves the market if this buyer is hit by a liquidity shock at rate κ. And finally, the owner wants to sell the bond when he is hit by a liquidity shock κ.

In normal times there is no disruptions which means the model is in the steady state.

$$\begin{aligned} 0 &= -\lambda u_B u_S - \kappa u_B + I \\ 0 &= -\lambda u_B u_S + \kappa u_O \\ 0 &= \lambda u_B u_S - \kappa u_O \end{aligned} \tag{16}$$

One can show in this case, more stringent capital requirements implies a longer trading delay. More formally, when the model is in the steady state, a lower capital commitment, $I \downarrow$ means that sellers face longer trading delays and have to wait longer to sell the asset: $\frac{1}{\lambda u_B} \uparrow$. A formal proof of this claim is in Afonso (2011). This results summarizes the findings in Wu (2020) that post-crisis banking regulations has lengthened the trading delays faced by investors, worsening the immediacy dimension of corporate bond liquidity (Dick-Nielsen and Rossi 2018).

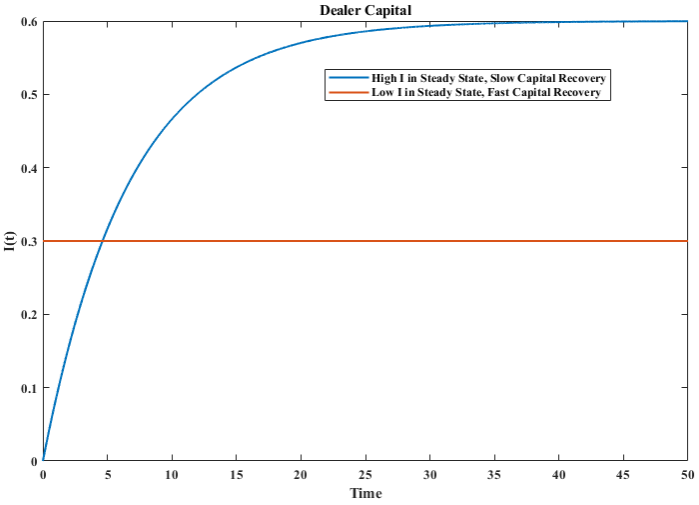
However, the above analysis is only one side of the argument. The design of regulations is to prevent large disruptions of the market. Therefore, it is important that we look beyond the steady state of the model and study the transition dynamics when there is an aggregate liquidity shock. Specially, suppose the aggregate shock hits the population all at once (at time 0). Buyers and owners are all destroyed and the entire assets are in the hands of sellers ($u_S(0) = s$). It is precisely this moment when additional capital $\bar{I} - I$ can be used to accommodate additional selling pressures:

$$\begin{aligned} \dot{u_B} &= -\lambda u_B u_S - k u_B + e^{-\hat{k}t}(\bar{I} - I) + (1 - e^{-\hat{k}t})I \\ \dot{u_S} &= -\lambda u_B u_S + k u_O \\ \dot{u_O} &= \lambda u_B u_S - k u_O \end{aligned} \tag{17}$$

Specifically, $(1 - e^{-\hat{k}t})I$ represents capital destruction upon the aggregate shock. $e^{-\hat{k}t}(\bar{I} - I)$ represents the additional capital that can be brought to restore the market. In other words, this is the amount of capital dealers can use to "lean against the wind" during market crashes. If dealers use too much capital during normal times $I \approx \bar{I}$, then there is no additional capital that dealers can commit in a crisis. Figure A1 shows the recovery of capital in both high and low I states.

Finally, we look at the evolution of asset prices. The value functions of bond investors satisfy

Figure A1: Dealer Capital Recovery



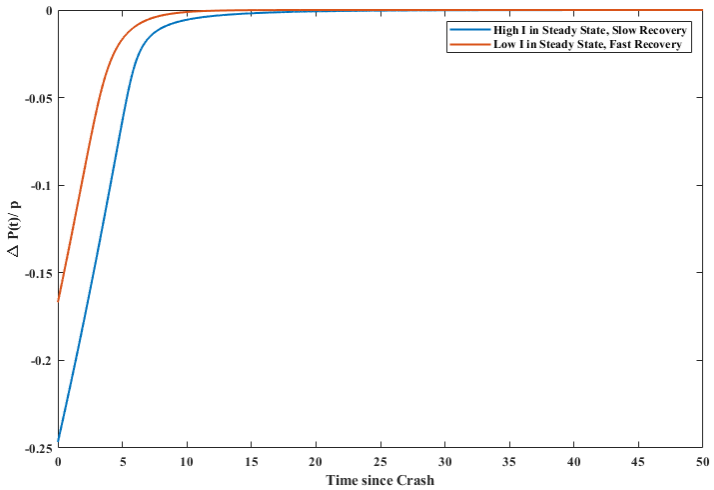
This figure shows the destruction and recovery in capital when the inventory level is high or low in the steady state.

the following:

$$\begin{aligned} \dot{V_B} &= rV_B - \lambda u_S(V_O - p - V_B) - k(0 - V_B) \\ r\dot{V_S} &= rV_S - \lambda u_B(p - V_S) \\ r\dot{V_O} &= rV_O - k(V_S - V_O) \end{aligned} \tag{18}$$

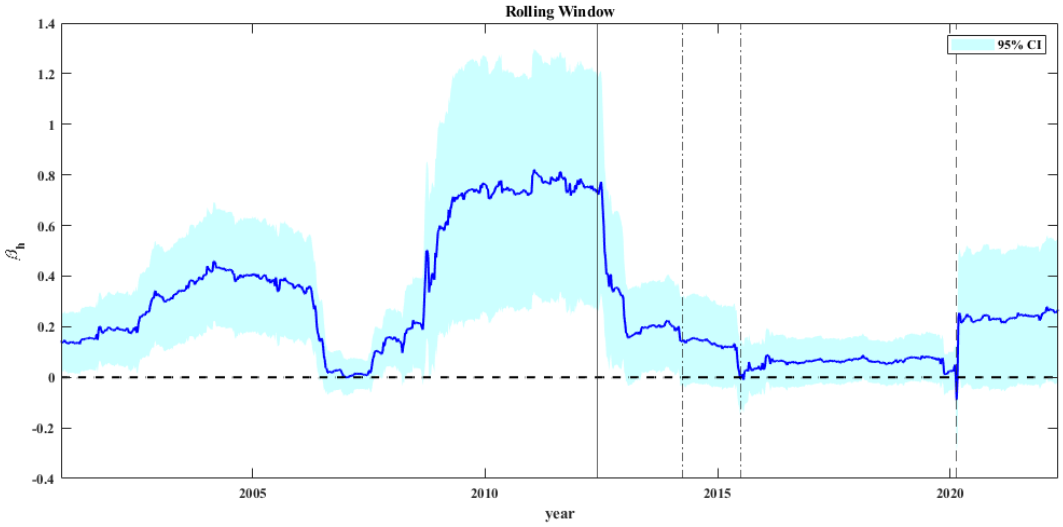
where price p is determined through the Nash bargaining: $p = (1-\eta)(V_O - V_B) + \eta V_S$ and η is buyer's bargaining power. These functions are intuitive. A bond buyer (B) meets a seller at the rate λu_S, upon which he buys the bond at the price p and becomes an owner (O). A buyer (B) can also exit the market if he is hit by a liquidity shock at the rate κ. Similarly, a seller (S) meets a buyer (B) at the rate λu_B, upon which the seller sells the bond at the price p and exits the market. Finally, an owner (O) becomes a low valuation seller (S) when he is hit by an liquidity shock at the rate κ. Figure A2 shows how the price will recover when dealers have more capital to "lean against with wind" during time of the crisis $(\bar{I} - I)$.

Figure A2: Price Recovery after Market Crash



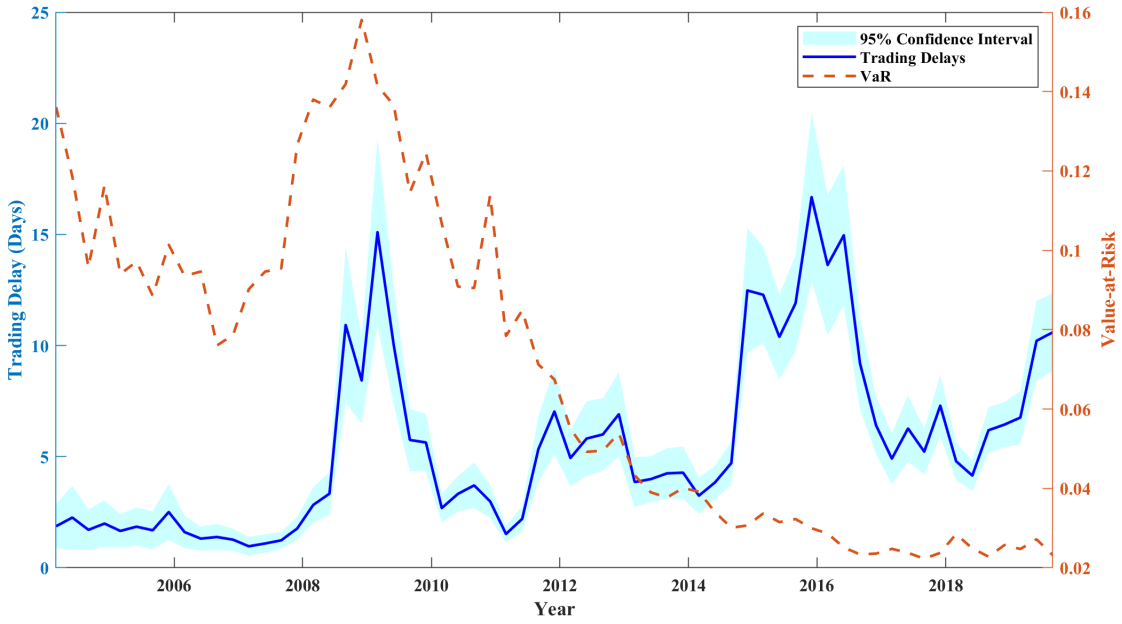
This figure shows the time evolution of bond prices upon the aggregate liquidity shock, when the inventory level is high or low in the steady state.

Figure A3: Rolling Window



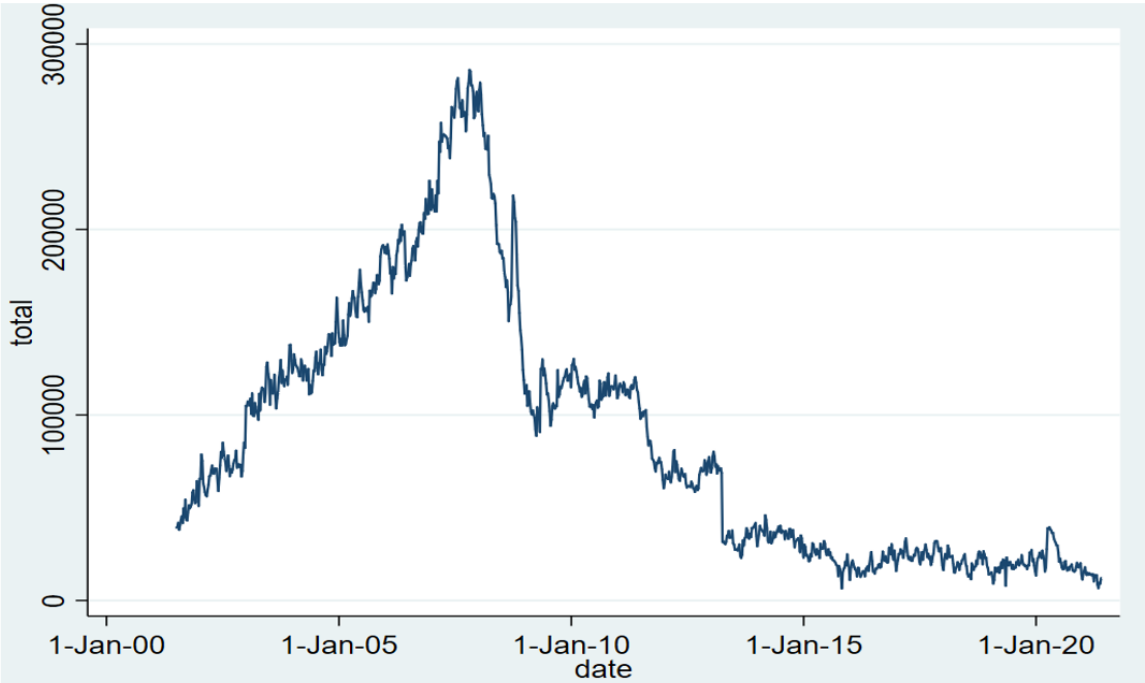
Notes: This figure plots β^5 from Equation (3) run on a rolling window basis. The dashed lines corresponds to the implementation of the post-GFC regulations and the market crash due to COVID.

Figure A4: Trading Delays



Notes: Figure 8 of Wu (2020). This figure presents the aggregate dealer regulatory constraint (Value-at-Rrisk, dashed red line) and the estimated trading delays (solid blue line). The shaded area is the 95% confidence interval of the estimated trading delays based on the asymptotic normality and the delta method.

Figure A5: Corporate Bond Dealer Inventory



Notes: This figure plots the aggregate corporate bond inventory level. The aggregate inventory data is from the New York Federal Reserve Primary Dealer Statistics. However, this statistics include non-corporate securities before the great financial crisis. The Goldman Sachs estimates that corporate bond dealer inventory in 2012 dropped 40% compared to the 2006 level. As the 2017-2018 inventory is further down by two-thirds from the 2012 level. It is an conservative estimate that the 2017-2018 inventory level is 20% of the 2006 pre-GFC level.