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Stock liquidity effect on leverage: The role of debt security, financial constraint, and risk around the global financial crisis and Covid-19 pandemic

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ABSTRACT

This study examines the heterogeneity of liquidity effect on leverage and the propensity of zero leverage. Using U.S. public firms from 1990 to 2021, we demonstrate that stock liquidity has significantly negative effects on total debt and secured debt while insignificant effects on unsecured debt. Firms with high stock liquidity reduce the portion of secured debt and increase unsecured debt amidst total leverage. The negative stock liquidity effect was alleviated following the 2007–2008 financial crisis (GFC) and was strengthened during the Covid-19 pandemic. We also provide the first evidence that stock liquidity increases the likelihood of zero leverage. Furthermore, we test potential economic channels and find that the liquidity effects on leverage are stronger for companies with more financial constraints and higher risk. Our results are robust to various measures of leverage and control for endogeneity. Overall, our results show that it is essential to consider the heterogeneity of corporate debt structure when analyzing the stock liquidity effect on leverage. Such effect varies significantly across different levels of debt security and the time periods around the GFC and the Covid health crisis.

1. Introduction

Stock liquidity recently received growing attention as a potential determinant of leverage in finance literature. There are two competing views on this issue: the equity preference view suggests a negative impact of stock liquidity on the firm leverage as high stock liquidity implies lower equity issuance costs (Butler, Grullon, & Weston, 2005; Hennessy & Whited, 2005), and thus firms with more liquid equity will have a lower cost of equity and borrow less. Consistent with this notion, empirical studies (such as Lipson & Mortal, 2009) find that firms with higher stock liquidity are associated with lower leverage. On the other hand, some researchers (Cheung, Im, Noe, & Zhang, 2018) propose the debt preference view and find evidence supporting the proposition that stock liquidity reduces the cost of debt and thus increases a firm's propensity to raise debt rather than equity capital.

Previous studies of the liquidity effect on leverage report mixed evidence and focus on total debt for the time period pre-2007. However, both theoretical work and empirical finance literature suggest a significant heterogeneity across multiple types of corporate debt (Diamond, 1993; Park, 2000; Rauh & Sufi, 2010). Such heterogeneity became even more obvious after the GFC as the credit risk and investor risk aversion increased, and banks also faced strengthened capital requirements and had a more limited funding capacity (Anginer, Bertay, Cull, Demirgüç-Kunt, & Mare, 2021; Gorton, 2009; Reinhart & Rogoff, 2011). Previous studies treat liquidity effect on leverage as homogeneous, and no study has examined whether stock liquidity has different effects on secured and unsecured debt across financial crisis or health crisis periods, nor the impact of stock liquidity on the zero-leverage puzzle has been explored. We aim to fill in this gap in the literature.

Examining a large sample of U.S. public firms from 1990 to 2021, we find a considerable heterogeneity in the association between stock liquidity and firm leverage. The liquidity effect is significantly negative for secured debt, while such effects become insignificant or even positive for unsecured debt. The logit regression results show that stock liquidity not only reduces the firm leverage but also increases the firm propensity to use zero leverage. The sub-period regression shows that the liquidity effect on leverage is significantly negative pre-GFC and becomes insignificant or positive for unsecured debt post-GFC, indicating the increase of risk aversion and bank capital requirements post-GFC alleviates the impact of stock liquidity on firm leverage (Fleming, 2012; Ivashina & Scharfstein, 2010). Furthermore, we examine the moderating effect of the GFC and the Covid-19 health crisis, and our results suggest that the

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GFC alleviated the stock liquidity effect on leverage, whereas the Covid-19 pandemic strengthened the negative effect of stock liquidity. After controlling for determinants of leverage in previous literature, this study provides the first evidence for the heterogeneous liquidity effect on secured (unsecured) debt and the variation of liquidity effect around the GFC and pandemic period. Moreover, we run various robustness tests and use a difference-in-difference approach and entropy balancing method to address endogeneity concerns and confirm that our results are not driven by endogeneity.

This study makes several contributions to literature. First, this is the first study that decomposes the stock liquidity effect on leverage to reveal a heterogeneous effect and confirms that firms replace secured debt with unsecured debt when their stock liquidity improves. This variation of liquidity effect between secured debt and unsecured debt helps reconcile the mixed results of stock liquidity effect on total leverage in the previous studies. Second, this paper provides the first evidence that stock liquidity increases the propensity of zero leverage in capital structure policy, which suggests stock liquidity is an important factor in explaining the zero-leverage puzzle discussed in the literature (e.g. Strebulaev & Yang, 2013; El Ghoul, Guedhami, Kwok and Zheng, 2018). Third, we examine the potential economic mechanisms and confirm the moderating role of financial constraints and risk on stock liquidity's effect on leverage. Our results suggest that liquidity effects on firm leverage are stronger for companies with more financial constraints and higher risk. Lastly, we contribute to the growing literature on the GFC and Covid-19 health crisis and show a significant heterogeneity of liquidity effects on leverage around the GFC and the Covid-19 pandemic. In particular, we test the moderating effect of GFC and Covid-19, and find that the stock liquidity effect on leverage (unsecured debt) was attenuated after the GFC and was strengthened after the Covid-19 pandemic. We discuss the possible reasons for such heterogeneity based on the change in risk aversion and cash flow uncertainty around the GFC and pandemic crisis.

The rest of the paper proceeds as follows. Section 2 examines the capital structure and stock liquidity literature. Section 3 describes the sample data and methodology. Section 4 reports the empirical results, and section 5 concludes.

2. Literature review

2.1. Stock liquidity and firm leverage

A large number of theoretical and empirical studies have examined the corporate capital structure and how it affects firm value. Several capital structure theories have been examined, including the trade-off, agency, and pecking order theories. Recent evidence indicates that both the cost of capital and the source of capital can influence the capital structure decision (Faulkender & Petersen, 2006). Market microstructure literature reports that liquidity risk is an important priced risk factor in stock returns in addition to the market risk and credit risk (Amihud, 2002; Chordia, Subrahmanyam, & Anshuman, 2001).

Liquidity has been shown as a relevant factor for corporate finance decisions. One growing stream of literature has linked market microstructure and corporate finance literature to examine the impacts of stock liquidity on firm valuation (Fang, Noe, & Tice, 2009) and various corporate policies, such as innovation (Fang, Tian, & Tice, 2014), payout policy (Banerjee, Gatchev, & Spindt, 2007; Jiang, Ma, & Shi, 2017; Nguyen, 2020), stock repurchase (Brockman, Howe, & Mortal, 2008), trade credit (Shang, 2020), risk-taking (Hsu, Ma, Wu, & Zhou, 2020) and corporate governance (Edmans, Fang, & Zur, 2013).

Stock liquidity was ignored for a long time in empirical studies of capital structure. Only recently, liquidity was considered a potential determinant of firm leverage, and there are competing views on how leverage may be influenced by stock liquidity. On the one hand, the equity preference view argues that stock liquidity reduces the cost of equity and thus increases a firm's preference to raise equity capital. The microstructure literature shows that stock liquidity can reduce the required rates of return on equity due to lower transaction costs and cost of equity (e.g., Hasbrouck, 2009; Pastor & Stambaugh, 2003).

The trade-off theory suggests that firm trades off between the cost of equity and the cost of debt when deciding upon the capital structure (Harris & Raviv, 1991; Ozkan, 2001). Amihud (2002) demonstrates that excess stock returns include a premium for illiquidity. Butler et al. (2005) find that equity issuance costs are significantly lower for firms with more liquid stock. These studies indicate that higher stock liquidity significantly reduces the cost of equity and gives firms easier access to the equity market. Consequently, the equity preference view suggests that companies with higher equity liquidity borrow less debt than those with low liquidity. Consistent with this notion, several studies (e.g. Lipson & Mortal, 2009) show that firms with liquid stocks have lower leverage and prefer equity financing.

On the other hand, the debt preference view suggests a positive relation between stock liquidity and firm leverage, which view is based on empirical evidence that stock liquidity reduces the cost of debt and credit risk. Empirical literature shows that firms with higher stock liquidity enjoy better credit ratings (Odders-White & Ready, 2006), lower default risk (Brogaard, Li, & Xia, 2017), and a faster speed of leverage adjustment than illiquid firms (Ho, Lu, & Bai, 2021). As stock liquidity may also increase the probability of hostile takeovers (Fang et al., 2014), managers can use debt as a tool for takeover defense (e.g., Safieddine & Titman, 1999). Thus, the debt preference view suggests that liquid firms may prefer issuing more debt than equity. Cheung et al. (2018) report a positive association between stock liquidity and debt financing. Several studies (e.g., Haddad, 2012; Nadarajah, Ali, Liu, & Huang, 2018) examine international samples and find mixed evidence of stock liquidity effects on firm leverage.

Previous studies of stock liquidity effect focus on total debt for the sample period pre-2007 and report inconclusive results. This study aims to reassess this topic and decompose the stock liquidity effect by dividing the total debt into secured debt and unsecured debt and examining the heterogeneity of stock liquidity effects across different levels of debt security and time periods.

2.2. Secured debt and unsecured debt

Corporate leverage is characterized by heterogeneity of debt type and security levels. Although several theoretical studies argue that capital structure analysis should consider multiple types of debt (e.g, Diamond, 1993; Hackbarth & Mauer, 2012; Park, 2000), many empirical studies still treat corporate debt as uniform. Moreover, a growing empirical literature reports that multiple types of debt instruments have different features, such as cash flow claims, sensitivity to information, and management incentives (e.g. Barclay & Smith Jr, 1995; Denis & Mihov, 2003; Vig, 2013). Rauh and Sufi (2010) find that correlations between leverage and firm characteristics vary a lot for different debt components, and 26% of sample firms significantly change their debt structure while keeping a relatively stable level of total leverage. They also report that high credit quality firms mainly focus on senior unsecured debt and equity financing, while lower credit quality firms use various types of debt, including both secured and unsecured debt.

Corporate finance literature suggests that secured and unsecured debt may have different features and play different roles in capital structure. Using secured debt to finance new investments may mitigate agency problems, such as asset substitution problem and underinvestment problem. The asset substitution problem can be prevented through the use of secured debt since it makes asset substitution more difficult (Smith & Warner, 1979). The underinvestment problem arises when stockholders lack incentives to invest in value-increasing projects that mainly benefit debtholders. Financing investment projects with secured debt alleviates this problem since it limits wealth transfer from stockholders to debtholders and reduces the incentives for stockholders to forego positive NPV projects (Barclay & Smith Jr, 1995).

Stulz and Johnson (1985) show that secured debt provides lenders with a large degree of protection against losses from asset substitution because unsecured debt is more affected by changes in asset risk than secured debt. They demonstrate that managers can increase firm value by financing new projects with secured debt and thus reduce monitoring costs when debtholders face potential losses from asset substitution. Thus, secured debt can provide more favorable financing terms when the company faces a higher risk and the value of reduced monitoring costs is higher, which benefits are more valuable for firms with illiquid stocks than their liquid counterparts. Empirical studies support such arguments (e.g., Barclay & Smith Jr, 1995; Rauh & Sufi, 2010).

Previous studies suggest that firms move from secured bank debt to unsecured debt as credit quality improves (Bolton & Freixas, 2000; Diamond, 1991). This implies that firms with higher stock liquidity may switch to unsecured debt since they enjoy lower credit risk (Brogaard et al., 2017; Odders-White & Ready, 2006). In Diamond (1991) model, firms shift from secured bank debt to unsecured debt by establishing a reputation for strong earnings as high quality firms can borrow directly from creditors and avoid additional costs of secured debt associated with bank monitoring and collateralization, which implies that the low quality firms may be rationed out of unsecured debt market. The model by Bolton and Freixas (2000) predicts that high quality firms do not value bank monitoring and, therefore, adopt more unsecured debt, while lower quality borrowers value the investigation ability of the banks and thus rely more on secured bank debt. According to Standard & Poor's, secured bank debt recovery rates are 75%, whereas unsecured bonds recover around 37%, which supports the value of bank monitoring for low quality firms. Therefore, previous studies imply that the improvement of stock liquidity may bring different impacts to secured debt and unsecured debt.

Market microstructure literature shows that stock liquidity can alleviate agency problems (Edmans et al., 2013) and information asymmetry (Subrahmanyam & Titman, 2001). Companies with high stock liquidity would have better credit ratings and lower credit risk compared to illiquid firms (Brogaard et al., 2017), and the benefits of bank monitoring and secured debt will become less valuable. For example, Odders-White and Ready (2006) find that corporate debt rating drops as the stock illiquidity increases. Ericsson & Renault (2006) report a positive relationship between the stock illiquidity and default components of corporate bond yield spreads. Consequently, strong stock liquidity may substitute the benefit of secured debt in the reduction of agency problems, and thus, the negative effect of stock liquidity on the secured debt is stronger.

On the other hand, stock liquidity may have a weaker effect on unsecured debt as the negative stock liquidity effect may be alleviated by the transition from secured debt to unsecured debt in more liquid companies. As unsecured debt implies a higher financial risk for creditors than secured debt, creditors will be more confident in extending unsecured debt to firms with strong stock liquidity (better credit rating) compared to illiquid firms. The lenders of secured debt are oftentimes banks that have better monitoring power and are less sensitive to liquidity risk and, thus, are more willing to issue secured debt to illiquid firms. The additional cost of collateralization and monitoring associated with secured debt will be more worthwhile for illiquid firms to build trust with creditors, but high stock liquidity firms can save these costs as they have access to financing via unsecured debt and equity. As a result, the liquidity impact on leverage may vary between secured and unsecured debt, which implies a shift between secured and unsecured debt. Based on the above discussion, we propose the following hypotheses:

Hypothesis 1. Firms with high stock liquidity will reduce firm leverage.

Hypothesis 2. Firms replace secured debt with unsecured debt as stock liquidity improves.

2.3. Global financial crisis and Covid-19 health crisis

Empirical evidence in the literature suggests that capital structure decisions are affected by macroeconomic conditions (Cook & Tang, 2010; Korajczyk & Levy, 2003). In an economic slowdown, firms use less debt because the collateral value for secured debt drops (e.g., Kiyotaki & Moore, 1997). Therefore, we directly test the moderating effect of the financial crisis and Covid-19 health crisis on the association of stock liquidity with leverage.

Corporate finance literature shows that corporate risk and debt financing have significantly changed post-GFC due to the credit crisis and higher risk aversion by investors and banks (e.g., Anginer et al., 2021; Reinhart & Rogoff, 2011). Higher asset prices led to a leverage cycle by which increases in home values led to more debt (Adrian & Shin, 2009; Mian & Sufi, 2009). The asset price boom was further fueled by lax lending practices that caused an explosion of subprime mortgage credit (Dell' Ariccia, Igan, & Laeven, 2012). This was followed by a credit crunch during and post-GFC when house prices fell and subprime mortgage defaults increased. These events caused investors to reappraise the risks of high-yielding securities, bank failures, and sharp increases in the spreads in interbank markets. The effect of liquidity risk on credit supply is clear by the sharp widening of the TED spread in the 2007–08 period[1] (Antoniades, 2016; Mizen & Tsoukas, 2012). The cost of debt and the risk premium of external financing also increased during the crisis period (Gertler & Kiyotaki, 2015; Yazdanfar & Öhman, 2021). As a result, we expect that the negative liquidity effect on the leverage will be alleviated due to the financial market disruptions during the 2007–2008 financial crisis.

After the Covid-19 health crisis broke out in 2019, many businesses experienced lockdowns and huge sales revenue losses, leading to cash flow shortfalls and earnings uncertainty, which makes external funding crucial to prevent insolvency risk. During crisis periods, financing becomes problematic when cash flows drop significantly over an extended period of time. When the economy started to recover, the debt overhang problem posed a big challenge and obstacle to investments (Caballero & Simsek, 2021; Carletti, Oliviero, Pagano, Pelizzon, & Subrahmanyam, 2020; Chakrabarty & Pascual, 2023). As the GFC is more related to the banking and financial sectors, secured bank debt and equity markets became less available due to a large economy-wide shock (Campello, Graham, & Harvey, 2010; Carvalho, Ferreira, & Matos, 2015). However, banks and financial markets entered the Covid-19 health crisis with a healthier position compared to the GFC period, and they are better positioned to meet the business funding needs (Acharya & Steffen, 2020; Li, Strahan, & Zhang, 2020).

The government policy interventions and the safe position of banks during the pandemic have made debt financing more accessible to companies and helped them overcome cash flow shortfalls (Almeida, 2021; Gopalakrishnan, Jacob, & Mohapatra, 2022). Therefore, as the health crisis started, firms immediately resorted to their banks and drew funds from lines of credit and debt financing at an unprecedented scale (Li et al., 2020). At the same time, the stock market remained functioning reasonably well and thus allowed firms with high stock liquidity to raise funds from equity. Acharya and Steffen (2020) report that while BBB or lower firms mostly borrow secured debt from banks, A or above-rated firms managed to maintain access to public capital markets and issued both bonds and equity. Tran & Uzmanoglu (2023) report that the Covid-19 lockdown increases the bond yield and risk premiums, which bond investors require. As a result, firms with high stock liquidity can still use equity financing to avoid the cost of leverage during the pandemic, thanks to the public policy response and the relative stability of the banking and financial sectors. In contrast, low stock liquidity firms

[1] The TED spread measures funding stresses in the banking sector and is defined as the difference between the 3-month LIBOR rate and the 3-month Treasury rate.

Table 1
Summary statistics.

	Mean	Median	SD	Q25	Q75
Bid-ask spread (%)	2.483	1.271	3.164	0.244	3.357
Amihud illiquidity measure	0.375	0.012	1.129	0.001	0.121
Return on Assets (%)	0.326	2.911	28.29	0.385	7.632
Total debt (millions)	847.1	34	2868	1.362	320.3
Total assets (millions)	3854	371.3	12,787	76.08	1755
Book leverage (%)	21.42	17.48	19.69	3.939	33.77
Secured debt/assets (%)	7.996	0.316	14.27	0	9.812
Unsecured debt/assets (%)	14.80	8.589	16.90	0.324	24.79
Secured debt/total debt (%)	35.15	17.13	38.18	0	72.40
Secured debt/total liability (%)	13.11	6.132	21.33	0	19.13
R&D/sales (%)	5.694	0	15.04	0	3.448
D&A/assets (%)	3.903	3.412	3.194	1.711	5.285
M/B	2.426	1.776	1.944	1.096	2.992
PPE/assets (%)	44.21	33.92	40.24	10.12	70.30
Dummy R&D	0.599	1	0.490	0	1
Dummy tax loss	0.343	0	0.475	0	1
Price (dollars)	25.40	17.06	28.06	7.616	32.74
Observations	101, 201				

This table presents the summary statistics of the main variables in this paper during the period 1990–2021. The liquidity and control variables are winsorized at the 1% and 99% levels by each year. SD, Q25 and Q75 denotes the standard deviation, the 25th and 75th percentile of each variable. Variable definition details are listed in Appendix A.

need to rely more on secured bank debt. If high liquidity firms need to borrow debt, they will also use more secured bank debt instead of unsecured debt due to the higher cost of debt following their cash flow shortfalls and uncertainty during the pandemic period. Given the above discussion, we propose the next hypothesis:

Hypothesis 3. The negative effect of stock liquidity on leverage was alleviated during the 2007–2008 GFC, and such effect was strengthened during the Covid-19 health crisis.

We test this hypothesis by examining the moderating effect of the GFC and the Covid-19 pandemic on the stock liquidity effect on firm leverage in Section 4. We also explore whether stock liquidity can explain the zero-leverage puzzle discussed in previous literature.

2.4. Zero leverage puzzle

One well-known puzzle in corporate finance literature is the stylized fact that firms carry much less debt than what is predicted by capital structure theories, which is called the "low leverage puzzle" (e.g., Devos, Dhillon, Jagannathan, & Krishnamurthy, 2012; Korteweg, 2010). Recent research documented the "zero leverage puzzle" that many firms in the U.S. and across countries borrow zero debt (e.g. Bessler, Drobetz, Haller, & Meier, 2013; Strebulaev & Yang, 2013) though the traditional theory suggests that firms choose their optimal leverage by trading off the interest tax saving with costs of debt. Although a number of studies have examined why firms adopt such conservative financial policies (e.g. Dang, 2013; El Ghoul et al., 2018), the discussion is far from completed, given the conflicting hypotheses and mixed evidence of the zero leverage puzzle. For example, Strebulaev and Yang (2013) report that zero-leverage is affected by corporate governance, such as CEO ownership, board size, independence, etc. However, Devos et al. (2012) show that governance mechanisms cannot explain this puzzle and that firms use zero leverage as they have limited access to capital markets and face credit rationing. Dang (2013) argues that firms choose zero leverage not only due to limited exposure to capital markets but also based on strategic considerations to mitigate underinvestment incentives and preserve financial flexibility.

Faulkender and Petersen (2006) report that firms without access to the public bond market have 35% less debt than firms with such access. Therefore, the financial constraint hypothesis suggests firms borrow little debt due to limited access to the capital market (Devos et al., 2012), while the financial flexibility hypothesis argues that firms use low leverage to avoid investment distortion and preserve their borrowing capacity when valuable investment opportunities arise (Gamba & Triantis, 2008). Since stock liquidity improves a firm's access to the capital market and reduces agency problem and information asymmetry, which in turn mitigates the financial constraint and underinvestment problem, we expect the stock liquidity may have a negative impact on the zero-leverage phenomenon. Supposing either the financial constraint hypothesis or the financial flexibility hypothesis holds, we should expect that stock liquidity will reduce the incentives for firms to adopt zero leverage as they can borrow more debt due to better access to financial markets and lower concerns of underinvestment problems. On the other hand, if the equity preference view holds that high stock liquidity reduces the cost of equity and thus makes equity more attractive, then we argue that stock liquidity increases the likelihood for firms to borrow zero or little debt as firms can obtain cheaper financing via equity. Given the above discussion, we propose the following hypotheses:

Hypothesis 4A. Stock liquidity reduces the propensity for firms to borrow zero leverage or low leverage in capital structure based on the financial constraint/financial flexibility views.

Hypothesis 4B. Stock liquidity increases the propensity for firms to borrow zero leverage or low leverage in capital structure based on the equity preference view.

3. Data and methodology

3.1. Data

The data sample in this paper includes U.S. public firms from 1990 to 2021. The financial data are sourced from COMPUSTAT, and stock trading information comes from the CRSP database. Consistent with previous studies, utilities and financial firms are excluded, and firms with less than three years of observations are eliminated. The final sample consists of 101,201 firm-year observations.

3.2. Leverage and liquidity measures

To examine the determinants of firm leverage, several measures are used as the dependent variables: total debt/total assets, secured debt, and unsecured debt scaled by total assets, total debt, and total liability. Following prior literature (e.g., Chai, Faff, & Gharghori, 2010; Jiang, Kim, & Zhou, 2011; Shang, 2020), two variables are adopted as a proxy for liquidity: quoted bid-ask spread and Amihud (2002) measure. To make it easier to see the stock liquidity effect, we use -ln(bid-ask spread) and -ln(Amihud measure) as measures of stock liquidity.

Quoted spread is defined as (ask-bid)/[(ask+bid)/2]. Stock with a high bid-ask spread has low liquidity, and a low bid-ask spread implies high stock liquidity. We calculate the annual liquidity measure using the daily bid-ask spread and then averaging across each firm's fiscal year.

The Amihud (2002) measure is defined as the daily ratio of the absolute stock return to trading volume, which is averaged over the fiscal year. This measure can be interpreted as the average price response to the trading volume: Amihud = |stock return|/(dollar trading volume). A high Amihud measure indicates low stock liquidity and thus is negatively related to stock liquidity.

3.3. Control variables

We employ the control variables that are documented in previous studies as determinants of capital structure (e.g. Baker & Wurgler, 2002; Fama & French, 2002; Ho et al., 2021). The variables include asset tangibility, profitability, firm size, growth opportunities, non-debt tax

Table 2
Correlation coefficients.

		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
(1)	Bid-ask spread	1.00										
(2)	Amihud measure	0.67***	1.00									
(3)	Total leverage	0.03***	−0.13***	1.00								
(4)	Secured debt/TA	0.08***	0.08***	0.62***	1.00							
(5)	Unsecured debt/TA	−0.02***	−0.23***	0.70***	−0.09***	1.00						
(6)	LN(Total Assets)	−0.49***	−0.77***	0.22***	0.03***	0.34***	1.00					
(7)	MTB	−0.15***	−0.20***	−0.01***	−0.07***	0.02***	−0.08***	1.00				
(8)	PPE/Total assets	0.04***	-0.06***	0.20***	0.11***	0.11***	0.03***	−0.04***	1.00			
(9)	D&A/Total assets	0.09***	0.08***	0.14***	0.08***	0.05***	−0.17***	0.06***	0.58***	1.00		
(10)	ROA	−0.16***	-0.19***	0.01	−0.01***	0.001	0.21***	−0.05***	0.01***	−0.10***	1.00	
(11)	R&D/Sales	−0.02***	0.13***	−0.11***	−0.09***	−0.09***	−0.25***	0.23***	−0.12***	0.03***	−0.32***	1.00
(11)	LN(Price)	−0.48***	−0.72***	0.03***	−0.11***	0.15***	0.66***	0.20***	−0.03***	−0.18***	0.28***	−0.19***

This table presents the pairwise correlation coefficients for leverage variables, liquidity measures, and control variables in this paper. ***, **, * indicate significance at the 1%, 5%, and 10% levels. Variable definition details are listed in Appendix A.

Table 3
Regressions of firm's leverage on stock liquidity measures.

	TD/TA	TD/TA	Secured/TA	Secured/TA	Unsecured/TA	Unsecured/TA
	(-Spread)	(-Amihud)	(-Spread)	(-Amihud)	(-Spread)	(-Amihud)
Liquidity	−0.0056***	-0.0070***	-0.0066***	-0.0055***	−0.0017	-0.0017*
	(0.000)	(0.000)	(0.000)	(0.000)	(0.275)	(0.051)
LN(TA)	0.0513***	0.0537***	0.0180***	0.0179***	0.0369***	0.0381***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
PPE/TA	0.0451***	0.0413***	0.0219***	0.0150**	0.0240***	0.0282***
	(0.000)	(0.000)	(0.000)	(0.024)	(0.000)	(0.000)
ROA	-0.0772***	-0.0716***	-0.0196*	−0.0185*	-0.0619***	-0.0590***
	(0.000)	(0.000)	(0.060)	(0.091)	(0.000)	(0.000)
MTB	0.0069***	0.0069***	0.0024***	0.0024***	0.0048***	0.0047***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
D&A/TA	0.0936	0.1251*	0.0165	0.0381	0.0456	0.0450
	(0.133)	(0.059)	(0.692)	(0.396)	(0.346)	(0.398)
R&D/Sales	-0.0266***	-0.0242***	-0.0161***	-0.0164***	-0.0127	−0.0113
	(0.002)	(0.000)	(0.001)	(0.002)	(0.101)	(0.169)
D (R&D)	0.0184***	0.0185***	0.0091***	0.0091***	0.0048	0.0045
	(0.000)	(0.000)	(0.001)	(0.001)	(0.145)	(0.198)
D (Tax loss)	0.0075***	0.0039	0.0025	0.0018	0.0018	-0.001
	(0.001)	(0.110)	(0.146)	(0.338)	(0.400)	(0.685)
LN(Price)	-0.0318***	-0.0282***	-0.0156***	-0.0127***	-0.0193***	-0.0183***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Constant	-0.0419***	-0.0606***	0.0176	0.0102	-0.0440***	-0.0562***
	(0.000)	(0.000)	(0.143)	(0.471)	(0.000)	(0.000)
Year F.E.	Yes	Yes	Yes	Yes	Yes	Yes
Firm F.E.	Yes	Yes	Yes	Yes	Yes	Yes
Observations	101,201	101,201	85,950	85,950	85,950	85,950
Adjusted R^2	0.6972	0.6976	0.6293	0.6313	0.5961	0.6063

This table presents the fixed effect regression results of firm leverage on stock liquidity and other control variables. Stock liquidity is measured by -ln(bid-ask spread) and –ln(Amihud measure). Firm leverage is measured by total debt/total assets, secured debt/total assets, and unsecured debt/total assets. Standard errors are corrected for clustering at the firm level, and *p*-values are in parentheses. ***, **, * indicate significance at the 1%, 5%, and 10% levels. Variable definition details are listed in Appendix A.

shield, R&D, and share price.

Growth: according to the trade-off theory, firms with more growth opportunities prefer equity to mitigate the underinvestment problem. Several studies report a negative relationship between leverage and growth (Ho et al., 2021; Rajan & Zingales, 1995). Growth opportunities are measured as the market value of equity divided by the book value of common equity (M/B).

Profitability: the pecking order theory suggests that firms prefer internal funds, and more profitable firms will have less debt. A negative relationship between profitability and leverage was reported in the literature (Titman & Wessels, 1988; Zhou, Li, & Chen, 2021). Profitability is measured by ROA.

Asset tangibility: tangible assets can be used as collateral, reducing the risk to creditors and the agency costs of debt. Hence, a positive relationship between tangible assets and leverage is supported in empirical studies (Harris & Raviv, 1991; Zhou et al., 2021). Asset tangibility is measured by Net Property, Plant, and Equipment (net PPE) divided by total assets.

Firm size: large firms are less exposed to bankruptcy risk, and firm size is positively related to leverage (Ozkan, 2001; Zhou et al., 2021). The natural log of total assets is used for firm size.

Stock price: the natural log of the average daily trading price during the year is used as a proxy for the stock price. The market timing theory (Baker & Wurgler, 2002) suggests that share price and leverage should be inversely related.

Non-debt tax shield: firms have incentives to use more debt due to interest tax savings, and non-debt tax shields are substitutes for the tax benefits of debt. Therefore, firms with larger non-debt tax shields tend to use less debt (DeAngelo & Masulis, 1980). The depreciation and amortization to total assets (D&A) are used as a proxy for the non-debt tax shield. We also include a dummy variable for tax loss, which takes one if the firm makes a net operating loss in the fiscal year and zero otherwise.

R&D: R&D as a proxy for intangible assets is expected to correlate negatively with leverage (Graham, 2000). R&D is measured R&D scaled

Table 4
Subperiod regressions of firm's total debt on stock liquidity measures.

Panel A)	TD/TA	TD/TA	Secured/TA	Secured/TA	Unsecured/TA	Unsecured/TA
1990–2006	(-Spread)	(-Amihud)	(-Spread)	(-Amihud)	(-Spread)	(-Amihud)
Liquidity	-0.0115***	-0.0060***	-0.0059***	-0.0048***	-0.0071***	-0.0015*
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.098)
Constant	−0.0223	-0.0542***	0.0241**	-0.0012	-0.0310**	-0.0469***
	(0.144)	(0.005)	(0.026)	(0.932)	(0.021)	(0.005)
Other controls	Yes	Yes	Yes	Yes	Yes	Yes
Year F.E.	Yes	Yes	Yes	Yes	Yes	Yes
Firm F.E.	Yes	Yes	Yes	Yes	Yes	Yes
Observations	49,062	49,062	41,125	41,125	41,125	41,125
Adjusted R^2	0.7322	0.7327	0.6276	0.6136	0.6143	0.6306

Panel B)	TD/TA	TD/TA	Secured/TA	Secured/TA	Unsecured/TA	Unsecured/TA
2007–2021	(-Spread)	(-Amihud)	(-Spread)	(-Amihud)	(-Spread)	(-Amihud)
Liquidity	-0.0049**	-0.0030**	-0.0101***	-0.0036***	0.0021	0.0001
	(0.015)	(0.026)	(0.000)	(0.003)	(0.314)	(0.990)
Constant	-0.0841***	-0.0782**	-0.0217	-0.0149	-0.0666**	−0.0671**
	(0.006)	(0.015)	(0.368)	(0.549)	(0.012)	(0.016)
Other controls	Yes	Yes	Yes	Yes	Yes	Yes
Year F.E.	Yes	Yes	Yes	Yes	Yes	Yes
Firm F.E.	Yes	Yes	Yes	Yes	Yes	Yes
Observations	51,600	51,600	44,332	44,332	44,332	44,332
Adjusted R^2	0.7680	0.7650	0.7271	0.7247	0.6978	0.6958

This table presents the subsample fixed effect regression results of the firm's total debt on stock liquidity over two subsample periods, and other control variables are included but not reported. ***, **, * indicate significance at the 1%, 5%, and 10% levels. Variable definition details are listed in Appendix A.

by sales. We also include a dummy variable for R&D, which takes one if the firm reports zero or no R&D in the year and zero otherwise. This R&D dummy, in conjunction with R&D, captures any potential non-linear relation between R&D and firm leverage.

The fixed-effects regression approach is adopted, which can partially alleviate concerns that stock liquidity and leverage are determined simultaneously by some unobservable firm-specific characteristics. We run the Hausman-test to determine whether the individual firm characteristics are correlated with the regressors, and the test statistics is significant at 1% level, which rejects the null hypothesis and suggests the fixed-effects model is more suitable than the random-effects model in this analysis. The baseline regression model is as follows:

$$\begin{aligned} Leverage_t = & \beta_1 Liquidity_{t-1} + \beta_2 Firm\ size_{t-1} + \beta_3 (PPE/TA)_{t-1} + \beta_4 ROA_{t-1} \\ & + \beta_5 (M/B)_{t-1} + \beta_6 (D\&A/TA)_{t-1} + \beta_7 (R\&D/Sales)_{t-1} \\ & + \beta_8 LN(Price)_{t-1} + \beta_9 Dummy(R\&D)_{t-1} \\ & + \beta_{10} Dummy(Tax\ loss)_{t-1} + \text{Year FE} + \text{Firm FE} + \epsilon \end{aligned} \quad (1)$$

Where *Liquidity* is measured by -ln(spread) or -ln(amihud), to ensure that the robust relationship between stock liquidity and firm leverage is causal, we run lead-lag regressions that the leverage from year t is regressed on the stock liquidity and control variables from year t-1. We cluster the standard errors by a firm and adjust for heteroscedasticity using White's (1980) heteroscedasticity adjusted standard errors.

To address concerns of reverse causality, we use an exogenous shock to liquidity, which is the decimalization of the NYSE, AMEX, and Nasdaq in the year 2001. Prior to 2001, stocks traded at fractional prices with 16 price points within a dollar. After switching to decimal prices in 2001, there were 100 price points to trade, which lowered bid-ask spreads, and thus, decimalization can improve stock liquidity (Bessembinder, 2003). This external change in liquidity is used to examine if increased liquidity following decimalization has a significant impact on firm leverage. Following previous studies (e.g., Jiang et al., 2017; Shang, 2020), we estimate the following difference-in-difference regression model on the subsample from year 1998 to 2003:

$$\begin{aligned} Leverage_t = & \beta_1 High\ Liquidity_{t-1} + \beta_2 Post^* High\ Liquidity_{t-1} \\ & + \beta_3 Post + \beta_4 Firm\ size_{t-1} + \beta_5 (PPE/TA)_{t-1} \\ & + \beta_6 ROA_{t-1} + \beta_7 (M/B)_{t-1} + \beta_8 (D\&A/TA)_{t-1} \\ & + \beta_9 (R\&D/Sales)_{t-1} + \beta_{10} LN(Price)_{t-1} \\ & + \beta_{11} D(R\&D)_{t-1} + \beta_{12} D(Tax\ loss)_{t-1} \\ & + \text{Year\&Firm FE} + \epsilon \end{aligned} \quad (2)$$

Where *High liquidity* is an indicator variable that is equal to 1 if stock liquidity is in the top tercile of liquidity in the year t and zero if it is in the bottom tercile of the year. The treated group in the regression includes firms with stock liquidity in the top tercile of the liquidity in year t. The control group includes firms with stock liquidity in the bottom tercile of the year. The *Post* is an indicator variable that takes 1 if the year is after 2001 and zero otherwise.

4. Empirical results

4.1. Summary statistics

The sample summary statistics are reported in Table 1. The average (median) book leverage is 21.42% (17.48%), with a standard deviation of 19.69%. The mean (median) of secured debt and unsecured debt scaled by total assets is 7.996% (0.316%) and 14.80% (8.589%), with a standard deviation 14.27% and 16.90%. The statistics for stock liquidity are similar to what was reported in previous literature. The mean (median) value of the bid-ask spread is 2.48% (1.27%). The Amihud measure average (median) is 0.375 (0.012).

Table 2 presents the correlation coefficients between leverage, liquidity, and other control variables. Most correlations are significant at the 1% level. Correlation coefficients for the Amihud measure and the bid-ask spread show a positive relationship with the secured debt but a negative relationship with unsecured debt. This supports our prediction that the impact of stock liquidity is not uniform at different security levels of debt structure. We further explore this heterogeneous effect in the following sections. Most control variables show significant correlations with leverage variables. The correlations among the other explanatory variables are generally <0.48, suggesting that collinearity is not a serious problem. The correlations between leverage, liquidity, and

control variables are largely consistent with the results from the multivariate regressions.

4.2. Baseline regression analysis

The regressions model (1) is adopted after controlling for various determinants of leverage. The results presented in Table 3 show that firm equity liquidity is negatively associated with total debt and secured debt but has a weaker effect on unsecured debt. For example, the coefficient of -ln(bid-ask spread) for total debt (secured debt) is significant at a 1% level at −0.0056 (−0.0066). Similarly, the coefficient of -ln (Amihud) is significantly negative at −0.0070 (−0.0055). Such negative associations are consistent with Hypothesis 1, that companies with high stock liquidity tend to use lower leverage, especially less secured debt. On the other hand, the coefficient of -ln(spread) on unsecured debt becomes insignificant, while the coefficient of -ln(Amihud) is only marginally significant at the 10% level. We further explore the heterogeneity of the liquidity effect and the allocation between secured and unsecured debts in the following sections.

The coefficients on the control variables are consistent with the previous literature. Profitability has a significantly negative effect on leverage, which corroborates previous studies (Titman & Wessels, 1988; Zhou et al., 2021). Asset tangibility is positively associated with leverage, suggesting that collateralized assets reduce the agency problem of leverage and hence make the debt more attractive, which is in line with previous literature (Rajan & Zingales, 1995; Zhou et al., 2021). Firm size is positively related to leverage, which supports the trade-off theory suggesting that larger firms are less risky and will be more leveraged (Harris & Raviv, 1991; Ozkan, 2001). The growth opportunity is positively related to leverage, which is different from some previous results (Rajan & Zingales, 1995) but is consistent with other prior studies (Nadarajah et al., 2018; Lin, Schmid, & Xuan, 2018).

R&D is negatively correlated with leverage, which supports the argument that firms with more intangible assets tend to avoid leverage. The coefficient for the R&D dummy is positively significant, which combines with the negative coefficient on the R&D level, indicating a non-linear relation between R&D and firm leverage. The relation between R&D and firm leverage is consistent with previous literature (Fama & French, 2002; Titman & Wessels, 1988). The share price has a significantly negative relationship with leverage, confirming that firms prefer equity to debt when share prices increase (Baker & Wurgler, 2002). Finally, the positive relationship between depreciation and leverage is similar to previous studies (Titman & Wessels, 1988).

4.3. Sub-period analysis: pre- and post-GFC

Next, we examine if the negative liquidity effect varies before and after GFC, and the results are presented in Table 4. The sub-period regression results in Panel A show that stock liquidity has a negative impact on both secured debt and unsecured debt, as well as the total leverage pre-GFC. However, in Panel B, such a negative association remains significant for secured debt and total debt but becomes insignificantly positive for unsecured debt post-GFC. For example, −ln(spread) has a negative coefficient of −0.0071 for unsecured debt pre-GFC, whereas it has a positive coefficient of 0.0021 post-GFC. Illiquid firms tend to borrow more debt pre-GFC, including both secured and unsecured debt. In contrast, illiquid firms have to rely more on secured debt after GFC, possibly due to the fact that they have greater costs and difficulty borrowing unsecured debt. This is in line with the argument that banks and investors are more risk averse after the GFC (Carvalho et al., 2015; Ivashina & Scharfstein, 2010), and creditors prefer secured debt while tending to avoid unsecured debt to illiquid firms due to having more agency problems, higher financial risks, and thus lower credit quality (Odders-White & Ready, 2006; Ericsson & Renault, 2006; Edmans, 2009; Brogaard et al., 2017).

Table 5
Regressions of firm's secured and unsecured debt to total debt on stock liquidity measures.

Panel A)	Secured/ TD	Secured/ TD	Secured/Total Liab	Secured/Total Liab
1990–2021	(-Spread)	(-Amihud)	(-Spread)	(-Amihud)
Liquidity	-0.0134**	-0.0160***	-0.0051***	-0.0074***
	(0.018)	(0.000)	(0.007)	(0.000)
Constant	0.6837***	0.6273***	0.0736***	0.0455***
	(0.000)	(0.000)	(0.000)	(0.000)
Other controls	Yes	Yes	Yes	Yes
Year F.E.	Yes	Yes	Yes	Yes
Firm F.E.	Yes	Yes	Yes	Yes
Observations	85,950	85,950	85,950	85,950
Adjusted R^2	0.6145	0.6153	0.6291	0.6378

Panel B)	Secured/ TD	Secured/ TD	Secured/Total Liab	Secured/Total Liab
1990–2006	(-Spread)	(-Amihud)	(-Spread)	(-Amihud)
Liquidity	-0.0121*	-0.0114***	−0.0055***	-0.0060***
	(0.062)	(0.003)	(0.009)	(0.000)
Constant	0.6455***	0.5898***	0.0834***	0.0598***
	(0.000)	(0.000)	(0.000)	(0.000)
Other controls	Yes	Yes	Yes	Yes
Year F.E.	Yes	Yes	Yes	Yes
Firm F.E.	Yes	Yes	Yes	Yes
Observations	41,125	41,125	41,125	41,125
Adjusted R^2	0.6566	0.6575	0.6506	0.6608

Panel C)	Secured/ TD	Secured/ TD	Secured/Total Liab	Secured/Total Liab
2007–2021	(-Spread)	(-Amihud)	(-Spread)	(-Amihud)
Liquidity	−0.0127*	-0.0179***	-0.0074***	-0.0046***
	(0.086)	(0.000)	(0.010)	(0.009)
Constant	0.5948***	0.5776***	0.0042	-0.0129
	(0.000)	(0.000)	(0.911)	(0.735)
Other controls	Yes	Yes	Yes	Yes
Year F.E.	Yes	Yes	Yes	Yes
Firm F.E.	Yes	Yes	Yes	Yes
Observations	44,332	44,332	44,332	44,332
Adjusted R^2	0.7031	0.7041	0.7383	0.7385

This table presents the fixed effect regression results of the firm's total debt on stock liquidity over the full sample and two subsample periods, and other control variables are included but not reported. ***, **, * indicate significance at the 1%, 5%, and 10% levels. Variable definition details are listed in Appendix A.

4.4. Choice between secured debt and unsecured debt

The baseline regression shows that stock liquidity reduces the total debt and secured debt in capital structure while having a much weaker effect on unsecured debt. In this section, we explore the impact of stock liquidity on the choice between secured debt and unsecured debt. We test the stock liquidity effect on the ratio of secured and unsecured debt divided by either total debt or total liability, and the test results are reported in Table 5 below.

The results in Panel A of Table 5 show a significantly negative relation between stock liquidity and secured debt allocation, which implies a positive relationship between stock liquidity and unsecured debt. For example, the coefficient of -ln(spread) (−ln(Amihud)) on secured debt/total debt is significantly negative at −0.0134 (−0.016). At the same time, the coefficient of -ln(Amihud) (−ln(spread)) on secured debt/total liability is significant and negative at −0.0074 (−0.0051). This result confirms the prediction of Hypothesis 2 that firms with high stock liquidity tend to replace secured debt with unsecured

Table 6
The moderating effect of GFC and Covid-19 risk.

Panel A) GFC	TD/TA	TD/TA	Secured/TA	Secured/TA	Unsecured/TA	Unsecured/TA
	(-Spread)	(-Amihud)	(-Spread)	(-Amihud)	(-Spread)	(-Amihud)
Liquidity x GFC	0.0020**	0.0011**	0.0006	0.0001	0.0030**	0.0014***
	(0.039)	(0.023)	(0.526)	(0.786)	(0.016)	(0.007)
Liquidity	-0.0014	0.0005	-0.0026	-0.0021	-0.0006	0.0032**
	(0.557)	(0.737)	(0.253)	(0.105)	(0.823)	(0.039)
GFC	0.0075	0.0144***	0.0053	0.0090***	-0.0074	0.0022
	(0.223)	(0.000)	(0.380)	(0.002)	(0.338)	(0.533)
Constant	0.0151	0.0283	0.0065	0.0094	0.0308	0.0375
	(0.661)	(0.442)	(0.843)	(0.791)	(0.313)	(0.255)
Other controls	Yes	Yes	Yes	Yes	Yes	Yes
Firm F.E.	Yes	Yes	Yes	Yes	Yes	Yes
Observations	13,835	13,835	11,740	11,740	11,740	11,740
Adjusted R^2	0.8635	0.8643	0.8131	0.8096	0.7696	0.7710

Panel B) Covid-19	TD/TA	TD/TA	Secured/TA	Secured/TA	Unsecured/TA	Unsecured/TA
	(-Spread)	(-Amihud)	(-Spread)	(-Amihud)	(-Spread)	(-Amihud)
Liquidity x Cov-19	-0.0045**	-0.0022*	-0.0004	0.0006	-0.0076***	-0.0053***
	(0.034)	(0.071)	(0.818)	(0.558)	(0.004)	(0.000)
Liquidity	0.0023***	-0.0027***	-0.0014***	0.0018**	0.0005	0.0009
	(0.000)	(0.001)	(0.002)	(0.042)	(0.343)	(0.364)
Covid-19	0.0305***	0.0624***	-0.0079*	-0.0125	0.0414***	0.1154***
	(0.000)	(0.000)	(0.059)	(0.327)	(0.000)	(0.000)
Constant	0.0371	0.0633	0.1236***	0.1059***	-0.1014	−0.1111*
	(0.508)	(0.245)	(0.004)	(0.010)	(0.127)	(0.081)
Other controls	Yes	Yes	Yes	Yes	Yes	Yes
Firm F.E.	Yes	Yes	Yes	Yes	Yes	Yes
Observations	18,170	18,170	16,212	16,212	16,212	16,212
Adjusted R^2	0.8481	0.8478	0.8683	0.8682	0.8226	0.8229

This table presents the subsample regression results for the moderating effect of the 2007–2009 GFC and Covid-19 pandemic on the impact of stock liquidity on firm leverage. Leverage is measured by total debt, secured debt, and unsecured debt scaled by total assets. GFC is the dunny variable that takes the value of 1 if the year is 2007 to 2008 and zero otherwise. Covid-19 is the dunny variable that takes the value of 1 if the year is 2019 to 2021 and zero otherwise. Panel A presents the moderating effect of GFC over the subsample from the year 2006 to 2009. Panel B presents the moderating effect of GFC over the subsample from the year 2017 to 2021. ***, **, * indicate significance at the 1%, 5%, and 10% levels. Variable definition details are listed in Appendix A.

debt in the capital structure. The financial theory holds that firms with low stock liquidity tend to have more agency problem and lower credit ratings (Subrahmanyam & Titman, 2001; Edmans, 2009). From a supply-side perspective, illiquid firms may not have a strong credit rating to borrow unsecured debt and need to rely more on secured debt, which enables bank monitoring to help mitigate the agency problem and reduce the high costs associated with financial risk. Therefore, illiquid firms tend to use more secured debt and reduce unsecured debt. Those companies with strong stock liquidity are able to reduce secured debt and increase unsecured debt to avoid the additional cost of bank monitoring and collateralization, as they are in a better credit position to be financed through unsecured debt and stock equity. The shift from secured debt to unsecured debt is consistent with the views in previous studies suggesting that firms with high stock liquidity enjoy high credit ratings and lower default risks (Odders-White & Ready, 2006; Ericsson & Renault, 2006; Brogaard et al., 2017), and hence when credit quality improves, firms move from secured bank debt to unsecured debt (Bolton & Freixas, 2000; Diamond, 1991). Such transition also helps explain why the stock liquidity has a much weaker effect on unsecured debt, as reported in Table 3. The shift from secured debt to unsecured debt alleviates the negative liquidity effect on unsecured debt in high stock liquidity firms.

Next, we perform a sub-period analysis for secured and unsecured debt. Results in Panel B and C of Table 5 show a similar pattern that firms use more unsecured debt to replace secured debt as their stock liquidity improves across all time periods. For example, the coefficient of -ln(Amihud) on secured debt/total debt before (after) GFC is significantly negative at 1% level at −0.0114 (−0.0179), and similarly, the coefficient of -ln(spread) on secured debt/total liability before (after) GFC is significant and negative at −0.0055 (−0.0074). Results in Table 5 indicate that the stock liquidity effects on secured debt are similar pre- and post-GFC, and liquid firms tend to borrow less secured debt than illiquid firms. When liquidity is low, agency costs are likely to be high, and thus, firms have to rely more on secured debt to help control agency costs and improve access to the debt market. Banks and investors are more risk-averse post-GFC (Fleming, 2012; Ivashina & Scharfstein, 2010), but the secured debt may help reduce financial risk and borrowing costs, and thus secured debt is more needed than unsecured debt for illiquid firms despite the higher cost of collaterals and monitoring associated with secured debt. The results in Table 5 help explain why liquidity effects on leverage significantly changed for unsecured debt pre- and post-GFC but secured debt didn't experience a significant variation around GFC. Stock liquidity has a negative effect on both secured debt and unsecured debt, as firms with liquid stock can be financed at lower costs via equity before GFC. However, the negative effect of stock liquidity on unsecured debt may be partially offset by the increase in unsecured debt as equity and bank financing became less accessible after the GFC.

4.5. Moderating effects of the GFC and Covid-19 pandemic

In this section, we directly test the moderating effect of the GFC and the Covid-19 health crisis on the association between stock liquidity and leverage. The baseline regression model (1) is augmented with interaction variables of stock liquidity with GFC or Covid-19. GFC is a dummy variable that takes one if the year is 2007 or 2008, and zero, otherwise. Covid-19 is a dummy variable that takes one if the year is 2019 to 2021, and zero, otherwise. Panel A of Table 6 presents the regression results of the moderating effect of GFC based on a subsample from the year 2006 to 2009. Panel B of Table 6 presents the regression

Table 7
Firm leverage and stock liquidity: moderating effect of financial constraints.

Panel A) WW index	TD/TA	TD/TA	Secured/TA	Secured/TA	Unsecured/TA	Unsecured/TA
	(-Spread)	(-Amihud)	(-Spread)	(-Amihud)	(-Spread)	(-Amihud)
Liquidity x FC	-0.0077***	0.0020	-0.0010	0.0033	-0.0092***	-0.0003
	(0.000)	(0.423)	(0.591)	(0.103)	(0.000)	(0.913)
Liquidity	-0.0048***	-0.0071***	-0.0065***	-0.0057***	-0.0007	0.0016*
	(0.000)	(0.000)	(0.000)	(0.000)	(0.646)	(0.055)
FC	0.0071***	-0.0003	0.0008	-0.0030	0.0113***	0.0043**
	(0.001)	(0.877)	(0.671)	(0.114)	(0.000)	(0.043)
Constant	-0.0505***	-0.0601***	0.0167	0.0136	-0.0568***	-0.0608***
	(0.000)	(0.001)	(0.179)	(0.343)	(0.000)	(0.000)
Other controls	Yes	Yes	Yes	Yes	Yes	Yes
Year F.E.	Yes	Yes	Yes	Yes	Yes	Yes
Firm F.E.	Yes	Yes	Yes	Yes	Yes	Yes
Observations	101,201	101,201	85,950	85,950	85,950	85,950
Adjusted R^2	0.6973	0.6976	0.6293	0.6314	0.5963	0.6063

Panel B) non-Dividend paying	TD/TA	TD/TA	Secured/TA	Secured/TA	Unsecured/TA	Unsecured/TA
	(-Spread)	(-Amihud)	(-Spread)	(-Amihud)	(-Spread)	(-Amihud)
Liquidity x FC	-0.0091***	0.0002	-0.0023	0.0039	-0.0064***	-0.0053*
	(0.001)	(0.962)	(0.262)	(0.157)	(0.010)	(0.100)
Liquidity	-0.0046***	-0.0067***	-0.0061***	-0.0057***	-0.0010	−0.0014
	(0.003)	(0.000)	(0.000)	(0.000)	(0.523)	(0.118)
FC	0.0107***	0.0035	0.0158***	0.0124***	0.0015	0.0023
	(0.003)	(0.366)	(0.000)	(0.001)	(0.678)	(0.552)
Constant	-0.0415***	-0.0602***	0.0190	0.0126	-0.0443***	-0.0579***
	(0.006)	(0.001)	(0.114)	(0.373)	(0.000)	(0.000)
Other controls	Yes	Yes	Yes	Yes	Yes	Yes
Year F.E.	Yes	Yes	Yes	Yes	Yes	Yes
Firm F.E.	Yes	Yes	Yes	Yes	Yes	Yes
Observations	101,201	101,201	85,950	85,950	85,950	85,950
Adjusted R^2	0.6973	0.6976	0.6299	0.6320	0.5962	0.6063

Panel C) SA Index	TD/TA	TD/TA	Secured/TA	Secured/TA	Unsecured/TA	Unsecured/TA
	(-Spread)	(-Amihud)	(-Spread)	(-Amihud)	(-Spread)	(-Amihud)
Liquidity x FC	-0.0110***	-0.0043	0.0008	0.0070***	-0.0133***	-0.0114***
	(0.000)	(0.182)	(0.688)	(0.008)	(0.000)	(0.001)
Liquidity	-0.0045***	-0.0067***	-0.0067***	-0.0060***	-0.0003	-0.0010
	(0.004)	(0.000)	(0.000)	(0.000)	(0.840)	(0.249)
FC	-0.0006	-0.0098**	−0.0062*	-0.0103***	0.0088**	0.0023
	(0.894)	(0.020)	(0.052)	(0.001)	(0.029)	(0.540)
Constant	-0.0399**	-0.0471**	0.0259**	0.0224	-0.0534***	-0.0575***
	(0.016)	(0.015)	(0.048)	(0.131)	(0.000)	(0.000)
Other controls	Yes	Yes	Yes	Yes	Yes	Yes
Year F.E.	Yes	Yes	Yes	Yes	Yes	Yes
Firm F.E.	Yes	Yes	Yes	Yes	Yes	Yes
Observations	101,201	101,201	85,950	85,950	85,950	85,950
Adjusted R^2	0.6974	0.6978	0.6294	0.6316	0.5964	0.6064

This table presents the moderating effect of financial constraint on the impact of the stock liquidity on the firm leverage. The leverage is measured by total debt, secured debt, and unsecured debt scaled by total assets in Panel A, B, and C. The interaction variable is calculated as the liquidity variable multiplied by three proxies of financial constraint variables: non-dividend-paying dummy, firm age, and size. ***, **, * indicate significance at the 1%, 5%, and 10% levels. Variable definition details are listed in Appendix A.

results of the moderating effect of the Covid-19 pandemic based on a subsample from the year 2017 to 2021.

The regression results in Panel A of Table 6 shows that the coefficient of interaction term *liquidity x GFC* is significantly positive for total leverage and unsecured debt at 5% level and becomes insignificant for secured debt. For example, the interaction variable of -ln(spread) and GFC dummy has a significantly positive coefficient of 0.0020 for total debt and 0.0030 for unsecured debt. In contrast, it has an insignificant coefficient of 0.0006 for secured debt. Similarly, the interaction term of -ln(Amihud) and the GFC dummy has a significant coefficient of 0.0011 for total debt and 0.0014 for unsecured debt, while it has an insignificant coefficient of 0.0001 for secured debt. This result supports our prediction in hypothesis 3 that the GFC alleviates the negative stock liquidity effect on leverage.

Such a pattern is consistent with the previous literature showing the cost of new credit and the external finance premium spike during the crisis period (Gertler & Kiyotaki, 2015; Mizen & Tsoukas, 2012). In addition, the stock and bond return conditional covariance is lower when there are two positive shocks compared to two negative ones (Baele & Inghelbrecht, 2010; Goyenko & Sarkissian, 2014). Connolly, Stivers, and Sun (2005) show that uncertainty in the stock markets is a significant determinant of stock-bond correlation. The stock-bond correlation tends to increase during periods of market turmoil (Baur & Lucey, 2009; Gulko, 2002). Kahle and Stulz (2013) report a significant decrease in equity issuance and find that unlevered firms decrease capital expenditures more than levered firms during the crisis. Consequently, the spread between the cost of debt and the cost of equity is shrinking, and equity financing is less accessible, which may lead to a

Table 8
Firm leverage and stock liquidity: moderating effect of risks.

Panel A) Zscore	TD/TA	TD/TA	Secured/TA	Secured/TA	Unsecured/TA	Unsecured/TA
	(-Spread)	(-Amihud)	(-Spread)	(-Amihud)	(-Spread)	(-Amihud)
Liquidity x Risk	-0.0092***	0.0031	0.0039**	0.0049**	-0.0124***	-0.0060**
	(0.000)	(0.252)	(0.041)	(0.022)	(0.000)	(0.026)
Liquidity	-0.0028**	-0.0054***	-0.0060***	-0.0051***	0.0008	−0.0002
	(0.050)	(0.000)	(0.000)	(0.000)	(0.598)	(0.804)
Risk	-0.1101***	-0.1141***	-0.0470***	-0.0459***	-0.0660***	-0.0693***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Constant	0.0526***	0.0441***	0.0561***	0.0507***	0.0116	−0.0051
	(0.000)	(0.008)	(0.000)	(0.000)	(0.326)	(0.726)
Other controls	Yes	Yes	Yes	Yes	Yes	Yes
Year F.E.	Yes	Yes	Yes	Yes	Yes	Yes
Firm F.E.	Yes	Yes	Yes	Yes	Yes	Yes
Observations	101,201	101,201	85,950	85,950	85,950	85,950
Adjusted R^2	0.7267	0.7257	0.6392	0.6408	0.6144	0.6233

Panel B) Stock beta	TD/TA	TD/TA	Secured/TA	Secured/TA	Unsecured/TA	Unsecured/TA
	(-Spread)	(-Amihud)	(-Spread)	(-Amihud)	(-Spread)	(-Amihud)
Liquidity x Risk	-0.0138***	-0.0049**	0.0034*	0.0021	-0.0160***	-0.0048**
	(0.000)	(0.041)	(0.073)	(0.286)	(0.000)	(0.050)
Liquidity	-0.0039***	-0.0064***	-0.0071***	-0.0058***	0.0004	-0.0011
	(0.009)	(0.000)	(0.000)	(0.000)	(0.785)	(0.207)
Risk	0.0035**	-0.0012	0.0009	0.0028**	0.0028	-0.0034**
	(0.048)	(0.455)	(0.508)	(0.030)	(0.110)	(0.033)
Constant	-0.0478***	-0.0619***	0.0188	0.0099	-0.0501***	-0.0567***
	(0.002)	(0.001)	(0.122)	(0.483)	(0.000)	(0.000)
Other controls	Yes	Yes	Yes	Yes	Yes	Yes
Year F.E.	Yes	Yes	Yes	Yes	Yes	Yes
Firm F.E.	Yes	Yes	Yes	Yes	Yes	Yes
Observations	101,201	101,201	85,950	85,950	85,950	85,950
Adjusted R^2	0.6974	0.6976	0.6294	0.6314	0.5966	0.6064

Panel C) Interest coverage	TD/TA	TD/TA	Secured/TA	Secured/TA	Unsecured/TA	Unsecured/TA
	(-Spread)	(-Amihud)	(-Spread)	(-Amihud)	(-Spread)	(-Amihud)
Liquidity x Risk	-0.0168***	0.0029	0.0016	0.0090***	-0.0144***	-0.0092***
	(0.000)	(0.309)	(0.359)	(0.000)	(0.000)	(0.001)
Liquidity	-0.0027*	-0.0052***	-0.0058***	-0.0051***	0.0006	-0.0001
	(0.065)	(0.000)	(0.000)	(0.000)	(0.693)	(0.998)
Risk	-0.0537***	-0.0647***	-0.0303***	-0.0329***	-0.0259***	-0.0306***
	(0.000)	(0.00)	(0.000)	(0.000)	(0.000)	(0.000)
Constant	0.0059	0.0037	0.0456***	0.0450***	−0.0182	-0.0236
	(0.683)	(0.833)	(0.000)	(0.001)	(0.135)	(0.111)
Other controls	Yes	Yes	Yes	Yes	Yes	Yes
Year F.E.	Yes	Yes	Yes	Yes	Yes	Yes
Firm F.E.	Yes	Yes	Yes	Yes	Yes	Yes
Observations	101,201	101,201	85,950	85,950	85,950	85,950
Adjusted R^2	0.7091	0.7091	0.6349	0.6368	0.6016	0.6117

This table presents the moderating effect of business risk and financial risks on the impact of stock liquidity on firm leverage. The leverage is measured by total debt, secured debt, and unsecured debt scaled by total assets in Panel A, B, and C. The interaction variable is calculated as the liquidity variable multiplied by three proxies of business risk and financial risks: Altman z-score, stock beta, and interest coverage. ***, **, * indicate significance at the 1%, 5%, and 10% levels. Variable definition details are listed in Appendix A.

weaker stock liquidity effect after the GFC and increase the demand for debt financing.

Panel B of Table 6 tests the moderating effect of Covid-19, which reports that the coefficient of interaction term *liquidity x Covid-19* is significantly negative for total debt and unsecured debt but becomes insignificant for secured debt. For example, the interaction variable of -ln(spread) and the Covid-19 dummy has a significantly negative coefficient of −0.0045 for total debt and − 0.0076 for unsecured debt. In contrast, it has an insignificant coefficient of −0.0004 for secured debt. Similarly, the interaction of -ln(Amihud) and Covid-19 has a significantly negative coefficient of -0.0022 for total debt and − 0.0053 for unsecured debt, while it has an insignificant coefficient of 0.0006 for secured debt. This pattern confirms the prediction in hypothesis 3 that the negative stock liquidity effect on leverage is strengthened during the Covid-19 period. The results are consistent with the previous findings that although American companies experienced cash flow shortfalls and uncertainty after the Covid-19 crisis, both banks and financial markets are in a much healthier situation, and hence, many firms are able to turn to their banks for funding supply through line of credit and secured bank debt (Almeida, 2021). Firms with high stock liquidity maintain their access to capital markets and thus can still be financed through equity (Acharya & Steffen, 2020). Consequently, firms with both high and low stock liquidity tend to use more secured bank debt and reduce unsecured debt. Tran and Uzmanoglu (2023) report that bond yield and risk premiums both increased after the Covid-19 lockdown. As a result, we expect companies with high stock liquidity tend to reduce unsecured debt and raise funds from equity. At the same time, the illiquid firms have to use more leverage and rely primarily on secured bank debt,

Table 9
Difference-in-Difference Regressions of firm leverage on stock liquidity surrounding decimalization in 2001.

	TD/TA	TD/TA	Secured/TA	Secured/TA	Unsecured/TA	UnSecured/TA
	(-Spread)	(-Amihud)	(-Spread)	(-Amihud)	(-Spread)	(-Amihud)
High liquidity x Post	-0.0081***	-0.0145***	0.0032	0.0001	-0.0134***	-0.0178***
	(0.000)	(0.000)	(0.376)	(0.989)	(0.002)	(0.000)
High liquidity	-0.0088***	-0.0123***	-0.0061***	−0.0030	-0.0045*	-0.0104***
	(0.000)	(0.000)	(0.003)	(0.208)	(0.084)	(0.001)
Post	-0.0332***	-0.0301***	-0.0219***	-0.0208***	-0.0133***	-0.0113***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Constant	0.0066	-0.0090	0.0031	-0.0029	0.0396	0.0274
	(0.803)	(0.734)	(0.870)	(0.881)	(0.150)	(0.319)
Other controls	Yes	Yes	Yes	Yes	Yes	Yes
Year F.E.	Yes	Yes	Yes	Yes	Yes	Yes
Firm F.E.	Yes	Yes	Yes	Yes	Yes	Yes
Observations	19,086	19,086	15,823	15,823	15,823	15,823
Adjusted R^2	0.1206	0.1216	0.0519	0.0523	0.0952	0.0993

This table reports the difference-in-difference regression estimates in firm leverage on stock liquidity and control variables around decimalization in the year 2001. The *Post* is an indicator variable that takes on the value of 1 if a year is after the decimalization year 2001 and zero otherwise. *High liquidity* is defined as indicator variables that take on the value of 1 if the stock liquidity in year t is in the top tercile of liquidity in the year and zero if it is in the bottom tercile of the year. The treated group in the regression includes firms with stock liquidity in the top tercile of the liquidity in year t. The control group is the firms whose stock liquidity in year t is in the bottom tercile of liquidity in the year. ***, **, * indicate significance at the 1%, 5%, and 10% levels. Variables are defined in Appendix A.

Table 10
Entropy balancing method.

Panel A: Mean-variance of a matched sample.

Before matching		Treat			Control	
	Mean	Variance	Skewness	Mean	Variance	Skewness
LN(TA)	6.868	3.462	0.025	4.448	2.520	0.444
MTB	2.715	4.552	1.487	2.044	3.817	2.021
PPE/TA	0.433	0.153	0.813	0.436	0.149	0.805
ROA	0.005	0.023	−2.771	−0.046	0.037	−2.092
D&A/TA	0.037	0.001	1.732	0.043	0.001	1.596
R&D/Sales	0.097	0.091	4.516	0.094	0.093	4.498
LN(Price)	2.914	0.965	−0.825	1.807	1.083	−0.181
Dummy-R&D	0.575	0.244	−0.304	0.621	0.235	−0.498
Dummy- Tax loss	0.402	0.240	0.399	0.280	0.202	0.982

After matching		Treat			Control	
	Mean	Variance	Skewness	Mean	Variance	Skewness
LN(TA)	6.868	3.462	0.025	6.868	3.462	0.016
MTB	2.715	4.552	1.487	2.715	4.553	1.012
PPE/TA	0.433	0.153	0.813	0.433	0.153	0.841
ROA	0.005	0.023	−2.771	0.005	0.023	−3.030
D&A/TA	0.037	0.001	1.732	0.037	0.001	1.392
R&D/Sales	0.097	0.091	4.516	0.097	0.091	4.413
LN(Price)	2.914	0.965	−0.825	2.914	0.966	−0.673
Dummy-R&D	0.575	0.244	−0.304	0.575	0.244	−0.304
Dummy- Tax loss	0.402	0.240	0.399	0.402	0.240	0.398

Panel B: Regression results.

	TD/TA	TD/TA	Secured/TA	Secured/TA	Unsecured/TA	Unsecured/TA
	(-Spread)	(-Amihud)	(-Spread)	(-Amihud)	(-Spread)	(-Amihud)
Liquidity	-0.0224***	-0.0113***	-0.0169***	−0.0089***	-0.0044	-0.0024**
	(0.000)	(0.000)	(0.000)	(0.000)	(0.156)	(0.046)
Constant	-0.0197	-0.1059***	0.0336	-0.0244*	-0.0522**	-0.0957***
	(0.487)	(0.000)	(0.173)	(0.054)	(0.045)	(0.000)
Other controls	Yes	Yes	Yes	Yes	Yes	Yes
Year F.E.	Yes	Yes	Yes	Yes	Yes	Yes
Firm F.E.	Yes	Yes	Yes	Yes	Yes	Yes
Observations	101,201	101,201	85,950	85,950	85,950	85,950
Adjusted R^2	0.4499	0.4271	0.2974	0.2366	0.3687	0.3540

This table reports the entropy balancing method regression estimates. Panel A reports a comparison of the mean, variance, and skewness of the variables between treated and control groups. Panel B reports the entropy balancing regression results. ***, **, * indicate significance at the 1%, 5%, and 10% levels Variables are defined in Appendix A.

which explains why the negative liquidity effect exists on the total debt and unsecured debt, but the impact on secured debt is insignificant after the Covid-19 health crisis.

Empirical results so far indicate that the stock liquidity has heterogeneous effects on firm leverage, which effect can be moderated by financial and health crisis. Companies and investors should react responsibly to financial and health crises to guarantee financial stability and lessen the damaging effects of crisis. When examining their financial policy, firms must consider the heterogeneity of leverage and optimize a diversified capital structure across equity and various debt types. Companies with strong stock liquidity can enjoy more financial flexibility and act rationally to avoid the rising financing costs by shifting from secured debt to unsecured debt. Companies with low stock liquidity, higher risk and more financial constraints will experience a stronger impact of stock liquidity on leverage. During crisis periods, firms should concentrate on controlling their cash flow uncertaingy and managing the financial constraints, which can be accomplished by employing efficient cash flow management, lowering expenses, and looking into non-traditional funding options. Firms should also carefully evaluate and manage their risk exposure during crises. This may entail diversifying their investment holdings, putting risk management techniques into practice, and carefully watching market circumstances (Davis & Stone, 2004).

Having a strong framework in place to improve equity liquidity and risk managementcan help companies lessen the effects of crisis and sustain investor confidence. Investors can evaluate the potential impact of crisis on various industries and businesses, taking the financial stability, stock liquidity and debt structure of investment instruments into account. Investors should choose well-diversified investment portfolios based on market circumstances and equity liquidity which can help mitigate their losses and improve portfolio performance during economic downturn and crisis period. In order to stabilize the economy during crisis, governments often adjust their policies. Investors and businesses should keep up with these new policy changes by modifying financial estimates, adjusting investment policy and utilizing government incentives or assistance programs to optimize their performance (Almeida, 2021; Hoang, Arif, & Nguyen, 2022).

4.6. Channel analysis: the role of financial constraint and business and financial risk

The baseline regression results suggest a negative effect of stock liquidity on firm leverage. If stock liquidity affects firm leverage due to an improved firm's access to financial markets and reduced cost of equity, as suggested by the equity preference view, such effects should be stronger for financially constrained companies. If stock liquidity affects the firm leverage due to lower default risk and improved credit rating, then we expect the liquidity effects to be stronger for firms with a higher risk. Therefore, we use financial constraints and risks to gauge potential channels of stock liquidity effects on leverage. Since constrained firms may have more financial needs and risky firms may be subject to higher cost of capital, these firms should benefit more from improved access to the equity market. Such firms are more likely to adjust their leverage when equity financing becomes cheaper and easier to access as a result of strong stock liquidity. Moreover, companies with low stock liquidity have stronger incentives to employ secured debt as a governance mechanism to reduce agency problems or as a signaling tool to indicate low risk to the market. We next explore two potential channels of the negative liquidity effect: financial constraint and risk on secured debt and unsecured debt, as well as total leverage.

First, we augment the baseline model (1) with the interaction variable of the liquidity variable with three measures of financial constraints: non-dividend paying dummy, Whited-Wu index (Whited & Wu, 2006), and Size-Age index (Hadlock & Pierce, 2010) to examine if the stock liquidity effect is moderated by financial constraint. As shown in Table 7, the coefficient of the interaction term is significantly negative for total leverage and unsecured debt, and it becomes insignificant or positive for secured debt, which pattern is consistent across three measures of financial constraints. For example, the interaction of low spread and high Whited-Wu index has a significantly negative coefficient of −0.0077 for total debt and − 0.0092 for unsecured debt. In contrast, it has an insignificant coefficient of −0.0010 for secured debt. Similarly, the interaction of low spread and non-dividend payment dummy has a significantly negative coefficient of −0.0091 for total debt and − 0.0064 for unsecured debt, while it has an insignificant coefficient of 0.0039 for secured debt.

The regression results based on firm size and age index (SA index) show a similar pattern that liquidity effects on firm total leverage and unsecured debt are more pronounced for financially constrained companies. However, they are insignificant for secured debt, which supports our proposition that financial constraints can moderate the stock liquidity effect on firm leverage. This is consistent with the argument that low stock liquidity makes it more expensive and difficult to finance via equity and unsecured debt and thus illiquid firms have to rely more on secured debt financing. As a result, such a negative liquidity effect on total debt and unsecured debt is stronger for financially constrained firms, and the moderating effect of financial constraint plays a more important role for unsecured debt than for secured debt.

Secondly, we examine if the stock liquidity effect differs between risky firms and low-risk firms. The baseline regression is augmented with the interaction variable of the liquidity variable with three measures of risks: *Z*-score (Altman, 1968), stock beta, and interest coverage. Results in Table 8 from the moderating effect of firm risks report that the coefficient of interaction variable is significantly negative for total leverage and unsecured debt and becomes significantly positive for secured debt similarly across three measures of risks. For example, the interaction variable of *liquidity x risk* for -ln(spread) and Z-score is significantly negative at −0.0092 and − 0.0124 for total debt and unsecured debt at a 1% significance level. In contrast, the interaction term has a significant and positive coefficient of 0.0039 for secured debt, indicating a significantly different moderating effect of risk on secured debt compared to unsecured debt. Similarly, the interaction variable of *liquidity x risk* for -ln(spread) and stock beta has a significantly negative coefficient of −0.0138 for total debt and − 0.0160 for unsecured debt but a significantly positive coefficient of 0.0034 for secured debt.

This pattern is consistent across three measures of risks, and results are similar when interest coverage is used which indicates a high financial risk with low interest coverage. The results are in line with our expectation that illiquid firms may face higher risk and information asymmetry and find it more difficult and costly to finance through equity and hence have to adopt more leverage through secured debt, while high liquidity firms can reduce both total debt and secured debt. However, when firms have high business and financial risks, they have to rely more on secured debt as they face more expensive and limited access to the unsecured debt market. Consequently, business and financial risks can moderate the stock liquidity effect on firm leverage, which moderating role impacts the secured debt and unsecured debt in different ways.

4.7. Robustness check and reverse causality

Our baseline results suggest a negative relation between stock liquidity and firm leverage. Although we have used various controls commonly used in the literature for our regression analysis, it could still

Table 11
Logit regressions of zero leverage and low leverage on stock liquidity.

Panel A) 1990–2021	Zero leverage	Zero Leverage	Low Leverage	Low Leverage
	(-Spread)	(-Amihud)	(-Spread)	(-Amihud)
Liquidity	0.3526***	0.1621***	0.1785***	0.1829***
	(0.000)	(0.000)	(0.000)	(0.000)
LN(TA)	-1.1149***	-1.1352***	-1.0705***	-1.1737***
	(0.000)	(0.000)	(0.000)	(0.000)
PPE/TA	-0.9649***	-0.6999***	-1.0902***	-0.9437***
	(0.000)	(0.000)	(0.000)	(0.000)
ROA	1.3505***	1.4378***	1.4719***	1.5349***
	(0.000)	(0.000)	(0.000)	(0.000)
MTB	-0.1112***	-0.1069***	-0.0880***	-0.0888***
	(0.000)	(0.000)	(0.000)	(0.000)
D&A/TA	-3.7804***	-4.2251***	-2.3471***	-2.4241***
	(0.000)	(0.000)	(0.005)	(0.000)
R&D/Sales	1.1234***	1.1760***	1.1703***	1.1032***
	(0.000)	(0.000)	(0.000)	(0.000)
Dummy-R&D	-0.2208***	-0.2838***	-0.2217***	-0.2322***
	(0.001)	(0.000)	(0.000)	(0.000)
Dummy- Tax loss	-0.2144***	-0.2125***	-0.1672***	-0.1573***
	(0.000)	(0.000)	(0.000)	(0.000)
LN(Price)	0.2319***	0.2136***	0.4295***	0.3461***
	(0.000)	(0.000)	(0.000)	(0.000)
Year F.E.	Yes	Yes	Yes	Yes
Firm F.E.	Yes	Yes	Yes	Yes
Observations	51,260	51,260	82,029	82,029

Panel B) 1990–2006	Zero-leverage	Zero-leverage	Low-leverage	Low-leverage
	(-Spread)	(-Amihud)	(-Spread)	(-Amihud)
Liquidity	0.3912***	0.1106***	0.2280***	0.1359***
	(0.000)	(0.000)	(0.000)	(0.000)
Other controls	Yes	Yes	Yes	Yes
Year F.E.	Yes	Yes	Yes	Yes
Firm F.E.	Yes	Yes	Yes	Yes
Observations	21,561	21,561	35,419	35,419

Panel C) 2007–2021	Zero-leverage	Zero-leverage	Low-leverage	Low-leverage
	(-Spread)	(-Amihud)	(-Spread)	(-Amihud)
Liquidity	0.3046***	0.1905***	0.2076***	0.1632***
	(0.000)	(0.000)	(0.000)	(0.000)
Other controls	Yes	Yes	Yes	Yes
Year F.E.	Yes	Yes	Yes	Yes
Firm F.E.	Yes	Yes	Yes	Yes
Observations	18,495	18,495	30,106	30,106

This table presents the logit regression results of firm zero leverage and low leverage on stock liquidity and other control variables. Firm zero leverage is an indicator variable that takes one if a firm has no debt in the year or zero otherwise. Low leverage is an indicator variable that takes one if a firm has book leverage <5% in the year or zero otherwise. Panel A presents the regression results of the full sample data from 1990 to 2021. Panel B presents the regression results of the subsample from the year 1990 to 2006. Panel C presents the regression results of the subsample from the year 2007 to 2021. ***, **, * indicate significance at the 1%, 5%, and 10% levels. Variable definition details are listed in Appendix A.

be argued that our findings may be spurious due to the endogeneity issues. It is possible that firm leverage affects stock liquidity as leverage has an important effect on stock prices while the stock price is linked with stock liquidity; hence, reverse causality can be a potential problem for our analysis. Previous studies have used a lagged modeling specification to help alleviate the concerns associated with reverse causality (e.g. Adams, Mansi, & Nishikawa, 2009). The stock liquidity and other control variables in the regression model (1) were lagged one period compared to the dependent variable leverage, which can help to mitigate the endogeneity concern caused by stock liquidity being dependent on the leverage as it is less likely that leverage in year t affects the stock liquidity in year t-1.

To further address the concern of reverse causality, we use the decimalization of the U.S. stock exchanges in 2001 as an exogenous shock to liquidity, to check causality. We adopt the difference-in-difference regression model (2) to run the fixed effect regression on a subsample over a 6-year period (1998 to 2003). The results are displayed in Table 9. Following previous studies (Jiang et al., 2017; Shang, 2020), *High liquidity* is defined as indicator variables that take 1 if the stock liquidity in year t is in the top tercile of liquidity in the year and zero if it is in the bottom tercile. The treated group includes firms with stock liquidity in the top tercile of the liquidity in year t. The control group includes those firms in the bottom tercile of stock liquidity in the year. The *Post* is an indicator variable that takes 1 if the year is after the decimalization year 2001 and zero otherwise.

The results in Table 9 show that the coefficient of variable *Post x High liquidity* for -ln(spread) on the total debt and unsecured debt is −0.0081 and − 0.0134 at the 1% significance level. The coefficient of *Post x High liquidity* for -ln(Amihud) on the total debt (unsecured debt) is −0.0145 (−0.0178) and significant at the 1% level. In contrast, the coefficient of variable *Post x High liquidity* for -ln(−spread) and -ln(Amihud) is insignificant for secured debt. These results suggest that companies borrow less debt as liquidity improves following decimalization, but the use of secured debt is relatively stable. High stock liquidity is associated with lower equity financing costs, which reduces the need for debt borrowing, consistent with the equity preference view. Overall, these results indicate that reverse causality should not be a serious concern for this study.[2]

4.8. Accounting for endogeneity: entropy balancing regression estimates

To further address potential endogeneity concerns, we adopt the entropy balancing regression, a generalized multivariate propensity score weighting approach. It has been documented that the entropy balancing method greatly improves covariate balance when compared with propensity-score matching approaches, and entropy balancing technique reduces the risk that design choices could impact our results (e.g., Hainmueller, 2012, McMullin & Schonberger, 2020).

A typical propensity score matching approach using a set of observable firm characteristics (covariate) has the limitation that balance may not be achieved for each covariate across treatment and control firms. However, the two groups may be perfectly balanced along the propensity score. Furthermore, it may not always be possible to find an adequate match for all treated firms, resulting in the loss of some unmatched treated firms and control firms, which can lead to a sharp decrease in the size of the matched sample.

To overcome this problem, the entropy balancing approach weights the observations of the control group so that the mean and variance of all covariates are balanced across the treatment and control groups. This weighing scheme allows observations that would have been dropped to remain in the sample, albeit with less weight. At the same time, the entropy balancing method strives to maintain the weights as equal as possible (Hainmueller, 2012). The observations of the treated group and the adequately weighed observations of the control group can then be used in place of the original sample.

The mean, variance, and skewness of our entropy-balanced sample compared to the unmatched sample in Panel A of Table 10 show that we

[2] As an additional test, following Fang et al. (2009), we examine the two-year change in firm leverage, liquidity, and control variables surrounding decimalization (from 2000 to 2002), and the results are not tabulated but show the increase in stock liquidity leads to a significant decrease of firm leverage.

Table 12
Zero leverage and stock liquidity: moderating effect of financial constraint and risks.

Panel A) Zero leverage and financial constraint	Non-Dividend paying	Non-Dividend paying	Whited-Wu Index	Whited-Wu Index	Size-Age Index	Size-Age Index
	(-Spread)	(-Amihud)	(-Spread)	(-Amihud)	(-Spread)	(-Amihud)
Liquidity x FC	0.3377***	0.2707***	0.1740***	0.1506***	0.1614***	0.2390***
	(0.000)	(0.000)	(0.000)	(0.002)	(0.000)	(0.000)
Liquidity	0.2917***	0.1409***	0.3231***	0.1501***	0.3184***	0.1450***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
FC	-0.7104***	-0.5770***	-0.2252***	-0.1803***	-0.3941***	-0.3091***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Other controls	Yes	Yes	Yes	Yes	Yes	Yes
Year F.E.	Yes	Yes	Yes	Yes	Yes	Yes
Firm F.E.	Yes	Yes	Yes	Yes	Yes	Yes
Observations	51,260	51,260	51,260	51,260	51,260	51,260

Panel B) Zero leverage and risk	Zscore	Zscore	Stock beta	Stock beta	Interest coverage	Interest coverage
	(-Spread)	(-Amihud)	(-Spread)	(-Amihud)	(-Spread)	(-Amihud)
Liquidity x Risk	0.2224***	0.3566***	0.2625***	0.1492***	0.2123***	0.2588***
	(0.000)	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)
Liquidity	0.2946***	0.1298***	0.3170***	0.1515***	0.2661***	0.1090***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Risk	1.3254***	1.3495***	-0.1781***	-0.0698**	3.8398***	3.9285***
	(0.000)	(0.000)	(0.000)	(0.047)	(0.000)	(0.000)
Other controls	Yes	Yes	Yes	Yes	Yes	Yes
Year F.E.	Yes	Yes	Yes	Yes	Yes	Yes
Firm F.E.	Yes	Yes	Yes	Yes	Yes	Yes
Observations	51,260	51,260	51,260	51,260	51,260	51,260

Panel C) Low leverage and financial constraint	Non-Dividend paying	Non-Dividend paying	Whited-Wu Index	Whited-Wu Index	Size-Age Index	Size-Age Index
	(-Spread)	(-Amihud)	(-Spread)	(-Amihud)	(-Spread)	(-Amihud)
Liquidity x FC	0.4506***	0.1528***	0.1935***	0.0659*	0.2224***	0.0993**
	(0.000)	(0.000)	(0.000)	(0.075)	(0.000)	(0.024)
Liquidity	0.1222***	0.1716***	0.1521***	0.1880***	0.1497***	0.1773***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
FC	-0.4174***	-0.2394***	-0.1422***	0.0557	-0.1668***	0.0271
	(0.000)	(0.000)	(0.000)	(0.126)	(0.000)	(0.530)
Other controls	Yes	Yes	Yes	Yes	Yes	Yes
Year F.E.	Yes	Yes	Yes	Yes	Yes	Yes
Firm F.E.	Yes	Yes	Yes	Yes	Yes	Yes
Observations	82,029	82,029	82,029	82,029	82,029	82,029

Panel D) Low leverage and risk	Zscore	Zscore	Stock beta	Stock beta	Interest coverage	Interest coverage
	(-Spread)	(-Amihud)	(-Spread)	(-Amihud)	(-Spread)	(-Amihud)
Liquidity x Risk	0.2347***	0.2765***	0.3127***	0.0979***	0.2637***	0.0802**
	(0.000)	(0.000)	(0.000)	(0.006)	(0.000)	(0.032)
Liquidity	0.1011***	0.1482***	0.1332***	0.1718***	0.0937***	0.1341***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Risk	1.9674***	2.0464***	-0.0902***	0.0365	1.5854***	1.6760***
	(0.000)	(0.000)	(0.004)	(0.193)	(0.000)	(0.000)
Other controls	Yes	Yes	Yes	Yes	Yes	Yes
Year F.E.	Yes	Yes	Yes	Yes	Yes	Yes
Firm F.E.	Yes	Yes	Yes	Yes	Yes	Yes
Observations	82,029	82,029	82,029	82,029	82,029	82,029

This table presents the logit regression results for the moderating effect of financial constraints and risks for the stock liquidity effect on the zero leverage and low leverage. Firm zero leverage is an indicator variable that takes one if a firm has no debt in the year or zero otherwise. Low leverage is an indicator variable that takes one if a firm has book leverage <5% in the year or zero otherwise. Panel A and B present the logit regression results of zero leverage from 1990 to 2021. Panel C and D present the logit regression results of low leverage from the year 1990 to 2021. ***, **, * indicate significance at the 1%, 5%, and 10% levels. Variable definition details are listed in Appendix A.

achieve a desirable covariate balance through matching. Using the entropy balancing approach, we combine the matched pairs into a pooled sample to perform the regression analysis. The results of the entropy-balanced sample are reported in Panel B. The coefficients on both liquidity measures remain significantly negative for total debt and secured debt but become much less significant for unsecured debt, indicating that liquid firms have lower leverage and borrow less secured debt. These results confirm that our baseline regression results are robust to control for endogeneity.[3]

4.9. Logit regression analyses: propensity for zero and low leverage

Results so far confirm that firms with high stock liquidity borrow less debt than those with low stock liquidity. Next, we test the zero-leverage puzzle through the logit regression on the firm's propensity to borrow zero or low leverage (book leverage<5%). Following previous literature (Dang, 2013; Devos et al., 2012; Strebulaev & Yang, 2013), we use the indicator variables of zero leverage and low leverage (total debt/total assets<5%) as the dependent variables and adopt similar control variables to model (1). As shown in Table 11,the coefficients for both liquidity measures are significant at 1% levels. Columns (1) to (2) of Panel A for the full sample suggest that strong stock liquidity is associated with a higher propensity of zero leverage, and Columns (3) to (4) show that liquid firms are more likely to borrow low leverage (<5%). For example, firms with high stock liquidity as measured by -ln(Amihud) are 16.21% more likely to borrow zero debt and have an 18.29% higher propensity to adopt <5% leverage. Results with bid-ask spread show a similar pattern that high stock liquidity firms are much more likely to use zero debt or low leverage.

These results support hypothesis 4B, which is consistent with the equity preference view that companies with high stock liquidity borrow less debt and are also more likely to have zero leverage. The results are not in line with hypothesis 4A based on the financial constraint or financial flexibility view that firms borrow zero leverage due to limited access to capital markets or firms use little debt to maintain their financial flexibility and avoid underinvestment incentive. Our results add to the literature on the zero-leverage puzzle and suggest that the increasing stock liquidity and the lower cost of financing in the equity market may help explain why so many companies continue using zero debt or very low leverage despite the tax shield benefits of debt borrowing.

Next, we perform a sub-period analysis for logit regression on zero leverage and low leverage. Results in Panel B and C of Table 11 show a similar pattern pre- and post-GFC that firms are more likely to borrow zero debt or low leverage when their stock liquidity improves. This pattern supports the argument that when firms have low stock liquidity and thus are more likely to face financial constraints, they have to rely more on debt financing as they find debt is cheaper and more accessible. As the stock liquidity improves, they tend to issue more equity to replace debt financing and thus are more likely to borrow low leverage or zero debt in their capital structure.

We next explore the moderating effect of financial constraint and risk on the stock liquidity effect on zero leverage and low leverage. First, we augment the logit regression of zero leverage with the interaction variable of the liquidity variable with three measures of financial constraints: non-dividend paying dummy, Whited-Wu index, and SA index. Regression results reported in Panel A of Table 12 show the moderating effect of financial constraint in the logit regression of zero leverage, and the coefficient of the interaction term is significantly positive across three measures of financial constraints. For example, the interaction variable of low spread (low Amihud) and high Whited-Wu index has a positive coefficient of 0.1740 (0.1506) at a 1% significance level. Similarly, the interaction of low spread (low Amihud) and non-dividend paying dummy is significantly positive at 0.3377 (0.2707). The moderating effect tests confirm our expectation that the positive stock liquidity effect on zero leverage is more pronounced for financially constrained companies.

Next, we augment the logit regression of zero leverage with the interaction variable of the liquidity variable with three measures of risk: Altman *Z*-score, stock beta, and interest coverage. Results in Panel B indicate that the interaction term coefficient is significantly positive across three measures of risks. For example, the interaction of low spread and high Z-score (stock beta) has a significantly positive coefficient of 0.2224 (0.2625). Similarly, the interaction of low spread (low Amihud measure) and interest coverage is significantly positive at 0.2123 (0.2588). These results suggest that the impact of stock liquidity on zero leverage is stronger for firms with higher risks.

We also perform the moderating effect of financial constraint and risks in the logit regression of low leverage. Results reported in Panel C and D of Table 12 report the results on the moderating effect of low leverage and suggest that the positive stock liquidity effect on low leverage dummy is more pronounced when companies are more financially constrained or are subject to higher business and financial risks.

5. Conclusion

Stock liquidity has become increasingly important for those involved in capital markets and also receives more attentions in corporate finance research. While previous studies have examined the effect of stock liquidity on total debt and treated corporate leverage as uniform, this paper is the first study to examine the heterogenous liquidity effects on secured and unsecured debt as well as the propensity of zero leverage. Using a large sample of U.S. firms during 1990–2021, we investigate the variation of stock liquidity effects on leverage at different debt security levels and time periods. Our results indicate that stock liquidity has negative impacts on total leverage and secured debt, while such liquidity effects become much weaker for unsecured debt. This is consistent with the argument that companies with low stock liquidity are more likely to employ secured debt as a governance mechanism to reduce agency problems or a signaling tool to indicate low risk to the market, while strong stock liquidity substitutes such benefits of secured debt. Consistent with this proposition, our results confirm that firms issue more unsecured debt to replace secured debt as their stock liquidity improves. We then test the zero-leverage puzzle and report the first evidence that firms with high stock liquidity are more likely to borrow zero debt or low leverage (<5%) in their capital structure, consistent with the equity preference view.

This study further explores the moderating role of financial constraint and risks on the stock liquidity effect on leverage. We interact the stock liquidity with various measures of financial constraint and risks, and the augmented regression results demonstrate that the liquidity effects on leverage are more pronounced for financially constrained and risky firms. Our results are robust to various measures of firm leverage and control for endogeneity.

In addition, the sub-period analyses show that stock liquidity effects on leverage become weaker post-GFC and even turn positive for unsecured debt. We also directly test the moderating effect of the GFC and the Covid-19 crisis, and the results indicate that the GFC alleviates the negative stock liquidity effect. This result is justified by the higher risk aversion of investors and more stringent capital requirements of banks post-GFC, which make it more difficult and costly for illiquid firms to borrow unsecured debt. Therefore, illiquid firms still use more debt

[3] As further robustness tests, we augment the regression model (1) with additional controls, including firm age, financial constraints (dividend-paying dummy and S&P debt rating), macroeconomic variables (3-month treasury rate, exchange rate, state fixed effect), and the results are not tabulated but confirm the baseline regression results are robust. We use alternative empirical approaches such as Poisson regression model with the same controls as model (1) and the main regression results of the relationship between stock liquidity and firm leverage continue holds.

financing than high stock liquidity firms post-GFC, but they rely more on secured debt to reduce borrowing costs and mitigate agency problems, while high liquidity firms borrow more unsecured debt to avoid the additional cost of collaterals. The analysis of the moderating effect of the Covid-19 pandemic shows that the high stock liquidity reduces total leverage and unsecured debt after the health crisis while having no significant effect on secured debt borrowing. Such a pattern may be explained by the government policy strengthening the banking sector and financial markets after the GFC, which policy enables businesses to maintain the access to bank financing and capital markets during Covid-19 period and allows firms with both high and low stock liquidity to be financed via secured bank debt and thus mitigate the increasing costs of unsecured debt after the pandemic.

This study sheds new light on the literature to explain firms' conservative financial policy in the zero-leverage puzzle and provides the first evidence that stock liquidity has an explanatory power to the firm's choice between secured debt and unsecured debt. Overall, our results suggest that stock liquidity is an essential determinant of firm leverage, and such liquidity effect is reflected differently with secured debt compared to unsecured debt. Our empirical findings demonstrate the important impacts of stock liquidity on corporate capital structure and financial flexibility, especially during the crisis period. Moreover, as highlighted in the previous literature, this study confirms the importance of considering the heterogeneity of firm leverage with various types of debt structure in the analysis of corporate capital structure.

Such heterogeneity of firm leverage in the context of equity liquidity provides several policy implications. When creating regulatory frameworks, policy makers should consider the impacts of stock liquidity and financial market development on corporate financial policy. This can be particularly important during the crisis period with more economic uncertainty and market volatility, as strong stock liquidity can allow companies to choose among various financing sources and avoid rising cost of capital for more financial flexibility and less volatile performance. Given that companies with low stock liquidity experience more financial difficulties during crisis, policy makers should consider taking specific measures to help these contrained firms, including opening up alternative financing options or implementing short-term assistance programs. Government response and policy after 2009 prove to be effective in helping both banking sector and financial markets maintain a healthier situation compared to GFC periods. This allows many firms to seek funding supply through bank debts or capital markets during the pandemic, which provide key assistance to these businesses and enable them to avoid the disruption to their business operation due to the cashflow shortfalls in the health crisis.

From the investment perspective, investors need to take into account the possible effects of stock liquidity on a firm's financial policy. This might assist investor in matching investments and portfolio risk well with their financial objectives and risk tolerance, and guiding their risk management strategies. By heeding these implications of stock liquidity for corporate financial policy, policy makers and investors can make more informed decisions in the dynamic landscape of financial markets and manage a more smooth transition during crisis periods.

Data availability

Data will be made available on request.

Appendix A

Variable definitions.

Variable	Source	Definition
Total debt/total assets	Compustat	(Long-term debt and debt in current liabilities)/total assets
Secured debt/total assets	Compustat	Secured debt / total assets
Unsecured debt/total assets	Compustat	(Total debt-secured debt)/total assets
Secured debt/total debt	Compustat	Secured debt / Total debt
Secured debt/total liability	Compustat	Secured debt/Total liability
Zero leverage	Compustat	Total debt is zero in year t
Low leverage	Compustat	Total debt/total assets <5% in year t
Bid-ask spread	CRSP	Annual average of daily relative bid-ask spread: (ask–bid)/[(ask+bid)/2]
Amihud measure	CRSP	Annual average of absolute daily stock return divided by dollar trading volume (as per Amihud (2002)).
Total assets	Compustat	Natural log of (total assets)
MTB	Compustat	(Stock price × shares outstanding)/book equity
Return on assets	Compustat	Net income/ total assets
PPE/total assets	Compustat	Property, plant, and equipment (net)/ total assets
R&D/sales	Compustat	R&D expense / sales
D&A / Total Assets	Compustat	Depreciation and amortization expense / total assets
LN (Price)	CRSP	The natural log of the stock price is the average daily trading price during the fiscal year.
Dummy-R&D	Compustat	The indicator variable equals one if a firm has missing or zero R&D expense in year t and zero otherwise.
Dummy-Non dividend paying	Compustat	The indicator variable equals one if a firm pay no dividend in year t and zero otherwise.
Dummy-Tax loss	Compustat	The indicator variable equals one if a firm makes a net operating loss in year t and zero otherwise.
Whited-Wu Index	Compustat	Following Whited and Wu (2006), WW Index = 0.091 * cash flow/total assets- 0.062 * dividend dummy +0.021 * long-term debt/total assets - 0.044 * log(total assets) + 0.102 * industry sales growth - 0.035 * firm sales growth
Size-Age Index	Compustat	Following Hadlock and Pierce (2010), SA index = [−0.737*log(Total Assets)] + [0.043*log(Total Assets)^2]-(0.040*Age)
Altman *Z*-Score	Compustat	Following Altman (1968), Z-Score = 1.2* (working capital / total assets) + 1.4*(retained earnings / total assets) + 3.3*(EBIT/ total assets) + 0.6*(market value of equity / total liabilities) + 1.0*(sales / total assets)
Stock beta	CRSP	Stock beta is estimated using the regression of the weekly data of stock return and S&P 500 in the previous 12 months.
Interest coverage	Compustat	Interest expenses/EBIT

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