How Does Stock Market Liquidity Affect the Willingness to Repurchase?[1]

Niklas Lyttkens* Alexandra Tham**

Master's Thesis
Department of Finance, Stockholm School of Economics
May 19, 2014

Tutor: Ulf von Lilienfeld-Toal

Abstract

In this paper we investigate what impact liquidity has on the propensity to repurchase equity. We suggest there is a negative impact of increased liquidity on management's propensity to repurchase. Using decimalisation as an exogenous liquidity shock, we analyse open market repurchase announcements for all stocks in the CRSP database between 1993 and 2013. Using decimalisation as (1) a liquidity proxy in a difference-in-difference OLS regression and (2) as an instrument for the Amihud and FHT liquidity proxies in a 2SLS regression, we find the impact to be negative, contradicting the findings of previous research. Our results are robust to excluding the potential impact of the global financial crisis in 2008. However, controlling for prior level of liquidity, we get results indicating that we cannot reject that firms with different prior liquidity levels react differently on liquidity improvements.

[1] We especially thank our tutor Ulf von Lilienfeld-Toal, Assistant Professor at the Department of Finance at the Stockholm School of Economics, for invaluable comments and generous support throughout the writing of this thesis. We also thank Björn Beckman and Markus Ederwall for helpful remarks in the final stage. Naturally, all mistakes are entirely our own.

*niklas.lyttkens@alumni.hhs.se
**alexandra.tham@alumni.hhs.se

Table of Contents

1 Introduction

How does stock market liquidity affect the propensity to repurchase? The act of returning capital to shareholders through stock repurchases has exploded during the last decades. The number of cases of repurchases and the dollar value of these have grown 15 and 27 percent annually between 1980 and 1999. This growth has been heavily fuelled by a burst of use of open market repurchase programs[2] (Grullon and Ikenberry 2000).

Moreover, stock repurchases represent significant events. Following a stock repurchase announcement, empirical studies have shown that analysts positively revise their forecasts of earnings per share (Hertzel and Jain 1991), stock prices increase (cf. Vermaelen (1981)) and abnormal returns are reported (cf. Masulis (1980)).

There are several theories that explain management's decision to return capital to shareholders via a stock repurchase. A theory that has been long prevailing states that management makes a repurchase in order to provide a credible signal of its anticipation of better-than-expected future free cash flows (cf. Vermaelen (1981) and Dann et al. (1991)). Another model says that management, through stock repurchases, signals its disagreement with the market's evaluation and pricing of existing public information (cf. Ikenberry et al. (1995)). Other theories state that repurchases are performed as means of minimising agency costs of free cash flow and letting investors enjoy tax gains from dividend substitution (cf. Lie (2000) and Grullon and Michaely (2002)).

The purpose of this paper is to look into the question of whether market microstructure affects corporate governance; more specifically whether market liquidity affects corporate pay-out policies with respect to stock repurchase announcements. Looking deeper into what affects these decisions will facilitate understanding historical and future patterns and trends in stock repurchases. This paper complements the literature in three ways. First, we note that previous research has focused on the impact of stock repurchases on stock market liquidity (cf. Barclay and Smith (1988), Singh et al. (1994), Miller and McConnell (1995) and Franz et al. (1995)), while few papers have looked on the reverse relationship. Second, we use a large dataset, enabling inference for the entire U.S. market. Third, liquidity and governance may be determined jointly via unobservable characteristics of a firm, or the causality may even go from governance to liquidity. In this paper, we address this challenge by using decimalisation as a natural experiment in order to provide an exogenous shock to stock market liquidity.

In order to examine this relationship between liquidity and repurchases, we analyse open market repurchase announcements for all the stocks in the CRSP (Center for Research of Securities Prices of the University of Chicago) database between 1993 and 2013. First, using the liquidity proxy Amihud (2002), previously used by Brockman et al. (2008), along with the

[2] Broadly categorized, repurchases can be made in three ways (1) on the open market, (2) as tender offers or (3) through Dutch auctions. Among these, open market repurchases has been the most common in the U.S. Between the years 1980 and 1999, the open market repurchases represented around 91 percent of total value of all repurchase announcements (Grullon and Ikenberry 2000). Open market repurchases are performed by the firm, acting like any other investor, on the stock market. Hence, the firm does not know at the announcing moment what the actual price it will pay for the shares will be. Tender offer repurchases means that the firm offers to buy back a certain number of shares at a certain fixed price, often around 20 percent above market price. Individual stockholders then choose to either sell or keep their shares. In a Dutch auction, a series of prices at which the firm can consider buying back shares at is stated by the firm. Shareholders then get to submit information on which quantity of shares that they are willing to sell at each price. With this information at hand, the firm aggregates the quotes and choses the lowest price at which it can repurchase the specified amount of shares. The same price is then offered to all tendering shareholders, Kalay and Lemmon (2008, p. 44-5).

relatively new proxy FHT (Fong et al. 2013), we find a positive impact of increased liquidity on the propensity to make a repurchase announcement. This is in line with the results of Brockman et al. (2008). Second, using the exogenous liquidity shock inherent in the introduction of decimalisation in 2001 in a difference-in-difference regression, we find increased liquidity to negatively impact the propensity to make a repurchase announcement, contradicting previous research. Third, using decimalisation as an instrumental variable for the liquidity proxies Amihud and FHT respectively, we find a similar negative impact. In all our regressions, we control for firm fixed effects and year fixed effects.[3]

We further check the robustness of the results by conducting two subsample analysis: (1) analysing the years 1994-2007 and hence excluding the potential impact of the financial crisis in 2008 and (2) analysing subsamples based on prior liquidity levels, as previous research have indicated that stocks with low liquidity should be particularly sensitive to changes in liquidity (cf. Brav et al. 2005). We also check the robustness of our results by using our subsamples constructed for the difference-in-difference estimations in the plain, initial, regressions of repurchase announcements on Amihud and FHT respectively. Performing these robustness checks, our results still indicate that the overall trend is that increased liquidity negatively impacts the propensity to make a repurchase announcement. Finally, we find indications of the impact of a liquidity increase to differ between stocks with low versus high initial liquidity. Our general trend of a negative impact of liquidity on the propensity to repurchase is most prominently reflected in stocks with high initial level of liquidity. However, in line with Brav et al. (2005) we find a pattern indicating that firms with low initial liquidity experience a positive impact of liquidity on willingness to make a repurchase announcement.

The organisation of the paper is as the following: Section 2 highlights previous research on reasons for firms to repurchase stock and the connection between stock market liquidity and corporate governance. Section 3 presents the liquidity measures used in this paper, the econometric framework applied and robustness checks and controls performed. Section 4 discusses our data sample. Section 5 exhibits our empirical results and Section 6 concludes.

2 Previous Research

Reasons for announcing a repurchase program

Firm management is typically better informed on the firm-value than external shareholders. In cases when management privately possesses information rendering in positive expectations of future earnings, this information asymmetry will cause the stock price to be below its intrinsic value. According to the cash flow signalling theory, management provides a credible signal of their private future earnings expectations if they are willing to accept cash outflows today (e.g. through repurchases or dividends) as they then will need to rely on future free cash flows financing the capital needs of tomorrow (Miller and Rock 1985). Hence, the theory indicates that repurchasing firms should experience increases in future free cash flows and earnings. In line with this theory, Vermaelen (1981) find abnormal increases in earnings

[3] We further use cluster robust standard error estimators in all our regressions to account for autocorrelation and within-firm effects. Further, we correct for heteroskedasticity in our standard OLS residuals, prevailing in most of our regressions since our dependent variable is binary.

per share after tender offer repurchase announcements. Dann et al. (1991) find positive earnings surprises along with a reduction in systematic risk of equity following tender offers.

Apart from the above mentioned private expectations of future free cash flows, it is probable that management has the best answer with regards to estimating the true value of the firm, based on information publicly available today as management has a strong understanding of the company and industry. The undervaluation theory states that management is, when making a repurchase, signalling its disagreement with the current market valuation of the firm, based on public information. The theory can also be reflected in real statements from management in relation to announcing repurchase programs, such as the stock being "a good buy". Focusing on this mispricing, Ikenberry et al. (1995) investigate whether value stocks (high book-to-market ratios) are more heavily represented in open market repurchase programs than growth stocks (low book-to-market ratios). They find no evidence of such a relationship; instead a relatively even distribution is reported. To the extent that book-to-market ratios reflect undervaluation, no evidence of the undervaluation theory is thus found. Yet, the authors report high compounded excess returns for value stocks, whereas little proof of undervaluation for growth stocks is shown. Hence, if markets are efficient, management appears to indicate an undervaluation at least in some cases.

Other theories are based on moral hazard; the separation of ownership and control in a firm enables management, as agent, to behave opportunistically at the expense of the shareholders, the principal. For some managers, the benefits of managing a larger and more influential firm outweigh the benefits of having satisfied shareholders. Hence, some managers sacrifice value and profitability and allocate capital to unprofitable projects, trying to achieve growth and expand the firm. The agency costs of free cash flow theory reflects the costs stemming from these conflicting interests (cf. Jensen and Meckling (1976)). The theory suggests that announcements of repurchase programs are likely to be good news as they reduce the possibility for management to use capital in empire building. Hence, shareholders can allocate the distributed capital more effectively as they have a broader spectrum of investment opportunities outside the firm. Thus, given that the repurchases do not jeopardise the firm's capacity to fund promising future investment opportunities, a repurchase is assumed to be good.

Supporting empirical evidence of the theory has also been put forward in the literature. Lie (2000) documents that firms that announce repurchase tender offers have higher cash levels compared to industry peers. He also finds the market reaction to these announcements to be positively correlated to the excess cash amount in the announcing firm. Grullon and Michaely (2004) find that the market reaction to open market share repurchases is negatively correlated with the operating return on investment, indicating that the market has a positive reaction to repurchase programs that are announced by companies with declining opportunities to invest. They further find that firms making open market announcements also demonstrate a subsequent reduction in capital expenditure.

Another dubious reason affecting management's decision to repurchase shares can be linked to the existence of management stock options. By repurchasing equity, the firm distributes cash without diluting the per-share value of the stock, as opposed to what would be the case if the firm distributed cash through dividends. Hence, as the strike price of the options often lack dividend-protection (i.e. being reduced in order to mirror increases in pay-outs), managers holding a substantial amount of options have clear incentives to hinder increased dividends. Instead, they would prefer the cash to be distributed via share repurchases, maintaining value per share, thus keeping the value of the stock options. Jolls (1996) finds that the increasing distribution of executive stock options represents a major factor, studying the increase in repurchase activities in the 1990s.

The tax treatment of investor's income is a factor that distinguishes dividends and stock repurchases as means of returning capital to shareholders. In share repurchases, investors choosing to sell their shares encounter a tax on capital gains. On the other hand, investors choosing to keep their shares get a pro-rata increase in their firm-ownership, but do not pay any immediate tax bill. When it comes to dividend pay-outs, investors incur income tax on these. Historically, there has always been a preference for capital gains, even though the tax benefits of capital gains over ordinary income have fluctuated over time (Grullon and Ikenberry 2000).

Grullon and Michaely (2002) find that while the dividend pay-out ratio among U.S. firms has declined since the middle of the 1980s, total pay-out ratio has remained more or less the same, indicating that repurchases have been a substitute for dividends. Also, considering that investors usually have the option to postpone the realization of taxes on capital gains, the preference of these have been even larger (cf. Protopapadakis (1983), who report present values of capital tax liability to be circa 7 percent of the realized gain). Research has thus suggested that the aggregate expenditures on stock repurchases are positively correlated with the relative tax benefit of capital gains (cf. Lie and Lie (1999) and Grullon and Michaely (2002)). Grullon and Michaely (2002) further find that the stock market reaction on dividend cuts, which tends to be strongly negative for an average firm, is not statistically different from zero if the firm recently has repurchased shares. Along with this, they also find evidence of the market reaction on a repurchase announcement to be stronger when expected tax benefits from dividend substitution are higher.

Apart from the tax benefits, management may also consider other benefits of distributing cash through share repurchases as opposed to dividends. Regular cash dividends tend to be funded by recurring earnings and are hence expected to be rather continuous in nature. Repurchases are on the other hand commonly accepted to have a more non-recurring character and hence entail an inherent flexibility. In line with this reasoning, Jagannathan et al. (2000) find that firms that repurchase equity have more volatile earnings than firms that distribute cash through dividends. Further, the discretion over the timing of repurchases, enables management to combine the cash distribution with cashing in on undervaluation.

Capital structure adjustment is another reason that has been put forward when it comes to explaining why management initiates a stock repurchase program. When it comes to tender offers, this may be an in important motive as firms typically buy a large fraction of the shares outstanding in such a transaction, clearly increasing the leverage ratio. When it comes to open market repurchase programs, this motive is less convincing as open market repurchase programs typically are much smaller in scope. These programs also take several years to complete (Grullon and Ikenberry 2000).

Liquidity and corporate governance

Stock market liquidity conceptually measures the cost of trading a stock. This cost can be calculated in relation to either the price of a stock, or to the volume of stocks being traded.

Fong et al. (2013) empirically compare the prevailing liquidity proxies in these two categories along with introducing a new measure, FHT. They find the FHT measure to strongly dominate the prevailing cost-to-price (percent cost) liquidity proxies, whereas the measures FHT Impact (Fong et al., 2013), LOT Mixed Impact, Zeroes Impact (Lesmond et al., 1999) and AMIHUD (Amihud, 2002) dominate the cost-to-volume liquidity proxies (see below for more detailed description of FHT and AMIHUD).

Edmans et al. (2013) apply Fong et al.'s (2013) conclusions in their study of liquidity on corporate governance. Looking at the impact of stock market liquidity on blockholder governance, Edmans et al. (2013) use FHT and AMIHUD as proxies for the two liquidity categories in their analysis. Further, they use the introduction of the decimalisation in the U.S. in 2001 (by which the minimum price movement of a stock went from 1/16 USD to 1/100 USD, cf. below) as a natural experiment and an external shock to liquidity in order to identify causal effects from liquidity on blockholder governance.

Brockman et al. (2008) use the liquidity measures turnover,[4] quoted bid-ask spread,[5] effective bid-ask spread,[6] depth,[7] quoted spreads/depth,[8] trade size[9] along with AMIHUD and modified AMIHUD when looking on the impact of stock market liquidity on corporate governance in managerial pay-out decisions. Using data from the CRSP, Compustat and TAQ databases, they analyse firm pay-out data from 1983 to 2006, excluding firms in the utilities and financial sectors. In their analysis, they control for operating cash flow/assets, non-operating cash flow/assets, standard deviation of operating cash flow, total assets, book leverage, stock price return, market-to-book along with age of firm. They find that firms initiating a repurchase are significantly more liquid than non-initiating firms. They moreover find a positive relation between a firm's stock liquidity in the current year and the decision to initiate a repurchase in the following year, i.e. the more liquid a firm's stock is in year t, the more probable it is that the firm will announce a repurchase in year $t + 1$. The authors further find that the size of the repurchase (repurchase scaled by assets) increases along with the market liquidity of the firm's stock.

The impact of liquidity on repurchases has to some extent been analysed prior to the study by Brockman et al. (2008). Barclay and Smith (1988) argue that there exists a specific cost associated with open market repurchase programs. This cost stems from the fact that the repurchase program increases the trading activity by better-informed managers in the secondary market. Thus, as market specialists still want to earn a competitive return on their activities, the more trading by better informed managers, the more the bid-ask-spreads will widen. The increased bid-ask spreads will in turn reduce the liquidity of the stock.

The more informed investors trading will also lead to increased required rate of return, reduced corporate investments and decreased market value of the firm. Hence, management is reluctant to repurchase shares when liquidity is low because their trading activity could widen the bid-ask spreads and thus also widen transaction costs. Using data from 244 open

[4] Monthly trading volume divided by total shares outstanding.

[5] Daily time-weighted bid–ask spread divided by the spread midpoint.

[6] Two times the daily trade size-weighted difference between the transaction price and spread midpoint divided by the spread midpoint.

[7] Daily time-weighted number of shares available at the highest bid and lowest ask prices divided by two.

[8] Daily quoted spread divided by the daily depth.

[9] Daily share volume divided by the daily number of trades.

market repurchase announcements made by 198 firms listed on the NYSE between 1970 and 1978, the authors find evidence supporting their hypothesis of widening bid-ask spreads as firms engage in a repurchase. The results of increased bid-ask spreads following a repurchase reported by Barclay and Smith (1988) have however been challenged. Miller and McConnell (1995) find no evidence of increased bid-ask spreads following repurchase announcements. Further, a number of studies have actually reported declining bid-ask spreads following repurchase announcements (cf. Wiggins (1994), Singh et al. (1994) and Franz et al. (1995)).

Further, Brav et al. (2005) analyse responses of a survey conducted with 384 financial executives along with interviews conducted with 23 top executives (treasurers, CFOs and CEOs). Analysing the survey responses for the 167 repurchasers in the sample, they find that one half of the financial executives believe the liquidity of their stock to be an important or very important factor affecting the repurchase decision. Further, the interview responses clarify that the executives believe that a reduction in liquidity can hurt their stock price as the demand for a stock decreases if investors believe that their trading would impact the stock price. Hence, a firm would limit repurchases if they feel that this activity would reduce the stock liquidity below some critical level.

The somewhat mixed implications on the impact of stock market liquidity on stock repurchases suggest a further analysis of the relationship to be fruitful. With an analysis of a dataset containing all firms in the CRSP database[10] between 1993 and 2013, this paper seeks to fill this gap in research.

3 Methodology

Proxies for liquidity

The illiquidity of a stock basically measures the cost that a buyer or seller incurs when transacting a stock beyond or below its intrinsic value. As previously mentioned, prior research has concluded that there are two main categories measuring these costs (1) cost-to-volume and (2) cost-to-price (percent-cost) proxies (cf. Fong et al. (2013)).

The cost-per-volume liquidity proxies represent the price concession per currency unit of volume. This type of proxy is useful when assessing the marginal cost of transacting an additional unit of a larger trade. Fong et al. (2013) argue that the illiquidity proxy developed by Amihud (2002) is one of the best proxies in the category cost-to-volume, being highly correlated to a cost-per-volume benchmark.[11] However, the authors do not find the measure to capture the level of this. The Amihud (2002) proxy is defined as

$$AMIHUD_{i,t} = \frac{1}{D_{i,t}} * \sum_{d=1}^{D} \frac{|RET_{i,d}|}{|VOLUME_{i,d}|}, \quad (1)$$

where $RET_{i,d}$ represents the returns and $VOLUME_{i,d}$ represents the dollar trading volume on day d for firm i, whereas $D_{i,t}$ represents the number of trading days for firm i in the year

[10] I.e. all stocks listed on the ARCA, AMEX, Nasdaq or NYSE.

[11] The benchmark at which they evaluate against is the slope of the price function.

t. $AMIHUD_{i,t}$ thus measures the daily ratio of the absolute value of return-to-stock dollar volume, averaged over the year t for firm i. Many research papers have used this illiquidity proxy (cf. Bortolotti et al. (2007), Brockman et al. (2008) and Edmans et al. 2013).

The second liquidity category, the cost-to-price proxies, correspond to the price concession of executing a trade. This type of proxy is useful when assessing the transaction cost of making a small trade (Fong et al. 2013). Within the category cost-to-price (percent-cost) proxies, Fong et al. (2013) find the illiquidity proxy FHT to be the dominating proxy. It is shown to be highly correlated with four other percent price benchmarks,[12] along with capturing the level of two of these. The FHT proxy is basically a simplification of the LOT-model (Lesmond et al. 1999). It is based on two features of transaction costs: the proportion of zero returns along with return volatility. The idea behind zero returns is based on the following model in which the true and unobserved return for stock i on day d is assumed to be $R^*_{i,d} = \beta_i * R_{m,d} + \varepsilon_{i,d}$,[13] whereas the actual return R on an individual stock is

$$R = R^* + \frac{S}{2} \quad \text{when} \quad R^* < -S/2,$$
$$R = 0 \quad \text{when} \quad -S/2 < R^* < S/2 \tag{2}$$

and

$$R = R^* - \frac{S}{2} \quad \text{when} \quad S/2 < R^*.$$

In the equation above, S represents the round-trip transaction cost. The percent transaction cost of selling a security is measured as $\alpha_{i1} = -\frac{S}{2}$, whereas the percent transaction cost of buying a security is measured by $\alpha_{i2} = \frac{S}{2}$. From the model can be concluded that zero return arises when the transaction costs are too large. Using this observation, the FHT proxy is calculated as

$$FHT_{i,t} = 2 * \sigma_{i,t} * N^{-1}\left(\frac{1+Zeros_{i,t}}{2}\right), \tag{3}$$

in which the variable $Zeros_{i,t}$ represent the proportion of days with zero returns over the period t for stock i, $\sigma_{i,t}$ represents the standard deviation of the returns of stock i, calculated over the time period t and N^{-1} represents the inverse of the cumulative normal standard distribution. The full derivation of this the FHT proxy can be seen in Appendix A.

As a further liquidity proxy, we use decimalisation as an exogenous liquidity shock. In 2001, the U.S. stock markets AMEX, NASDAQ and NYSE introduced a change with respect to what minimum tick size securities were allowed to trade in.[14] Going from 1/16 of a USD to 1/100 of a USD, the introduction of the decimalisation can be argued to have affected the liquidity of the securities with low prices, enabling a smoother price movement. It has also been shown that bid-ask spreads substantially declined following the introduction

[12] Percent effective spread, percent quoted spread, percent realized spread, and percent price impact

[13] In this formula, β_i represents the sensitivity of stock i to the return of the market, $R_{m,d}$ on day d and $\varepsilon_{i,d}$ represents the public information shock on day d. This shock assumed to be normally distributed and has a variance of σ_i and a mean of zero.

[14] By January 29th 2001 the majority of all stocks on AMEX, NASDAQ and NYSE were allowed to be traded with this reduced tick size. The last stocks were decimalised on April 9th 2001.

(cf. Bessembinder (2003) and Furfine (2003)). The introduction of decimalisation clearly functioned as a natural experiment, as it affected liquidity with an exogenous shock without having any impact on repurchase announcements, apart from its indirect impact through the shock on liquidity. It is thus straightforward to use this variable both as a liquidity proxy as well as an instrumental variable for the liquidity proxies when investigating how liquidity impacts repurchase decisions (cf. the empirical analysis in Appendix B and Appendix C).

Empirical framework

The empirical framework that we apply when investigating the impact of stock liquidity on stock repurchase announcements is to first evaluate whether liquidity, measured through the conventional illiquidity proxy, $AMIHUD$ (2002) and the new illiquidity proxy FHT (Fong et al. 2013), has the same impact on repurchase announcements as previous research have indicated. Hence, we perform regressions (4) and (5) below where LIQ_{AM} and LIQ_{FHT} represent liquidity proxies.[15] In the same manner as Brockman et al. (2008), the liquidity proxies are lagged one year in order to make sure that only the liquidity *before* the announcement is taken into account, as a reversed impact between repurchase announcement on stock liquidity otherwise could be captured (cf. studies on the effect of repurchases on liquidity discussed above). Thus, we perform the linear probability regression models

$$REP_{i,t} = \alpha_{i,t} + \beta_1 LIQ_{AM_{i,t-1}} + \boldsymbol{\rho Y_t} + \boldsymbol{\vartheta X_i} + \varepsilon_{i,t}{}^{16} \quad (4)$$

and

$$REP_{i,t} = \alpha_{i,t} + \beta_1 LIQ_{FHT_{i,t-1}} + \boldsymbol{\rho Y_t} + \boldsymbol{\vartheta X_i} + \varepsilon_{i,t}, \quad (5)$$

in which year and firm fixed effects are included ($\mathbf{Y_t}$ and $\mathbf{X_i}$ respectively). $REP_{i,t}$ is a dummy, taking the value of one if firm i has made a repurchase announcement in year t and zero otherwise. The idea with these regressions is to mimic the method of Brockman et al. (2008), which as previously mentioned use lagged $AMIHUD$ as one liquidity proxy. We further seek to reaffirm their results by also using FHT.

Further, we want to take advantage of the natural experiment- and exogenous liquidity shock-feature of the decimalisation introduction by performing the difference-in-difference regression

$$REP_{i,t} = \alpha_{i,t} + \beta_1 DEC_t + \beta_2 LOWPRC_i + \beta_3 DEC_t * LOWPRC_i + \boldsymbol{\rho}\mathbf{Y_t} + \boldsymbol{\vartheta X_i} + \varepsilon_{i,t} \quad (6)$$

in which $LOWPRC_i$ is a dummy variable equalling one if the security belongs to the group of stocks with lowest prices (which should be most affected by the exogenous liquidity shock). The variable equals zero if the security belongs to the group of stocks with the highest prices (which should be least affected by the exogenous liquidity shock). The dummy DEC_t

[15] As the liquidity proxies have shown to be positively skewed, they are transformed in the following manner $LIQ_{AM_{i,t-1}} = -ln(AM_{i,t-1} + 1)$ and $LIQ_{FHT_{i,t-1}} = -ln(FHT_{i,t-1} + 1)$, in line with Edmans et al. (2013).

[16] Brockman et al. (2008) and Edmans et al. (2013) add several company specific controls such as market-to-book and financial leverage as they highlight that these variables might jointly affect corporate governance decisions and liquidity. We use no such controls as our focus is on the exogenous shock of decimalisation and we are concerned about endogeneity in these variables.

takes the value one after the decimalisation and zero otherwise. With this econometric set-up, the coefficient β_3 should capture the causal impact liquidity has on repurchase announcement.

Using the above-described features of the decimalisation introduction, we also estimate the two stage least square regressions in which the structural models of interest are

$$REP_{i,t} = \alpha_{i,t} + \beta_1 LIQ_{AM_{i,t-1}} + \boldsymbol{\rho Y_t} + \boldsymbol{\vartheta X_i} + \varepsilon_{i,t} \tag{7}$$

and

$$REP_{i,t} = \alpha_{i,t} + \beta_1 LIQ_{FHT_{i,t-1}} + \boldsymbol{\rho Y_t} + \boldsymbol{\vartheta X_i} + \varepsilon_{i,t}. \tag{8}$$

The first stage regressions are

$$LIQ_{AM_{i,t}} = \alpha_{i,t} + \beta_1 DEC_t * LOWPRC_i + \beta_2 DEC_t + \beta_3 LOWPRC_i + \boldsymbol{\rho Y_t} + \boldsymbol{\vartheta X_i} + \varepsilon_{i,t} \tag{9}$$

and

$$LIQ_{FHT_{i,t}} = \alpha_{i,t} + \beta_1 DEC_t * LOWPRC_i + \beta_2 DEC_t + \beta_3 LOWPRC_i + \boldsymbol{\rho Y_t} + \boldsymbol{\vartheta X_i} + \varepsilon_{i,t}. \tag{10}$$

The second stage regressions are

$$REP_{i,t} = \alpha_{i,t} + \beta_1 LI\widehat{Q_{AM_{i,t-1}}} + \beta_2 DEC_t + \beta_3 LOWPRC_i + \boldsymbol{\rho Y_t} + \boldsymbol{\vartheta X_i} + \varepsilon_{i,t} \tag{11}$$

and

$$REP_{i,t} = \alpha_{i,t} + \beta_1 LI\widehat{Q_{FHT_{i,t-1}}} + \beta_2 DEC_t + \beta_3 LOWPRC_i + \boldsymbol{\rho Y_t} + \boldsymbol{\vartheta X_i} + \varepsilon_{i,t}. \tag{12}$$

The reduced form regression is

$$REP_{i,t} = \alpha_{i,t} + \beta_1 DEC_t + \beta_2 LOWPRC_i + \beta_3 DEC_t * LOWPRC_i + \mathbf{\rho Y_t} + \boldsymbol{\vartheta X_i} + \varepsilon_{i,t}. \tag{13}$$

By performing these regressions, $DEC_t * LOWPRC_i$ work as an instrumental variable for LIQ_{AM} and LIQ_{FHT}. The fitted values $LI\widehat{Q_{AM_{i,t-1}}}$ and $LI\widehat{Q_{FHT_{i,t-1}}}$ are obtained by using the output from the first stage regressions.

Considerations to be taken into account using decimalisation

Using decimalisation as a natural experiment, we are concerned about two categories of issues; (1) that there is noise in the data during the year of introducing decimalisation and (2) that repurchase activity in years far from decimalisation may have been affected by other events.

As for the first case, although consensus prevails in general, there has been some controversy as to whether decimalisation actually had a positive impact on liquidity (cf. Furfine (2003)). To control for this, we perform multiple checks on the reliability of the decimalisation liquidity shock (cf. e.g. Appendix B – E). One notable event that happened close to the decimalisation was the terrorist attacks against the World Trade Center in New York on September 11th 2001. As for the terrorist attacks, all the US stock exchanges closed and did not open until September 17th. This is an event clearly affecting liquidity. However, simply looking at the graphs in Appendix D, this seemingly did not affect liquidity different for our treatment group compared to our control group, keeping the validity of our instrument strong.

Regarding activities far from decimalisation, we, in line with Edmans et al. (2013) include year dummies for the years 1995-2000 and 2003-2013 respectively to capture such effects, meanwhile dropping the years 2001-2002 to avoid multicollinearity with DEC. A further worry is that repurchases were affected largely by the financial crisis. As a robustness check for this, we restrict the dataset from 1994-2007 (cf. part B in Section 5).

Further controls and robustness checks

For all regressions in section 5 and the appendices, we include firm fixed effects. By doing this we control for firm specific features affecting the decision to make a repurchase announcement that otherwise spuriously would have been interpreted as being a cause of liquidity changes. Further, we also include year dummies. In line with the above reasoning, our year dummies also capture yearly trends affecting firms' decision to make a repurchase announcement that otherwise spuriously might have been interpreted as being a cause of liquidity changes. Finally, for all regressions, we report standard errors clustered at firm and year level in order to control for heteroskedasticity in our linear probability models and autocorrelation in all our series.

As a robustness check, we further divide our sample according to level of liquidity in year 2000. Doing this division, we divide the sample into quintiles, both with respect to $AMIHUD$ and FHT.

4 Data

Sample construction

We collect daily price and volume data between 1993 and 2013 for all stocks included in the CRSP database, i.e. securities with primarily listing on ARCA, AMEX, Nasdaq or NYSE. Using the nCUSIP code of these securities, we match them with corresponding information on repurchase announcement date, available in the SDC (Securities Data Company) Platinum database.

In our dataset, we further only include information on open market repurchase announcements. When it comes to investigating the impact of liquidity on stock market repurchase decisions, open market repurchases represent the most obvious repurchase type to study; the fixed-price tender offers and Dutch auctions imply that the firm offers one price to the shareholders. Hence, as the open market repurchase programs involve repurchasing stocks on the open market, the connection between market liquidity and this type of repurchase is more straightforward to study. Further, the different average relative number of shares repurchased through the different repurchase program types[17] along with the diverse average

[17] In self-tender offerings and Dutch-auctions firms repurchase a large fraction of the shares outstanding on average. In self-tender offerings, around 15 percent of shares outstanding are repurchased as opposed to 5 percent in the case of open-market programs (cf. literature study by Grullon and Ikenberry 2000).

market reaction on these,[18] clearly illustrate their difference. Also, previous research has indicated that the open market repurchases represent the vast majority of the repurchases made in the U.S. (cf. Grullon and Ikenberry (2000), footnote 2 above). In line with this, numerous prior studies have consequently only looked on these repurchases (cf. Barclay and Smith (1988), Singh et al. (1994), Wiggins (1994), Franz and Tripathy (1995), Ikenberry et al. (1995), Miller and McConnell (1995) as well as Grullon and Michaely (2004)).

Descriptive statistics

In our sample, we define the dummy variable $REP_{i,t}$ as one if there has been a repurchase announcement in year t for stock i and zero otherwise.[19] The dummy DEC_t takes the value one after January 29th 2001 and zero otherwise.

When we divide our samples in treatment and control groups, we define our treatment (control) groups as the stocks with prices within the lowest (highest) 1st, 10th and 25th percentiles during the first trading day in year 2000. The variable $LOWPRC_i$ thus takes the value one for stocks within the lowest percentiles, whereas it takes the value zero for the stocks within the highest percentiles. The variable does not take any value when a stock lies in between the high and low price group; these observations are consequently dropped. Hence, for the difference-in-difference regressions, our sample only includes the stocks that were transacted during the first trading day in 2000 and where within our critical percentiles in terms of price.

TABLE I

Descriptive statistics

	N	Mean	Std. Dev	1%	10%	25%	Median	75%	90%	99%
REP	478,023	0.029	0.168	0.000	0.000	0.000	0.000	0.000	0.000	1.000
DEC	478,023	0.573	0.495	0.000	0.000	0.000	1.000	1.000	1.000	1.000
LIQ_{FHT}	154,115	-0.146	0.203	-0.941	-0.395	-0.196	-0.067	-0.016	-0.005	0.000
LIQ_{AM}	154,061	-0.509	0.949	-4.310	-1.776	-0.533	-0.053	-0.005	-0.001	0.000
Price (2000)	8,361	19.440	22.748	0.750	2.500	5.813	12.000	23.500	44.713	134.375

Table 1 shows the summary statistics of the variables used in the full sample analysis in Section 5. REP takes the value 1 if there has been a repurchase announcement in year t for stock i, 0 otherwise. DEC takes the value 1 after January 29th 2001, 0 otherwise. LIQ_{FHT} and LIQ_{AM} are the liquidity proxies for each stock, calculated on a yearly basis. *Price (Jan 2000)* corresponds to the price of each stock trading at the first trading day in January 2000.

For the first trading day in 2000, price data from the CRSP database was obtained for 8,361 stocks. 6,364 stocks made at least one repurchase announcement during the period 1993-2013. As can be read in Table I above, our dataset includes 13,863 repurchases from all companies.[20] Further, it is noted that LIQ_{AM} has a distribution with fatter tails than LIQ_{FHT}. For the observations within the top and bottom percentiles, we winsorise the LIQ_{AM} and LIQ_{FHT} variables.

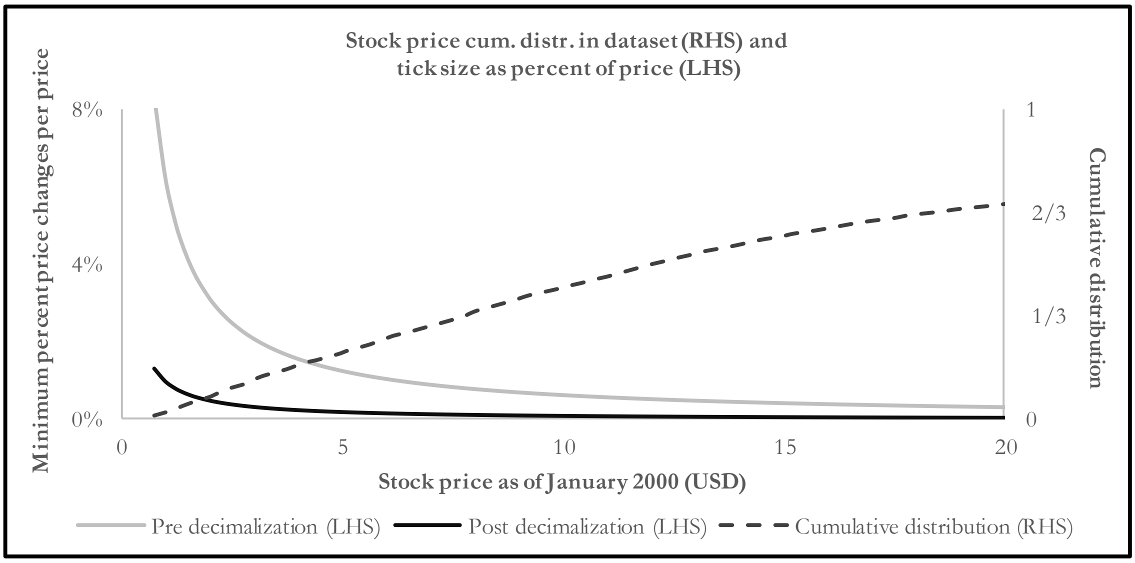
---

[18] Comment and Jarrell (1991), find the average excess return of fixed-price self-tender offers, Dutch auctions and open market repurchase programs to be 11, 8 and 2 percent respectively.

[19] We only look at repurchase announcements, not on actual repurchase dates.

[20] The figure 13,863 can simply be obtained by multiplying N with $Mean$ of REP

FIGURE I



The left hand side illustrates the minimum tick size, before (1/16 USD) and after decimalization (1/100 USD), as percent of stock price. On the right hand side, the cumulative distribution of the prices the first trading day in January 2000 is illustrated (up to the 67th percentile).

Further, in order to quantify our previous reasoning that stocks with low price would be more affected by the decimalisation than stocks with high price, we look at the relation between the tick size before and after decimalisation and stock price. In Figure I this relation is illustrated on the left hand side, whereas the cumulative distribution of prices is illustrated on the right hand side. The decreasing wedge between the grey and black line clearly shows the impact that the tick size change had on low price stocks as opposed to high price stocks. For a stock with price in the 1st percentile (0.750 USD), a tick size of 1/16 USD corresponds to 8.333 percent of the stock price, whereas a tick size of 1/100 USD corresponds to 1.333 percent. On the other hand, for a stock with price in the 99th percentile (134.375 USD, not visible in the graph), a tick size of 1/16 USD corresponds to 0.047 percent of the stock price, whereas a tick size of 1/100 USD corresponds to 0.007 percent.[21] This information reassures us that using low price and high price stocks as treatment and control groups respectively indeed will capture different tick-price relations and hence also different impacts of tick size changes on liquidity. The change in our liquidity measures that the decimalisation caused on the low price stocks can also be seen in the graphs in Appendix D.[22]

[21] For the stocks belonging to the 25th percentile (5.813 USD), which in our regressions responds to the stocks with the highest price in the low price (treatment) group, a tick size of 1/16 USD corresponds to 1.075 percent of the stock price, whereas a tick size of 1/100 USD corresponds to 0.172 percent. For the stocks belonging to the 75th percentile (23.500 USD), which in our regressions corresponds to stocks with lowest price in the high price (control) group, a tick size of 1/16 USD corresponds to 0.266 percent of the stock price, whereas a tick size of 1/100 USD corresponds to 0.043 percent.

[22] Further, in Appendix E, the average liquidity level over the entire period is illustrated, both with respect to LIQ_{AM} and LIQ_{FHT}. The rather smooth development of the proxies before the decimalisation make us reassured that our decimalisation variable do not to capture any potential other pre-trends.

5 Empirical Results

Using decimalisation as an exogenous shock on liquidity and controlling for firm and year fixed effects, our general finding is that increased liquidity makes a firm less prone to make a repurchase announcement. This result is not in line with previous findings of Brockman et al. (2008). Controlling for the potential impact of the financial crisis in 2008 by restricting our dataset to the years 1994-2007, our finding is robust. We moreover find indications of the impact of a liquidity increase to differ between stocks with low versus high initial liquidity. Our general trend of a negative impact of liquidity on the propensity to repurchase is most prominently reflected in stocks with high initial level of liquidity. However, in line with Brav et al. (2005) we find a pattern indicating that firms with low initial liquidity experience a positive impact of liquidity on willingness to make a repurchase announcement.

A. Does improved liquidity in a firm's stock increase a firm's willingness to announce a repurchase?

To investigate whether improved liquidity in a firm's stock increases a firm's propensity to announce a repurchase, we start by performing two OLS regressions: (I) repurchase announcement on the lagged liquidity proxy ${LIQ_{AM}}_{t-1}$ and (II) repurchase announcement on the lagged liquidity proxy ${LIQ_{FHT}}_{t-1}$. The regression in which we use ${LIQ_{AM}}_{t-1}$ as liquidity proxy somewhat replicates that of Brockman et al. (2008). However, we do not include their controls for other factors affecting repurchase.

TABLE II[23,24]

OLS Regressions: REP as dependent

	(1)	(2)	(3)	(4)
Intercept	0.027 ***	0.027 ***	0.027 ***	0.032 ***
	(0.007)	(0.000)	(0.008)	(0.002)
LIQ_{AM}	0.028 ***	0.021 ***		
	(0.004)	(0.004)		
LIQ_{FHT}			0.008	0.085 ***
			(0.025)	(0.025)
N	84,266	84,266	84,266	84,266
Firm fixed effects	Yes	Yes	Yes	Yes
Year fixed effects	No	Yes	No	Yes
Joint F-stat		410.6 ***		400.8 ***
R^2	0.002	0.014	0.000	0.014

All regressions are estimated by OLS. * indicates that the estimate is significant on a 10% level, ** indicates that the estimate is significant on a 5% level, *** indicates that the estimate is significant on a 1% level. Firm fixed effects are included for each regression. Standard errors, reported in parentheses, are robust and clustered on year and firm level. N represents the number of observations used in the regression. The F-statistic represents a joint significance test for all variables in respective regressions.

[23] Performing logistic regressions, coefficients show the same signs but an even better fit. However, we display OLS regressions since it makes it more straightforward to compare this stage with the later stages of our analysis, most notably the 2SLS regressions.

[24] We note that the R^2 of all our regressions with REP as dependent variable are rather low. Given the numerous other factors discussed in Section 2 affecting management's decisions to repurchase, we are not surprised by this. Further, these are in line with the R^2 figures, obtained by Brockman et al. (2008).

From the regression output seen in Table II, we note that the coefficients of $LIQ_{AM\,t-1}$ and $LIQ_{FHT\,t-1}$ both indicate a positive and statistically significant relationship (after having controlled for year fixed effects in the case of $LIQ_{FHT\,t-1}$) between liquidity in year $t-1$ and repurchase announcement in year t. This indicates that the more liquid the firm's stock is, the more prone the firm is to make a repurchase announcement. The positive sign on the conventional liquidity proxy, $LIQ_{AM\,t-1}$, is in line with the previous findings of Brockman et al. (2008) and the positive sign of the somewhat less conventional liquidity proxy $LIQ_{FHT\,t-1}$ provides us with an additional check of these results.

A possible concern that arises when using the liquidity proxies $LIQ_{AM\,t-1}$ and $LIQ_{FHT\,t-1}$ as determinants of repurchase announcement is the potential of inherent endogeneity in these. For instance, movements in liquidity may be conditional on corporate governance; e.g. corporate governance in t might be affected by corporate governance in $t-1$ and corporate governance in $t-1$ might affect the liquidity level the same period ($t-1$).

Being concerned about this potential endogeneity in the $LIQ_{AM\,t-1}$ and $LIQ_{FHT\,t-1}$ measures, we want to see what results we get when we use the exogenous liquidity shock of decimalisation in 2001 as a natural experiment.[25]

TABLE III

OLS Regressions: *REP* as dependent

	(1)	(2)	(3)	(4)	(5)	(6)
Intercept	-0.008	0.009	0.024 **	0.010	-0.006	0.002
	(0.016)	(0.011)	(0.011)	(0.029)	(0.026)	(0.026)
DEC*LOWPRC	-0.073 ***	-0.048 ***	-0.030 ***	-0.074 ***	-0.044 ***	-0.028 **
	(0.020)	(0.014)	(0.011)	(0.018)	(0.014)	(0.011)
DEC	0.052 **	0.024	-0.001	0.021	0.021	0.013
	(0.022)	(0.016)	(0.015)	(0.031)	(0.027)	(0.025)
LOWPRC	0.031 *	0.018 *	0.009	0.030 *	0.016	0.007
	(0.018)	(0.010)	(0.007)	(0.016)	(0.010)	(0.006)
N	1,464	15,602	41,558	1,464	15,602	41,558
LOWPRC percentile	1	10	25	1	10	25
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	No	No	No	Yes	Yes	Yes
Joint F-stat	3.7 ***	9.2 ***	16.9 ***	11.6 ***	42.1 ***	105.4 ***
Liq. proxy joint F-stat				2.0 ***	7.1 ***	8.7 ***
R^2	0.007	0.002	0.001	0.023	0.008	0.008

All regressions are estimated by OLS. * indicates that the estimate is significant on a 10% level, ** indicates that the estimate is significant on a 5% level, *** indicates that the estimate is significant on a 1% level. Firm fixed effects are included for each regression. The Liq. proxy joint F-stat represents the joint F-test for DEC, $LOWPRC$ and $DEC * LOWPRC$. Standard errors, reported in parentheses, are robust and clustered on year and firm level.

As can be seen in Table III, regressing repurchase announcements on our difference-in-difference variables, we surprisingly find the coefficient of the interactive variable $DEC * LOWPRC$ (our liquidity proxy) to have a statistically significant *negative* sign. The results are consistent for all regression specifications, i.e. independent on whether the treatment (control) group consists of the firms with stock price within the lowest (highest) 1st, 10th or 25th

[25] As can be concluded from Appendix B – E, we are already reassured that the difference-in-difference setup is an adequate way to proxy for LIQ_{AM} and LIQ_{FHT}.

percentiles during the first trading day in year 2000. Further, we note that both R^2 and the magnitude on the interactive variable fall as we include more price percentiles. This is reassuring as it mirrors the fact that for instance stocks in the 25th price percentile should be less affected by decimalisation than those in the 1st price percentile, thus decreasing the economic significance of the exogenous liquidity shock. We further note that all three specifications are more or less unaffected by dropping year fixed effects. The F-statistics further indicate that the variables $DEC * LOWPRC$, DEC and $LOWPRC$ also are jointly significant in all regressions. The sign of the coefficient of the interactive variable indicates that the more liquid a firm's stock is, the less prone the firm is to make a repurchase announcement. This clearly contradicts the results of our initial regressions (Table II) along with the prior findings of Brockman et al. 2008.[26]

We further want to take advantage of the fact that that the introduction of the decimalisation was an exogenous shock to liquidity and that our difference-in-difference variables hence are uncorrelated with the error terms in the regressions reported in Table III. We therefore continue our analysis by performing two-stage-least-square regressions (2SLS), with the above-mentioned interactive variable, $DEC * LOWPRC$, as an instrument for the two liquidity proxies LIQ_{AM} and LIQ_{FHT}.

[26] A potential concern in this analysis is if the interactive picks up any other effects affecting the decision to repurchase. One potential happening that could be the source to such effects is the terrorist attacks on the World Trade Center on September 11th 2001, when American stock markets closed for several trading days. However, since we have no reason to believe that firms with a low stock price would be affected differently than the ones with a high stock price, we deem our analysis to be robust to such noise. To further control for different movements in liquidity, far from the introduction of decimalisation, we include year dummies for 1995-2000 and 2003-2013.

TABLE IV

2SLS Regressions: *REP* as dependent (*DEC*LOWPRC* as IV)

Panel A

	(1)	(2)	(3)	(4)	(5)	(6)
Intercept	0.005	0.018	0.032	0.002	-0.021	-0.020
	(0.016)	(0.013)	(0.020)	(0.027)	(0.022)	(0.030)
LIQ_{AM} ***Hat***	-0.340 ***	-0.336 ***	-0.561 ***	-0.288 ***	-0.250 ***	-0.353 ***
	(0.131)	(0.097)	(0.156)	(0.110)	(0.071)	(0.098)
DEC	0.006	-0.003	-0.007	-0.002	-0.004	-0.006
	(0.048)	(0.034)	(0.041)	(0.040)	(0.025)	(0.025)
LOWPRC	0.039	0.013	-0.013	0.114 **	0.009	-0.062 *
	(0.035)	(0.035)	(0.047)	(0.052)	(0.020)	(0.032)
N	1,439	15,284	40,689	1,439	15,284	40,689
LOWPRC Percentile	1	10	25	1	10	25
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	No	No	No	Yes	Yes	Yes
Second stage F-stat	2.7 ***	12.3 ***	5.4 ***	4.2 ***	20.9 ***	12.9 ***
Instrument first stage T-stat	0.9	0.6	0.3	2.5 **	6.8 ***	6.2 ***
First stage R^2	0.007	0.003	0.001	0.097	0.066	0.055
Hausman (1978) coefficient	-0.018	-0.071 ***	-0.101 ***	0.340 ***	0.264 ***	0.315 ***
DWH z-score	-2.819 ***	-3.592 ***	-3.724 ***	-2.859 ***	-3.609 ***	-3.747 ***

Panel B

	(1)	(2)	(3)	(4)	(5)	(6)
Intercept	-0.002	0.012 **	0.025 ***	0.021 *	0.005	0.012 **
	(0.015)	(0.006)	(0.008)	(0.012)	(0.005)	(0.005)
LIQ_{FHT} ***Hat***	-0.382 **	-0.291 ***	-0.245 ***	-0.375 **	-0.268 ***	-0.226 ***
	(0.176)	(0.106)	(0.092)	(0.160)	(0.096)	(0.084)
DEC	0.011	0.000	-0.004	0.010	0.000	-0.005
	(0.028)	(0.010)	(0.006)	(0.027)	(0.009)	(0.006)
LOWPRC	0.050 **	0.024	0.000	0.233 ***	0.042 ***	-0.003
	(0.024)	(0.015)	(0.014)	(0.024)	(0.005)	(0.005)
N	1,439	15,284	40,689	1,439	15,284	40,689
LOWPRC Percentile	1	10	25	1	10	25
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	No	No	No	Yes	Yes	Yes
Second stage F-stat	21.3 ***	344.4 ***	678.3 ***	24.8 ***	364.9 ***	719.9 ***
Instrument first stage T-stat	2.3 **	3.7 ***	4.1 ***	3.1 **	4.2 ***	4.8 ***
First stage R^2	0.066	0.143	0.172	0.153	0.176	0.196
Hausman (1978) coefficient	0.185	0.181 ***	0.318 ***	0.404 **	0.315 ***	0.312 ***
DWH z-score	-2.683 ***	-3.173 ***	-3.386 ***	-2.596 ***	-3.219 ***	-3.464 ***

All regressions are estimated by 2SLS. * indicates that the estimate is significant on a 10% level, ** indicates that the estimate is significant on a 5% level, *** indicates that the estimate is significant on a 1% level. Firm fixed effects are included for each regression. Standard errors, reported in parentheses, are robust and clustered on year and firm level. N represents the number of observations used in the regression. The Hausman (1978) test represents an exogeneity test of the liquidity proxies LIQ_{AM} and LIQ_{FHT} in the structural model. The DWH test shows the consistency of the IV estimates compared to the OLS estimates (structural model estimates). Price percentiles are calculated as of the first trading day of year 2000.

The results of the 2SLS regressions can be seen in Table IV. Here, the figures again indicate a statistically significant negative impact of $\widehat{LIQ_{AM}}_{t-1}$ and $\widehat{LIQ_{FHT}}_{t-1}$ respectively on the propensity to make a repurchase announcement. The results are robust for all price percentiles used. Further, we note that the magnitude of the $\widehat{LIQ_{AM}}_{t-1}$ and $\widehat{LIQ_{FHT}}_{t-1}$ coefficients are stable across all regressions and that the instrument, $DEC * LOWPRC$, seems to be efficient in all specifications.[27] We also observe that apart from the $LOWPRC$ interaction

[27] It is noted that the instrument for the LIQ_{AM} 2SLS regressions without year fixed effects is not entirely stable on the first stage. Still, the fact that the coefficients are similar to when year fixed effects are added is reassuring.

effect with DEC in the instrumental variable, the $LOWPRC$ variable's impact in the second stage is inconsistent and for most cases statistically insignificant, justifying our usage of sub-samples grouped on price as they appear to be random in relation to repurchases. The congruent results of the regression specifications in Table III and Table IV are supporting the idea that there may be an endogeneity bias inherent in the first regression specifications (Table II).

Our endogeneity concern is further supported by the results of our Hausman (1978); our Hausman coefficients are statistically significant. Hence, we can reject that LIQ_{AM} and LIQ_{FHT} are exogenous in the structural model regression (Table II), meaning that we can reject that LIQ_{AM} and LIQ_{FHT} will provide unbiased coefficients. In line with this reasoning, all of the Hausman coefficients also carry the expected positive sign; in the structural model, LIQ_{AM} and LIQ_{FHT} seem to have overestimated the positive impact of liquidity on the propensity to make a stock repurchase announcement.

Aiming to further test the robustness of our results, we also perform the Durbin-Wu-Hausman (DWH) test (cf. Nakamura and Nakamura 1981) by using the $LIQ_{AM_{t-1}}$ and $LIQ_{FHT_{t-1}}$ estimates and standard errors from our structural equations and comparing these with our $LI\widehat{Q_{AM}}_{t-1}$ and $LI\widehat{Q_{FHT}}_{t-1}$ estimates and standard errors from the second stage regression. With all DWH statistics being statistically significant, we find our instrumental variables to generate more consistent repurchase announcement determinants ($LI\widehat{Q_{AM}}_{t-1}$ and $LI\widehat{Q_{FHT}}_{t-1}$) than the repurchase announcement determinants in our structural model specification ($LIQ_{AM_{t-1}}$ and $LIQ_{FHT_{t-1}}$).

With the above performed analysis and robustness checks, we get results indicating that improved liquidity of a firm's stock will make the firm *less* prone to announce a stock repurchase, implying that LIQ_{AM} and LIQ_{FHT} are endogenous in relation to repurchase announcements.

B. Do our results hold for a different period of time?

Aiming to test the robustness of our results further, we want to investigate whether our results hold for different time periods. More specifically, we are interested in excluding the potential extra impact – not controlled for by our year dummies – caused by the financial crisis 2008. By only using data from 1994 to 2007, we aim to exclude the potential bias on liquidity that the crisis might have caused in our regressions above.[28]

A side-effect of performing this analysis is that we check for another potential bias in our previous findings. In our sample, we note that not all stocks trading before decimalisation still trades long after. Hence, if this data dropout is correlated with stocks with e.g. low prices in year 2000, our results may be subject to a survivor bias. By decreasing the time period analysed, we control for these potential dropouts.

[28] In our data, we find clear indications of the negative impact on stock repurchase announcements that the financial crisis had. All our year dummies for the year 2009 are consistently negative in our regressions. In comparison can be mentioned that for the years between the decimalisation and the financial crisis, we predominantly have positive year dummies.

TABLE V

2SLS Regressions: *REP* as dependent (*DEC*LOWPRC* as IV), 1994-2007

	(1)	(2)	(3)	(4)	(5)	(6)
Intercept	0.006	-0.042	-0.096	0.021	0.004	0.010 *
	(0.021)	(0.036)	(0.085)	(0.013)	(0.006)	(0.006)
LIQ_{AM} Hat	-0.198 **	-0.428 ***	-1.104 ***			
	(0.083)	(0.135)	(0.341)			
LIQ_{FHT} Hat				-0.372 **	-0.338 ***	-0.333 ***
				(0.165)	(0.125)	(0.123)
LOWPRC	0.007	-0.011	-0.020	0.010	-0.003	-0.008
	(0.034)	(0.046)	(0.087)	(0.029)	(0.012)	(0.008)
DEC	0.145 ***	-0.005	-0.164 *	0.233 ***	0.045 ***	0.002
	(0.043)	(0.032)	(0.091)	(0.023)	(0.006)	(0.006)
N	1,226	12,804	33,793	1,226	12,804	33,793
LOWPRC Percentile	1	10	25	1	10	25
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Instrument first stage T-stat	1.0	0.8	0.5	2.4 **	3.8 ***	4.2 ***
First stage R^2	0.101	0.065	0.053	0.119	0.126	0.148
Hausman (1978) coefficient	0.230 **	0.437 ***	1.117 ***	0.446 **	0.389 ***	0.394 ***
DWH z-score	-2.743 ***	-3.238 ***	-3.271 ***	-2.678 ***	-3.025 ***	-3.159 ***

All regressions are estimated by 2SLS. * indicates that the estimate is significant on a 10% level, ** indicates that the estimate is significant on a 5% level, *** indicates that the estimate is significant on a 1% level. Firm fixed effects are included for each regression. Reported standard errors are robust and clustered on year and firm level. N represents the number of observations used in the regression. The Hausman (1978) test represents an exogeneity test of the liquidity proxies LIQ_{AM} and LIQ_{FHT} in the structural model. The DWH test shows the consistency of the IV estimates compared to the OLS estimates (structural model estimates). Price percentiles are calculated as of the first trading day of year 2000.

In Table V, the 2SLS regression output of the 1994-2007 subsample is presented. Like before, $\widehat{LIQ_{AM}}_{t-1}$ and $\widehat{LIQ_{FHT}}_{t-1}$ still show negative and statistically significant signs for all price percentiles. For the case of the 2SLS regression on $LIQ_{AM_{t-1}}$, the t-stat in the first stage is still weak. However, the R^2 values indicate that there is predictive power in the regressions. The coefficients for $\widehat{LIQ_{AM}}_{t-1}$, especially in the higher percentiles, are deviating substantially from the ones obtained in the previous 2SLS regressions for the full sample, even though they carry the same sign.

Further, almost all of our Hausman coefficients are statistically significant and we can hence also in this case reject that $LIQ_{AM_{t-1}}$ and $LIQ_{FHT_{t-1}}$ are exogenous in the corresponding structural model regression, meaning that we can reject that $LIQ_{AM_{t-1}}$ and $LIQ_{FHT_{t-1}}$ will provide unbiased coefficients also in the 1994-2007 subsample. In line with this reasoning, all of the Hausman coefficients also carry the expected positive sign. Hence, also in the subsample, the liquidity proxies $LIQ_{AM_{t-1}}$ and $LIQ_{FHT_{t-1}}$ seem to have overestimated the positive impact of liquidity increases on the propensity to make a stock repurchase announcement.

Finally, with all DWH statistics being statistically significant, we, also in this case, find our instrumental variable to generate more consistent repurchase announcement determinants ($\widehat{LIQ_{AM}}_{t-1}$ and $\widehat{LIQ_{FHT}}_{t-1}$ than the repurchase announcement determinants in our structural model specification ($LIQ_{AM_{t-1}}$ and $LIQ_{FHT_{t-1}}$).

Consequently, having controlled for the potential impact of the financial crisis, our findings still show to be robust: ${LIQ_{AM}}_{t-1}$ and ${LIQ_{FHT}}_{t-1}$ seem to be endogenous and by using our instrumental variable $DEC * LOWPRC$, we get results indicating that increased stock liquidity negatively impacts stock repurchase announcements.

C. Does prior liquidity level affect a firm's reaction on improved liquidity?

Wanting to test the robustness of our results even further, we continue by dividing our total sample in subsamples conditional on the liquidity level (LIQ_{AM} and LIQ_{FHT} respectively) of each stock in the year 2000, i.e. the year before the introduction of decimalisation. We find this analysis important to make as previous research have indicated that the impact of liquidity changes on repurchases seems to be especially important for firms with certain stock characteristics. The findings of Brav et al. (2005) indicate that for firms with low liquidity stocks, a decrease in liquidity negatively affects the willingness to announce a repurchase as the firm believes that this would reduce the liquidity of the stock below a certain level. Hence, rerunning the difference-in-difference and 2SLS regressions in Section A above and analysing the results within different liquidity quintiles, we aim to investigate whether firms with stocks in different liquidity groups react differently on liquidity increases. Looking at the distribution of repurchase announcements within the different liquidity quintiles, we are further reassured that this analysis will not be misleading as the repurchases are relatively evenly distributed within each quintile.[29]

Therefore, we continue by again using decimalisation as liquidity proxy in a difference-in-difference regression. We chose to focus on the 10^{th} price-percentile group as this represents the group with most explanatory power without interfering with the sample size. The regression output of these regressions for liquidity quintiles can be seen in Table VI.

[29] When the quintiles are formed based on level of LIQ_{AM} in 2000, 32 percent of the repurchase announcements are included in the first quintile (highest liquidity), whereas 19, 16, 19 and 14 percent belong to quintile two, three, four and five respectively. When the quintiles are formed based on level of LIQ_{FHT} in 2000, 23 percent of the repurchase announcements are included in the first quintile, whereas 23, 25, 22 and 10 percent belong to quintile two, three, four and five respectively.

TABLE VI

OLS Regressions: ***REP*** **on** ***DEC***

Panel A: Liquidity groups based on LIQ_{AM}

	(1)	(2)	(3)	(4)	(5)
Intercept	0.018 *	0.021	0.017	0.034 **	0.073 ***
	(0.011)	(0.016)	(0.012)	(0.016)	(0.018)
DEC*LOWPRC	-0.061 *	-0.060 **	0.003	0.019	0.044 *
	(0.035)	(0.025)	(0.015)	(0.022)	(0.027)
DEC	0.001	0.018	0.000	-0.024	-0.045 **
	(0.010)	(0.021)	(0.012)	(0.017)	(0.020)
LOWPRC	0.038	0.023	-0.008	-0.020 **	-0.051 **
	(0.027)	(0.016)	(0.009)	(0.009)	(0.020)
N	3,252	2,959	3,077	3,273	3,368
LOWPRC Percentile	10	10	10	10	10
Firm fixed effects	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes
Joint F-stat	12.2 ***	9.9 ***	14.0 ***	16.1 ***	20.4 ***
Liq. proxy joint F-stat	3.4 ***	3.6 ***	0.2	1.2 ***	6.5 ***
R^2	0.009	0.009	0.014	0.018	0.022

Panel B: Liquidity groups based on LIQ_{FHT}

	(1)	(2)	(3)	(4)	(5)
Intercept	0.012	0.033 ***	0.047 ***	0.074 ***	0.042 ***
DEC*LOWPRC	-0.084 **	-0.040 **	0.016	0.050 **	0.067 **
	(0.042)	(0.018)	(0.013)	(0.025)	(0.026)
DEC	0.017	-0.013	-0.010	-0.068 ***	-0.056 ***
	(0.012)	(0.016)	(0.012)	(0.014)	(0.014)
LOWPRC	0.042	0.017 **	-0.029 ***	-0.042 ***	-0.061 ***
	(0.027)	(0.007)	(0.003)	(0.008)	(0.021)
N	2,374	3,093	3,152	3,038	2,690
LOWPRC Percentile	10	10	10	10	10
Firm fixed effects	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes
Joint F-stat	14.6 ***	13.3 ***	13.4 ***	21.1 ***	33.6 ***
Liq. proxy joint F-stat	3.4 ***	1.9 ***	2.1 ***	5.5 ***	9.4 ***
R^2	0.018	0.013	0.013	0.020	0.036

All regressions are estimated by OLS. * indicates that the estimate is significant on a 10% level, ** indicates that the estimate is significant on a 5% level, *** indicates that the estimate is significant on a 1% level. Firm fixed effects are included for each regression. Reported standard errors are robust and clustered on year and firm level. N represents the number of observations used in the regression. Liquidity quintile 1 is the subsample with the most liquid stocks whereas liquidity quintile 5 is the subsample with the least liquid stocks. The F-statistic represents a joint significance test for all variables in respective regressions. Price percentiles are calculated as of the first trading day of year 2000.

From the table, we note that we get results indicating a *positive* impact of liquidity increases on the propensity to make a repurchase announcement for firms with low initial liquidity stocks (liquidity quintiles four and five), whereas we get a negative impact of liquidity increase on firms with high liquidity (liquidity quintiles one and two). Our results are most significant in the case when the liquidity division is done according to level of LIQ_{FHT} in 2000. From these regressions we conclude that the results obtained with respect to the low liquidity groups seems to be in line with the implications of the findings of Brav et al. 2005. Our results for high the high liquidity groups are in line with our previous findings using our alternative liquidity proxy decimalisation.

Checking the robustness of the results in Table VI, we proceed in the same manner as in section A of our empirical analysis. We perform the 2SLS analysis with the interactive variable $DEC * LOWPRC$ as an instrument for LIQ_{AM} and LIQ_{FHT} respectively.

TABLE VII

2SLS Regressions: *REP* as dependent (*DEC*LOWPRC* as IV)

Panel A: Liquidity groups based on LIQ_{AM}

	(1)		(2)		(3)		(4)		(5)	
Intercept	0.130		0.121	**	0.006		0.025	**	0.104	***
	(0.086)		(0.061)		(0.012)		(0.011)		(0.030)	
LIQ_{AM} *Hat*	-6.399	***	-1.126	***	0.184	***	0.246	***	0.164	***
	(2.214)		(0.356)		(0.046)		(0.066)		(0.039)	
LOWPRC	0.023		-0.009		-0.006		-0.011		-0.029	
	(0.027)		(0.024)		(0.009)		(0.015)		(0.018)	
DEC	0.132		-0.129	**	-0.006		0.080	***	-0.041	
	(0.088)		(0.058)		(0.015)		(0.025)		(0.027)	
N	3,252		2,959		3,077		3,273		3,368	
LOWPRC Percentile	10		10		10		10		10	
Firm fixed effects	Yes		Yes		Yes		Yes		Yes	
Year fixed effects	Yes		Yes		Yes		Yes		Yes	
Joint F-stat	1.0		2.6	***	0.1		3.2	***	7.9	***
Hausman (1978) coefficient	6.423	***	1.141	***	-0.150		-0.228		-0.145	**
DWH z-score	-2.900	***	-3.202	***	3.362	***	3.448	***	3.771	***

Panel B: Liquidity groups based on LIQ_{FHT}

	(1)		(2)		(3)		(4)		(5)	
Intercept	0.170		0.053		0.045	***	0.079	**	0.075	*
	(0.116)		(0.041)		(0.010)		(0.033)		(0.039)	
LIQ_{FHT} Hat	-4.197	***	-1.738	***	0.331	***	1.136	***	0.554	***
	(1.545)		(0.601)		(0.071)		(0.356)		(0.162)	
LOWPRC	0.108		0.018		-0.026	***	-0.033		-0.046	**
	(0.113)		(0.026)		(0.005)		(0.030)		(0.020)	
DEC	0.244	**	0.006		-0.088	***	-0.114	***	-0.052	
	(0.114)		(0.046)		(0.012)		(0.033)		(0.039)	
N	2,374		3,093		3,152		3,038		2,690	
LOWPRC Percentile	10		10		10		10		10	
Firm fixed effects	Yes		Yes		Yes		Yes		Yes	
Year fixed effects	Yes		Yes		Yes		Yes		Yes	
Joint F-stat	2.3	***	4.3	***	6.3	***	12.1	***	10.5	***
Hausman (1978) coefficient	4.198	***	1.849	*	-0.203		-1.091	***	-0.490	**
DWH z-score	-2.715	***	-3.083	***	3.303	***	3.050	***	3.025	***

All regressions are estimated by 2SLS. * indicates that the estimate is significant on a 10% level, ** indicates that the estimate is significant on a 5% level, *** indicates that the estimate is significant on a 1% level. Firm fixed effects are included for each regression. Reported standard errors are robust and clustered on year and firm level. N represents the number of observations used in the regression. Liquidity quintile 1 is the subsample with the most liquid stocks whereas liquidity quintile 5 is the subsample with the least liquid stocks. The Hausman (1978) test represents an exogeneity test of the liquidity proxies LIQ_{AM} and LIQ_{FHT} in the structural model. The DWH test shows the consistency of the IV estimates compared to the OLS estimates (structural model estimates). Price percentiles are calculated as of the first trading day of year 2000.

As can be seen in Table VII, the results of these regressions indicate that for stocks with low liquidity (liquidity quintile four and five), increasing stock liquidity will make the firm more prone of making a repurchase announcement. Checking the robustness of these results through a Hausman test, we get negative Hausman coefficients, indicating that the structural regression on the low liquidity subsamples underestimates the impact of liquidity on the propensity to make a repurchase announcement. Further, the statistical significance of the Hausman coefficient indicate that we can reject that LIQ_{AM} and LIQ_{FHT} are exogenous in the structural model regression for the low liquidity groups, i.e. we can reject that LIQ_{AM} and LIQ_{FHT} will provide unbiased coefficients. Further, performing a DWH test on the results stemming from the fourth and fifth quintile, we find our instrumental variable to generate more consistent repurchase announcement determinants ($LI\widehat{Q_{AM}}_{t-1}$ and $LI\widehat{Q_{FHT}}_{t-1}$) than the repurchase announcement determinants in the corresponding structural model specification (${LIQ_{AM}}_{t-1}$ and ${LIQ_{FHT}}_{t-1}$) for the low liquidity quintiles.

Analysing the output of the 2SLS regressions with respect to stocks with high initial liquidity (liquidity quintiles one and two), we get different results. Again, we get indications of a negative impact of liquidity increases on repurchase announcements. Hence, the trend observed for high liquidity stocks confirms our previous findings in section A and B: firms with high liquidity stocks seem to be less prone to announce a repurchase as a consequence of increased liquidity. This is further supported by the Hausman test performed. Both in the LIQ_{AM} and LIQ_{FHT}case, Hausman coefficients are all significant, indicating that we can reject that ${LIQ_{AM}}_{t-1}$ and ${LIQ_{FHT}}_{t-1}$ are exogenous in the structural models. Further, the Hausman coefficients all carry the expected positive sign, indicating that the coefficients of ${LIQ_{AM}}_{t-1}$ and ${LIQ_{FHT}}_{t-1}$ in the corresponding structural regression overestimate the positive impact of liquidity on the propensity to make a repurchase announcement. Finally, performing a DWH test, we find that our instrumental variable generates more consistent repurchase announcement determinants ($\widehat{LIQ_{AM}}_{t-1}$ and $\widehat{LIQ_{FHT}}_{t-1}$than the repurchase announcement determinants in the corresponding structural model specification (${LIQ_{AM}}_{t-1}$ and ${LIQ_{FHT}}_{t-1}$).

From the above, we conclude that the proxies LIQ_{AM} and LIQ_{FHT} still seem to be endogenous in relation to repurchase announcements, also within different liquidity groups. Further, it also seems like the general trend found in section A and B in the empirical analysis above still seems to hold: increased liquidity in a firm's stock has a negative impact on the decision to make a repurchase announcement. However, for stocks with low prior liquidity, we get indications of a reversed effect. Hence, our findings imply that we cannot reject that firms with different prior liquidity levels react differently on liquidity increases.

6 Conclusion

Using the Amihud and FHT liquidity proxies, we find a positive impact of increased liquidity on the propensity to make a repurchase announcement. This is in line with the results of Brockman et al. (2008). However, using the exogenous liquidity shock of decimalisation, we find increased liquidity to negatively impact the propensity to make a repurchase announcement, clearly contradicting previous research. Indeed, our results indicate that the Amihud and FHT liquidity proxies are endogenous. We cannot distinguish whether this is due to reversed causality, i.e. that repurchase decisions determines liquidity to some extent, or that Amihud and FHT are jointly determined together with the propensity to repurchase through some unobservable factor.

Our results are also robust for restricting the dataset to ending before the global financial crisis of 2008. However, creating subsamples based on initial liquidity level, we find results similar to Brav et al. (2005), indicating that firms with low initial liquidity become more prone to make a repurchase, conditional on increased liquidity.

A plausible reason for our finding of a negative effect of liquidity on the propensity to repurchase might result from managers' anticipation of price responses in relation to repurchase announcements. With a highly liquid stock, the market reaction can be believed to be efficient, i.e. quickly and accurately adjusting the price according to new information. Assuming that the stock was undervalued prior to announcement, it may be more expensive for a firm to repurchase shares with a highly liquid stock, as opposed to a firm with a less liquid stock. In the latter case, the market reaction on new information (stock repurchases) will not be as efficient. Hence, a less liquid stock could be less expensive to repurchase. This is however not clear cut and it might even be that this relation goes the other way. In order to shed further light on this, a proxy for information asymmetry might be introduced, which could be subject to future research.

Even though our results indicate that decimalisation constitutes a solid instrumental variable, ideally, we would also like to use an additional liquidity shock, occurring later in time in order to draw stronger inference on repurchases today. Further, using the CRSP database implies that we only include U.S. data in our sample. Ideally, we would like to pursue our study on a global scale. However, lacking a common global exogenous shock on stock market liquidity impedes this type of analysis. Hence, we can only make inference of our results with respect to the U.S. as there may be other confounding factors affecting liquidity and repurchase announcements in other countries. Still, the U.S. stock market is the largest in the world, rendering strong explanatory power of our results.

This paper has sought to fill the gap in research in understanding how liquidity affects the decision to make a stock repurchase announcement. The paper's main contribution is examining this relationship with an exogenous shock, finding new and contradictory results compared to previous research, providing new insight to how market microstructure affects corporate governance. We believe this relationship to be important to understand in order to comprehend (1) how managers act, (2) trends in repurchases, especially as markets are becoming more liquid, and (3) how to make predictions for firms based on their characteristics. Even though there are many important factors affecting managers' decision to repurchase, our results as well as previous research such as Brav et al. (2005) indicate that liquidity is an important determinant. In order to increase the understanding of our suggested relationship between liquidity and repurchases, we suggest future research to look at this with regard to information asymmetry between managers and the market.

7 References

Amihud, Y. (2002), "Illiquidity and stock returns: cross-section and time-series effects", *Journal of financial markets*, **5**(1), 31-56.

Barclay, M. J., and Smith Jr, C. W. (1988), "Corporate payout policy: Cash dividends versus open-market repurchases", *Journal of Financial Economics*, **22**(1), 61-82.

Bessembinder, H. (2003), "Trade execution costs and market quality after decimalisation", *Journal of Financial and Quantitative Analysis*, **38**(4), 747-777.

Bortolotti, B., De Jong, F., Nicodano, G., and Schindele, I. (2007), "Privatization and stock market liquidity", *Journal of Banking & Finance*, **31**(2), 297-316.

Brav, A., Graham, J. R., Harvey, C. R., and Michaely, R. (2005), "Payout policy in the 21st century", *Journal of Financial Economics*, **77**(3), 483-527.

Brockman, P., Howe, J. S., and Mortal, S. (2008), "Stock market liquidity and the decision to repurchase", *Journal of Corporate Finance*, **14**(4), 446-459.

Comment, R., & Jarrell, G. A. (1991), "The relative signalling power of Dutch-auction and fixed-price self-tender offers and open−market share repurchases", *The Journal of Finance*, **46**(4), 1243-1271.

Dann, L. Y., Masulis, R. W., and Mayers, D. (1991), "Repurchase tender offers and earnings information", *Journal of Accounting and Economics*, **14**(3), 217-251.

Edmans, A., Fang, V. W., and Zur, E. (2013), "The effect of liquidity on governance", *Review of Financial Studies*, **26**(6), 1443-1482.

Kalay, A. and Lemmon, M., (2008), "Payout Policy", in Eckbo, B. E. (ed.). *Handbook of Corporate Finance: Empirical Corporate Finance, Volume 2*. Amsterdam: Elsevier.

Fong, K., Holden, C., and Trzcinka, C. (2013), "What Are the Best Liquidity Proxies for Global Research?", SSRN Working Paper 1558447, University of New South Wales and Indiana University.

Franz, D. R., Rao, R. P., and Tripathy, N. (1995), "Informed trading risk and bid-ask spread changes around open market stock repurchases in the NASDAQ market", *Journal of Financial Research*, **18**(3), 311-27.

Furfine, C. (2003), "Decimalization and market liquidity", *Economic Perspectives*, **27**(4), 2-12.

Grullon, G., and Ikenberry, D. L. (2000). "What do we know about stock repurchases?", *Journal of Applied Corporate Finance*, **13**(1), 31-51.

Grullon, G., and Michaely, R. (2002), "Dividends, share repurchases, and the substitution hypothesis", *The Journal of Finance*, **57**(4), 1649-1684.

Grullon, G., and Michaely, R. (2004), "The information content of share repurchase programs", *The Journal of Finance*, **59**(2), 651-680.

Hertzel, M., and Jain, P. C. (1991), "Earnings and risk changes around stock repurchase tender offers", *Journal of Accounting and Economics*, **14**(3), 253-274.

Ikenberry, D., Lakonishok, J., and Vermaelen, T. (1995), "Market underreaction to open market share repurchases", *Journal of financial economics*, **39**(2), 181-208.

Jagannathan, M., Stephens, C. P., & Weisbach, M. S. (2000), "Financial flexibility and the choice between dividends and stock repurchases", *Journal of financial Economics*, **57**(3), 355-384.

Jensen, M. C., and Meckling, W. H. (1976), "Theory of the firm: Managerial behavior, agency costs and ownership structure", *Journal of financial economics*, **3**(4), 305-360.

Jolls, Christine, (1996), "The Role of Incentive Compensation in Explaining the Stock Repurchase Puzzle," Working Paper, Harvard Law School, Cambridge, MA.

Lesmond, D. A., Ogden, J. P., and Trzcinka, C. A. (1999), "A new estimate of transaction costs", *Review of Financial Studies*, **12**(5), 1113-1141.

Lie, E., and Lie, H. J. (1999), "The role of personal taxes in corporate decisions: An empirical analysis of share repurchases and dividends", *Journal of Financial and Quantitative Analysis*, **34**(4), 533-552.

Lie, E. (2000), "Excess funds and agency problems: an empirical study of incremental cash disbursements", *Review of Financial Studies*, **13**(1), 219-248.

Miller, M. and Rock, K (1985), "Dividend Policy Under Asymmetric Information", *Journal of Finance,* **40**(4), 1031-1051.

Miller, J. M., and McConnell, J. J. (1995). "Open-market share repurchase programs and bid-ask spreads on the NYSE: Implications for corporate payout policy", *Journal of Financial and Quantitative analysis*, **30**(03), 365-382.

Masulis, R. W. (1980). "Stock repurchase by tender offer: An analysis of the causes of common stock price changes", *The Journal of Finance*, **35**(2), 305-319.

Nakamura, A., & Nakamura, M. (1981), "On the relationships among several specification error tests presented by Durbin, Wu, and Hausman", *Econometrica*, **49**(6), 1583-1588.

Nohel, T., and Tarhan, V. (1998). "Share repurchases and firm performance: new evidence on the agency costs of free cash flow", *Journal of Financial Economics*, **49**(2), 187-222.

Protopapadakis, A. (1983), "Some indirect evidence on effective capital gains tax rates" *Journal of Business*, **56**(2) 127-138.

Singh, A. K., Zaman, M. A., and Krishnamurti, C. (1994). "Liquidity changes associated with open market repurchases", *Financial Management*, **23**(1), 47-55.

Vermaelen, T. (1981), "Common stock repurchases and market signaling: An empirical study", *Journal of financial economics*, **9**(2), 139-183.

Wiggins, J. B. (1994), "Open market stock repurchase programs and liquidity", *Journal of Financial Research*, **17**(2), 217-29.

Appendix A

Following equation (3) in section 3 above, the derivation of the FHT liquidity proxy (Fong et al. 2013) is the following:

The theoretical probability of a return of zero is given by the probability of being in the mid region. This is given by

$$N\left(\frac{S}{2\sigma}\right) - N\left(\frac{-S}{2\sigma}\right). \tag{14}$$

Further, the empirically observed zero return frequency is given by the Zeros proxy

$$Z \equiv Zeros = \frac{ZRD}{TD+NTD}. \tag{15}$$

In the above, ZRD is the number of days with zero return, TD is the number of days trading and NTD is the number of days with no trade in a given period.[30] Equating the theoretical probability of a return of zero to the empirically observed frequency of return of zero, we get

$$N\left(\frac{S}{2\sigma}\right) - N\left(\frac{-S}{2\sigma}\right) = z. \tag{16}$$

Because of the symmetry of the cumulative normal distribution, (16) can be rewritten as

$$N\left(\frac{S}{2\sigma}\right) - \left[1 - N\left(\frac{S}{2\sigma}\right)\right] = z. \tag{17}$$

Solving for S, we get

$$FHT \equiv S = 2\sigma N^{-1}\left(\frac{1+z}{2}\right). \tag{18}$$

In the above, $N^{-1}(\,)$ is the inverse function of the cumulative normal distribution.

[30] In our analysis, we calculate this on a yearly basis.

Appendix B

In order to check the validity of the decimalisation as a proxy for liquidity, we regress our liquidity proxies LIQ_{AM} and LIQ_{FHT} respectively on the difference-in-difference variables $DEC * LOWPRC$, DEC and $LOWPRC$. As can be seen in Table VIII, all coefficients on the interactive variable are positive and statistically significant, both in the LIQ_{AM} and LIQ_{FHT} case. The result holds for all price percentile groups. The F-statistics further indicate that all difference-in-difference variables also are jointly statistically significant. As further proof of the validity, we observe that the economic impact of the interactive variable decreases when including more price percentiles. This is logical as stocks in higher price-percentiles should be less affected by decimalisation.[31]

We further note that the R^2 of the regressions are significantly higher when LIQ_{FHT} is the regressand as opposed to when LIQ_{AM} is the regressand. We interpret this as the interactive variable, $DEC * LOWPRC$, being a better proxy for LIQ_{FHT} than for LIQ_{AM}. This is also rather intuitive as a percent-cost proxy should capture the dynamics of decimalisation more than a cost-to-volume proxy.

TABLE VIII

OLS Regressions: liquidity variables as dependent

	LIQ_{AM} as dependent			LIQ_{FHT} as dependent		
	(1)	(2)	(3)	(4)	(5)	(6)
Intercept	-0.063	-0.139 ***	-0.162 ***	0.035	0.011	-0.005
	(0.048)	(0.014)	(0.008)	(4.000)	(5.000)	(6.000)
DEC*LOWPRC	0.291 **	0.169 ***	0.077 ***	0.210 **	0.146 ***	0.106 ***
	(0.117)	(0.025)	(0.012)	(0.068)	(0.035)	(0.022)
DEC	-0.165 **	-0.167 ***	-0.123 ***	-0.082 ***	-0.029	-0.002
	(0.078)	(0.026)	(0.015)	(0.089)	(0.038)	(0.025)
LOWPRC	-0.084 **	-0.049 ***	-0.023 ***	-0.029	-0.031	-0.028
	(0.088)	(0.034)	(0.020)	(0.000)	(0.000)	(0.000)
N	1,464	15,602	41,558	1,464	15,602	41,558
LOWPRC Percentile	1	10	25	1	10	25
Joint F-stat	52.1 ***	368.0 ***	811.0 ***	88.4 ***	1,108.2 ***	3,370.4 ***
Liq. proxy joint F-stat	5.7 ***	32.2 ***	34.2 ***	29.4 ***	427.8 ***	917.2 ***
R^2	0.097	0.066	0.055	0.153	0.176	0.196

All regressions are estimated by OLS. * indicates that the estimate is significant on a 10% level, ** indicates that the estimate is significant on a 5% level, *** indicates that the estimate is significant on a 1% level. Firm fixed effects are included for each regression. The Liq. proxy joint F-stat represents the joint F-test for DEC, $LOWPRC$ and $DEC * LOWPRC$. Reported standard errors are robust and clustered on year and firm level. N represents the number of observations used in the regression.

[31] Previous studies such as Edmans et al. (2013) simply use decimalisation as a dummy. In order to check the validity of this proxy they compare statistical significance between subsamples for stocks above and below the median price in the sample. However, looking at Figure I, we believe that our approach more strongly captures the relationship.

Appendix C

In order to perform our difference-in-difference and 2SLS regressions, we divide our sample in subsamples according to price percentiles. Doing this, it is important that our liquidity proxies $LIQ_{AM_{t-1}}$ and $LIQ_{FHT_{t-1}}$ not show to be differently correlated with repurchase announcement within different subsamples (i.e. showing a different sign of correlation or showing trend in relation to price-percentiles). Hence, we rerunning the regressions in Table II above, but for subsamples based on price-percentiles, i.e. for the price-percentile 1 in Table IX below, we include data on the stocks from the lowest and highest percentile.

TABLE IX

OLS Regressions: *REP* on *LIQ*

Panel A

	(1)	(2)	(3)	(4)	(5)	(6)
Intercept	0.022 ***	0.022 ***	0.024 ***	0.034 ***	0.021 ***	0.031 ***
	(0.004)	(0.004)	(0.005)	(0.004)	(0.000)	(0.000)
***LIQ* AM**	0.030 ***	0.013 ***	0.018 ***	0.025 ***	0.007	0.012 ***
	(0.007)	(0.004)	(0.004)	(0.008)	(0.004)	(0.004)
N	1,439	15,284	40,689	1,439	15,284	40,689
LOWPRC Percentile	1	10	25	1	10	25
Joint F-stat				9.5 ***	29.7 ***	107.5 ***
R-Squared	0.005	0.001	0.001	0.019	0.006	0.008

Panel B

	(1)	(2)	(3)	(4)	(5)	(6)
Intercept	0.022 ***	0.022 ***	0.024 ***	0.034 ***	0.023 ***	0.035 ***
	(0.004)	(0.004)	(0.006)	(0.003)	(0.001)	(0.001)
***LIQ* FHT**	0.075 **	0.038 **	0.022	0.049	0.031	0.052 **
	(0.030)	(0.019)	(0.019)	(0.032)	(0.022)	(0.022)
N	1,439	15,284	40,689	1,439	15,284	40,689
LOWPRC Percentile	1	10	25	1	10	25
Joint F-stat				8.6 ***	29.8 ***	106.3 ***
R-Squared	0.003	0.000	0.000	0.018	0.006	0.008

All regressions are estimated by OLS. * indicates that the estimate is significant on a 10% level, ** indicates that the estimate is significant on a 5% level, *** indicates that the estimate is significant on a 1% level. Firm fixed effects are included for each regression. Reported standard errors are robust and clustered on year and firm level. N represents the number of observations used in the regression. The F-statistic represents a joint significance test for all variables in respective regressions. Price percentiles are calculated as of the first trading day of year 2000. Subsamples based on price-percentiles include the stocks within the bottom and top price percentile.

From the regression output in Table IX, we are however reassured by the fact that we, for all price-percentiles subsamples, still only observe positive correlations between repurchase announcement and $LIQ_{AM_{t-1}}$ and $LIQ_{FHT_{t-1}}$ respectively. Our positive coefficients are robust both with and without year fixed effects included. The coefficients are further statistically significant in the majority of the cases.

Further, we cannot distinguish any clear trend of changed economic significance of the coefficients in relation to increased price-percentile subsamples. Hence, by performing these regressions, we are reassured that the correlation between the liquidity proxies $LIQ_{AM_{t-1}}$ and $LIQ_{FHT_{t-1}}$ and repurchase announcement seem to be unaffected by subsample selection in relation to price.

Appendix D

From Figure II and Figure III below, we see a close-up on the changes in the average liquidity proxies LIQ_{AM} and LIQ_{FHT} for different price-percentile groups (the lowest, i.e. the treatment groups, on the left hand side and the highest, i.e. the control groups, on the right hand side) for the period surrounding the decimalisation. From the graphs, it is obvious that the treatment groups experienced an increase in liquidity around January 29th 2001, substantially larger than the one observed for the control groups, both with respect to LIQ_{AM} and LIQ_{FHT}. These observations reassure us of the validity of the decimalisation proxy.

FIGURE II. AVERAGE OF LIQ_{AM} 2001. STOCKS WITHIN TREATMENT (LEFT) AND CONTROL (RIGHT) GROUPS

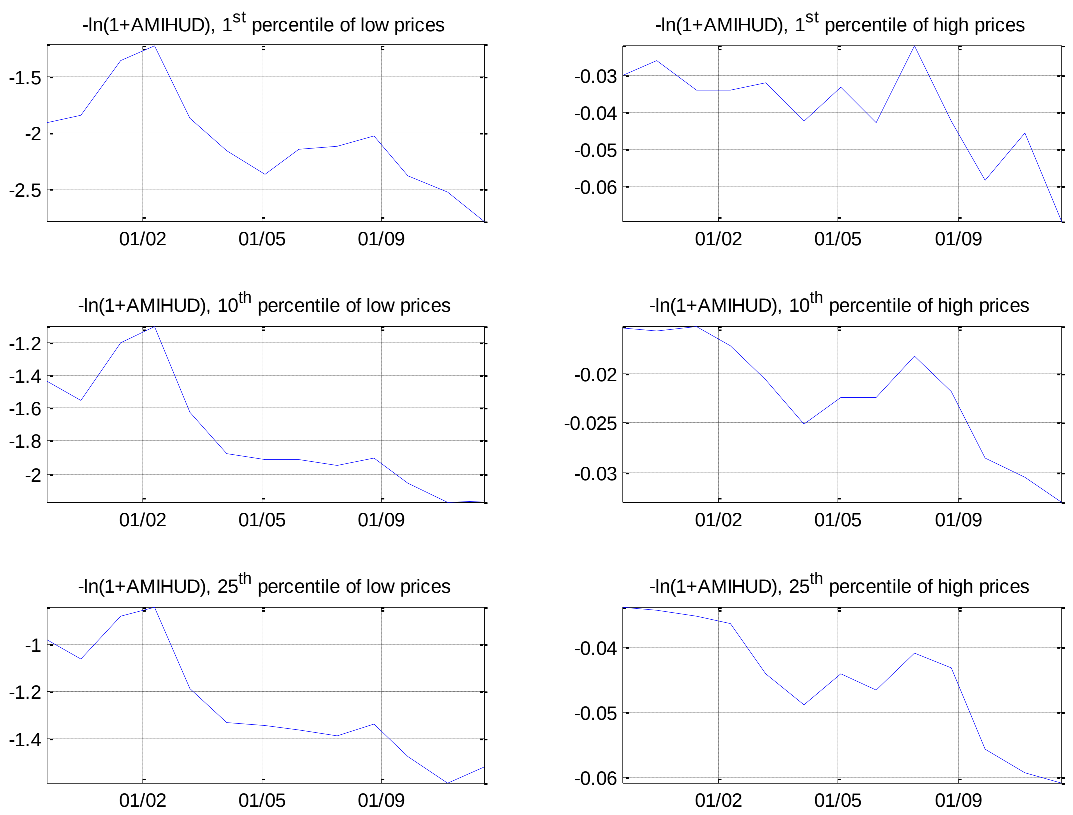


Figure II illustrates the average value of the liquidity proxy LIQ_{AM} for the stocks within the price percentile of lowest price and highest price, surrounding the decimalization on January 29th 2001. Price percentiles are calculated as of the first trading day of year 2000.

Figure III. Average of LIQ_{FHT} 2001. Stocks within treatment (left) and control (right) groups

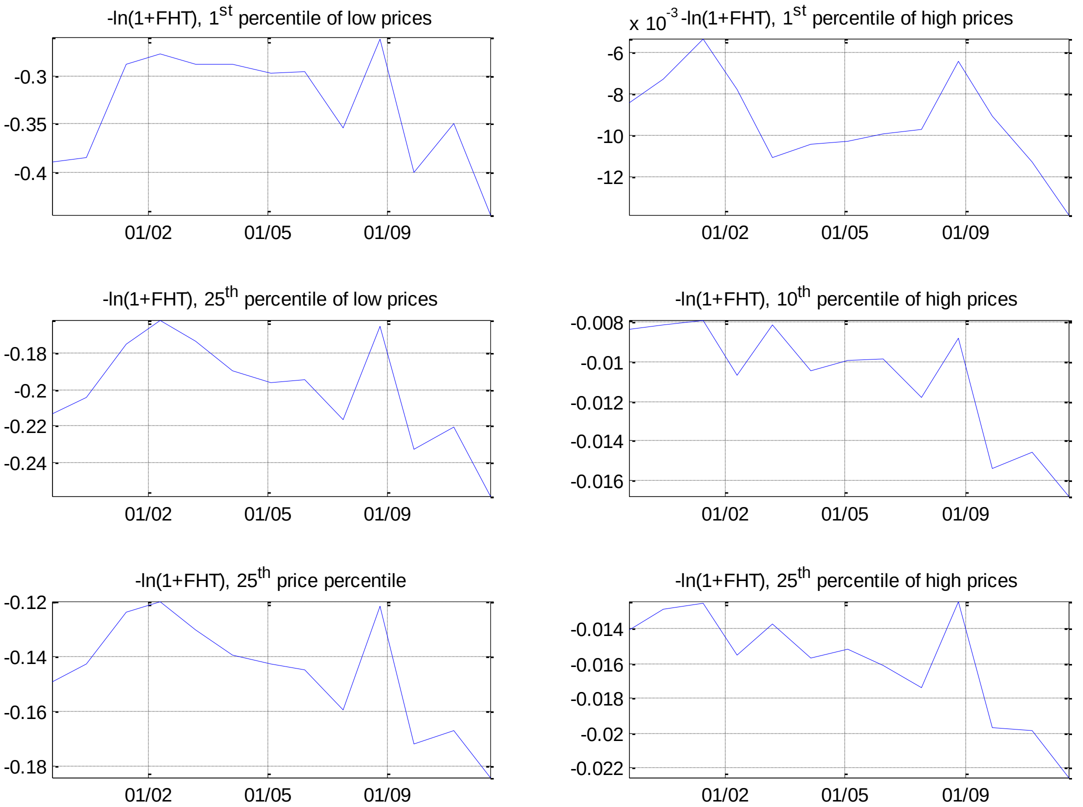


Figure II illustrates the average value of the liquidity proxy LIQ_{FHT} for the stocks within the price percentile of lowest price and highest price, surrounding the decimalization on January 29th 2001. Price percentiles are calculated as of the first trading day of year 2000.

Appendix E

From Figure IV below we see the development of the average liquidity proxies over the entire time period studied (1993-2013). We note that LIQ_{AM} show a more fluctuating liquidity level, whereas LIQ_{FHT} show a more smooth trend. However, neither for LIQ_{AM}, nor for LIQ_{FHT}, we are able to note a trend of decreasing average liquidity just prior to the decimalisation. This is reassuring as it implies that our variables accounting for the decimalisation do not capture any declining pre-trend in the data.

FIGURE IV. LIQ_{AM} AND LIQ_{FHT}, JAN 1ST 1993 – DEC 31ST 2013

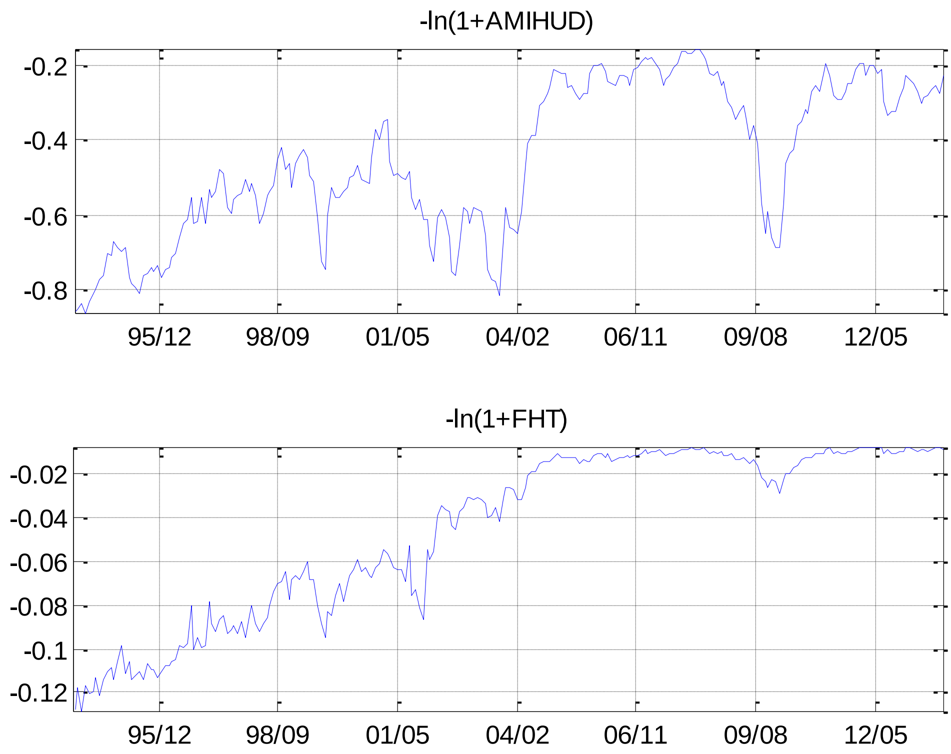


Figure IV illustrates the average values of the liquidity proxies LIQ_{AM} and LIQ_{FHT} over the sample period January 1st 1993 – December 31st 2013.