The effect of stock liquidity on the firm's investment and production

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Abstract

We propose that stock market liquidity affects corporate investment and production. Illiquidity, which raises firms' cost of capital, lowers investment in capital assets, R&D, and inventory. This effect holds after we control for endogeneity using exogenous liquidity events, the 2001 decimalization and the 1997 Nasdaq reform, and after employing instrumental variable estimation. Illiquidity affects investment regardless of firms' financial constraints. Consequently, illiquidity induces firms to adopt less capital-intensive production processes. Illiquid firms have higher marginal productivity of capital, greater labor input increases for given increases in assets, and lower operating leverage, which means lower reliance on fixed costs.

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"The Stock Market and Investment: Is the Market a Sideshow?"

Morck, Shleifer, and Vishny (1990)

1. Introduction

This paper proposes that one channel by which the stock market affects investment and production is through market liquidity. It is well known that illiquidity raises the expected return required by investors,[1] thus raising the cost of capital that managers use in evaluating investment projects. We show that illiquidity lowers corporate investment and leads firms to adopt production processes that are less capital intensive. This results in higher revenue productivity of capital, higher labor input relative to capital, and lower operating leverage and greater reliance on variable costs.

The main takeaway from our results is that secondary market liquidity affects the real economy through its effect on firms' real investment and production processes. We show that reforms in the secondary market trading procedures that improve market liquidity, such as the 1997 Nasdaq market-making reform and the 2001 decimalization, induced higher corporate investment. The results in this paper on the beneficial effects of market liquidity on investment and production suggest a motivation for regulatory reforms and corporate policies that improve liquidity.[2]

Our evidence on the real-economy effects of trading in the secondary market is related to the analysis of Bond, Edmans, and Goldstein (2012). These authors distinguish between the real effects of primary financial markets, where firms raise capital, and the real effects of secondary financial markets where securities are traded and prices are set but there is no active flow of capital to the firm. The real effect of the secondary markets results from a feedback effect proposed by Chen, Goldstein and Jiang (2007) by which managers incorporate in their investment decisions private information that they learn from market prices. We offer another channel of feedback from secondary market price information into real corporate decisions. Managers learn information from the secondary market on their firm's stock liquidity and illiquidity premium and use it to set

[1] See the theory and evidence in Amihud and Mendelson (1986), Brennan and Subrahmanyam (1996), and a review in Amihud, Mendelson, and Pedersen (2013). Damodaran (2002) applies a lower multiple of cash flow when valuing illiquid firms.

[2] We discuss such policies in the concluding section. Liquidity-enhancing policies are suggested in Amihud and Mendelson (1986, 1988). Regulators can increase the secondary market liquidity by improving market trading procedures (see Amihud, Mendelson and Lauterbach, 1997), improving corporate disclosure (Leuz and Wycozki, 2016), and by limiting insider trading which reduces asymmetric information. For a review on the effect of corporate disclosure on liquidity and the corporate cost of capital see Leuz and Wycozki (2016).

the investment hurdle rate, and select investment projects that are commensurate with investors' required return.[3] We find that the negative effect of illiquidity on investment holds regardless of capital raising needs, and after controlling for Chen et al.'s (2007) feedback effect from market prices.

The negative effect of stock illiquidity on corporate investment holds after controlling for firm characteristics (including fixed effects), it holds consistently over time and across all five major industries considered. The negative investment-illiquidity relation remains significant after accounting for potential endogeneity by employing two exogenous liquidity-increasing events, the 2001 decimalization and the 1997 Nasdaq market-making reform. We find that investment increased in firms whose stock liquidity benefited more from decimalization and from the reform. The negative investment-illiquidity relationship also holds when employing an instrumental variable (IV) analysis.

In addition to illiquidity raising the cost of capital, it may constrain firms in raising capital thus inhibiting investment. This alternative channel by which the secondary market affects real activity matters mostly for financially constrained firms; see Morck, Shleifer, and Vishny (1990), and Bond, Edmans, and Goldstein (2012).[4] If illiquidity lowers investment only by exacerbating the firm's financial constraint, its effect should be muted for unconstrained firms; however, if illiquidity also affects investment by raising the cost of capital, it should lower investment even for unconstrained firms. We find that the negative investment-illiquidity relation does not depend on financial constraints and it holds strongly for unconstrained firms. Using ten common measures of financial constraint[5] and following Fazzari, Hubbard, and Petersen (1988) we divide firms by financial constraints into three groups and estimate the investment-illiquidity relation for each group. We find that the negative illiquidity-investment sensitivity is similarly strong for all groups including that of unconstrained firms without any systematic pattern across the groups. Also, the significant negative effect of stock illiquidity on investment remains after controlling for corporate

[3] Our analysis is similar to the traditional analysis of the role of risk in investment decisions, where managers set as a hurdle rate for investment projects the expected return required by investors.
[4] The effect of market liquidity on the firm's cost of raising external capital is studied by Butler, Grullon, and Weston (2005), Gao and Ritter (2010), and Asem, Chung, Cui, and Tian (2016). They find that in seasoned equity offerings (SEOs), investment banking fees are higher and the price discount is greater for firms with less liquid stocks. Over time and across world markets, higher stock market illiquidity negatively affects equity issuance; see Hanselaar, Stulz, and van Dijk (2016).
[5] These measures include management indication of a need to delay investment, stock illiquidity, firm capitalization, asset size, cash distribution, cash flow, cash balances, age, leverage, and the Whited-Wu (2006) measure.

liquidity (cash and marketable assets). The fact that the negative investment-illiquidity relation holds even for firms that are not financially constrained suggests that the effect of illiquidity on investment is through the secondary rather than through the primary market. The results suggest that when selecting projects, even managers that do not need to access the primary market to raise capital would consider the secondary market illiquidity, because it reflects stockholders' required return.[6]

We test the effect of lagged stock illiquidity on investment measured by capital expenditures or changes in total assets, on investment in intangible assets that include research and development expenses (using Peters and Taylor's (2017) measure), and on inventory investment (all scaled by lagged assets). Stock illiquidity is measured by Amihud's (2002) *ILLIQ* or by the relative bid-ask spread (*SPRD*). The results are consistent across measures of investment and of illiquidity. The estimation models include control variables that significantly affect investment: current cash flow and lagged Tobin's Q (following Fazzari et al., 1988), as well as lagged total assets, return volatility, and cumulative two-year stock return. The models also include firm (or industry) fixed effects and year fixed effects. The estimation is over 57 years, 1963 through 2019, and over two subperiods, 1963-1990 and 1991-2019. The negative and significant effect of illiquidity on investment is similar for the entire period and for both subperiods. The negative illiquidity effect is also similar in estimations using industry fixed effects and when using the Fama-MacBeth (1973) cross-section estimation method.

The negative and significant investment-*ILLIQ* relation robustly holds across all five major industries using a one-digit SIC code (excluding financials and utilities). As a robustness test, we estimate the model in *changes* rather than in levels and find that lagged changes in *ILLIQ* have a negative and significant effect on investment, controlling for lagged changes in all control variables and further controlling for lagged changes in investment. And, to mitigate a concern of simultaneity, we estimate the model with the illiquidity variable lagged by two or three years relative to investment. In all estimates, we find a negative and significant effect of illiquidity.

We test another channel by which illiquidity may affect investment: the information feedback effect. Chen, Goldstein and Jiang (2007, p. 620) propose that "managers learn from the private information in stock price when they make corporate investment decisions" and find that

[6] The negative effect of illiquidity on investment is thus similar to the effect of risk, which raises the firm hurdle rate and consequently lowers corporate investment even when the firm has sufficient funds to invest.

the sensitivity of investment to stock price increases in the extent of private information incorporated in the price. Given that illiquidity increases in the extent of traders' private information (see Glosten and Milgrom, 1985; Kyle, 1985), we follow Chen et al.'s (2007) empirical specification and add to our model an interaction term of illiquidity and *Q*. We find that *both* effects are in play. Consistent with Chen et al., the investment sensitivity to the firm's Tobin's Q significantly increases in illiquidity while the direct negative effect of illiquidity on investment remains highly significant.

We deal with concerns of endogeneity or co-determination of illiquidity and investment by studying two exogenous liquidity-improving events. The first is the decimalization of quoted prices in the U.S. exchanges in 2001, which reduced the minimum tick (price increment) from 6.25 cents ($1/16) to 1 cent thus enabling narrower quoted bid-ask spreads. Bessembinder (2003) documents a greater decline in illiquidity following decimalization for stocks with smaller bid-ask spreads. We find that following decimalization, investment increased significantly more for firms whose stock liquidity benefitted most—those whose initial bid-ask spread was smaller. Also, for such stocks the effect of decimalization on investment should have been greater, since by Amihud and Mendelson (1986), required returns decline more for a given fall in the bid-ask spread in stocks with narrower spreads.

The second liquidity-improving event is the 1997 reform in Nasdaq trading. Barclay, Christie, Harris and Kandel (1999) document a significant reduction in the bid-ask spread for Nasdaq stocks with even-eighths quoted prices before the reform due to increased competition of traders with market makers who were allegedly colluding beforehand to raise the spread. We find that for such stocks there was a significant increase in investment after the reform.

We also account for endogeneity by employing an instrumental variable (IV) estimation. Finding a valid instrument is usually challenging. We instrument *ILLIQ* with the concentration of institutional holdings which is known to increase illiquidity; see theory and evidence in Bolton and von Thadden (1998) and Rubin (2007). Yet, the concentration of institutional holdings is not known to affect investment. We find that the instrumented *ILLIQ* has a negative and significant effect on investment.

Our investment model includes lagged *Q* as an explanatory variable which may preclude the use of other explanatory variables following Hayashi's (1982) proposition that investment is sufficiently explained by marginal *Q*, which equals average *Q* under some conditions. However, we find that in addition to the effect of lagged Q on investment there are significant effects of *all* explanatory variables: current cash flow and lagged values of illiquidity, total assets, return volatility, and cumulative two-year stock returns. Our finding is consistent with those of Chen et al. (2007) and Bai et al. (2019) that capital expenditures are significantly affected by a number of lagged firm characteristics in addition to lagged Q. The reason may be that standard average Q, which we use, is different from marginal Q, which the model demands. Although the two are equal when financing is frictionless and profits are linear in capital (Hennessy, Levy, and Whited, 2007), frictionless financing is inconsistent with stock illiquidity. Also, Q is measured with error,[7] potentially because its calculation employs assets' book value which differs from replacement value and does not fully account for intangible capital.[8]

Inventory investment is also negatively affected by the cost of capital but unlike capital investment, it is not affected by Tobin's Q. We thus expect that inventory investment declines in illiquidity, which raises the cost of capital, as is the case for capital investment. Our findings support this prediction. Lagged illiquidity has a significant negative effect on inventory investment after controlling for lagged Q, which has an insignificant effect, and all the other control variables used in the capital-investment model as well as for the change in sales.

Next, we study the real effect of market liquidity on firm production. We propose that the negative effect of illiquidity on investment induces illiquid firms to reduce the capital intensity of their production processes. We find the following:

(1) Illiquidity raises the value of the marginal productivity of capital so that it is commensurate with the higher firm's cost of capital. Empirically, illiquidity raises the sensitivity of sales growth to asset growth and it raises the sales-to-assets ratio.

(2) Illiquidity raises the labor-to-capital marginal rate of substitution reflected in greater increase in labor for a given increase in capital. This result holds for all five main manufacturing industries (using one-digit SIC code). We also find that illiquidity raises the labor/capital ratio. These results follow from our earlier finding that illiquidity inhibits investment, thus inducing firms to

[7] The use of Tobin's Q as a measure incorporating all the information on managerial quality is challenged by the evidence in Edmans, Goldstein, and Jiang (2012).

[8] Still, the negative investment-*ILLIQ* relation remains practically unchanged when using Peters and Taylor's (2017) "total Q" whose calculation accounts for intangible assets. The adjustment employs capitalized values of research and development expenditures and part of selling, general and administrative expenditures, all duly depreciated over time.

economize on their use of capital and switch to more labor-intensive production processes.

(3) Illiquidity lowers the firm's operating leverage, which is the extent of its reliance on fixed costs in production. We find that illiquidity raises the response of operating expenses to change in sales implying greater reliance on variable cost.

Our findings that firms' decisions on investment and production deviate from those that would be selected if their stock were liquid contribute to explaining the negative effect of illiquidity on firm value (Fang, Noe and Tice, 2009).

Our analysis is in line with studies on the real effects of financial markets, presented in Bond, Edmans, and Goldstein (2012)[9] and with the results of Goldstein, Yang and Zuo (2020). Employing a quasi-natural experiment—the implementation of the Electronic Data Gathering, Analysis, and Retrieval (EDGAR) system in the United States in the years 1993-1996—they find that it significantly improved stock liquidity and raised corporate investment. Studies on the effects on investment of deletion/additions of stocks from/to the S&P 500 and the FTSE 100 indexes find conflicting results. Whereas Becker-Blease and Paul (2006) find that firms whose stock was added to the S&P 500 index enjoyed an increase in stock liquidity and they increased their investment, Gregoriou and Nguyen's (2010) study of firms whose stock was deleted from the FTSE 100 index concludes that "deletion from a major stock index does not influence corporate investment decisions" (p. 267).[10] Notably, additions and deletions of firms from indexes are often not random, and may affect firms' information environment, and are therefore a confounded setting for testing how liquidity shocks affect investment.

The paper proceeds as follows. In section 2, we present evidence on the effect of the firm's stock illiquidity on investment. Section 3 presents evidence on the effect on investment of stock decimalization in 2001 and of the 1997 Nasdaq reform and test results on the effect of instrumented illiquidity on investment. Section 4 includes tests on the effects of stock illiquidity on a number of production processes of the firm, including its effect on the productivity of capital, the labor/capital ratio and the extent of operating leverage. Concluding remarks are offered in section 5.

[9] Bond, Goldstein, and Prescott (2009) analyze how managers incorporate into their decision-making process information from stock prices that are forward looking and partially reflect illiquidity.

[10] Bogachek, Bonacchi and Zarowin (2021) find that European public firms invest more than private firms after controlling for corporate determinants of investment, which is consistent with our results since public firms' stock is more liquid. Asker, Farre-Mensa and Ljungqvist (2015) find opposite results for U.S. firms. They explain their results by comparatively greater short-termism pressures on public companies that distort their decisions. In our analysis all firms are public and subject to the same pressures.

2. The effect of illiquidity on corporate investment

We estimate the effect of stock illiquidity on the firm's investment. We use Fazzari et al.'s (1988) model that explains the firm investment by contemporaneous cash flow and lagged Tobin's Q with firm fixed effects and time fixed effects and augment it by lagged explanatory variables:

$$INV_{j,t} = \mathbf{b1*ILLIQ_{j,t-1}} + b2*CF_{j,t} + b3*Q_{j,t-1} + b4*TA_{j,t-1} + b5*VOL_{j,t-1} + b6*RET2_{j,t-1} + firm\ FE + year\ FE. \quad (1)$$

$INV_{j,t}$, the investment of firm *j* in year *t*, equals *CEx*, capital expenditures, or *CExRD*, the sum of *CEx* and investment in research and development (R&D), both scaled by lagged total assets. *CExRD* is called "total investment" by Babenko et al. (2011) and is used by Chen et al. (2007) and Becker and Stromberg (2012). Our analysis employs annual values over a period of 57 years, 1963-2019. In addition, we analyze investment in intangible assets and in inventory.

We focus on the effect of lagged illiquidity, measured by Amihud's (2002) *ILLIQ*, and hypothesize that $b1 < 0$; that is, investment is a declining function of the firm's stock illiquidity. $ILLIQ_{j,t}$ is the (logarithm of the) average ratio of the daily absolute return to dollar volume for stock *j* in year *t*. *ILLIQ* is highly correlated with Kyle's (1985) theoretical measure of illiquidity, λ, the price impact of trades, and with the fixed cost of trading resulting from the bid-ask spread.[11] In calculating the annual average *ILLIQ*, we exclude trading days with volume of less than 100 shares and require that a stock has at least 150 trading days for the year. To avoid outliers, we delete 1% of the daily observations with the highest values of *ILLIQ* in each stock-year.[12] As a robustness test, we replace $ILLIQ_{j,t}$ with $SPRD_{j,t}$, the bid-ask spread (in logarithm) calculated as the dollar quoted spread divided by the quote's midpoint, averaged over the days of year *t*. Data for *SPRD* are available from CRSP[13] since the end of 1992, and thus we use the 1993 average spread for cross-sectional analysis that begins in 1994. Consequently, the sample size is smaller. The estimation results for $SPRD_{j,t-1}$ are presented in the appendix.

The control variables include contemporaneous cash flow, *CF*, following Myers and

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[11] This evidence is shown in Amihud (2002). Hasbrouck (2009) and Goyenlo et al. (2009) find that *ILLIQ* is highly correlated with Kyle's (1985) λ and with the effective bid-ask spread, Lesmond (2005) finds that in international markets *ILLIQ* is among the best low-frequency proxy measures of the bid-ask spread plus commissions, and Fong, Holden and Trzcinka (2017) find that *ILLIQ* is among the best low-frequency estimates of λ.

[12] If a firm has more than one trading stock, we assign to it the stock with the lowest ILLIQ. This applies to about 1% of the stocks.

[13] Chung and Zhang (2014) find that CRSP-based and TAQ-based data on the bid-ask spread are similar.

Majluf (1984) and Fazzari et al. (1988) who propose that firms invest first from available internal resources. *CF* is net income (before extraordinary items) plus depreciation and amortization, scaled by lagged total assets. All other explanatory variables are lagged by one year. *Q* (an estimate of Tobin's Q) is the market value of assets at the end of the calendar year divided by the book value of assets, where the market value of assets is defined as the market value of equity plus book value of assets minus book value of equity and balance-sheet deferred taxes (following the definition in Fang et al., 2009). This variable reflects growth opportunities and positively affects investment. *TA* is total assets (in logarithm), a measure of firm total size. *VOL* is volatility or risk, the standard deviation of weekly stock returns calculated over the year. Volatility positively affects the cost of capital, and thus it should negatively affect investment as does *ILLIQ*. *RET2* is the two-year cumulative stock return, which captures recent change in market expectations about the firm's opportunities, and thus its coefficient is expected to be positive. The inclusion of the control variables *TA*, *VOL* and *RET2* is necessary because in addition to their direct effect on investment, they are correlated with illiquidity. *TA* and *RET2* are negatively correlated with *ILLIQ*, and *VOL* is positively correlated with it. Omitting these variables may lead to the "missing variable problem" by which their effect on investment is erroneously attributed to *ILLIQ* with which they are correlated. *RET2* also controls for the effect of market sentiment on investment, following Morck et al.'s (1990, p. 167) proposition that a rise in the firm's stock price improves its access to cheaper financing through the stock market.[14]

Our sample includes firms whose stock traded on the New York Stock Exchange (NYSE) and the American Stock Exchange (AMEX) during 1963-2019. We conduct a separate analysis for firms whose stock traded on Nasdaq during a shorter period, 1998-2019, which follows the Nasdaq reform that enabled direct trading between buyers and sellers, similar to the trading regime on the NYSE and AMEX. Before that, trading volume (used to calculate *ILLIQ*) was usually double counted, reflecting buying and selling through market makers. We exclude firms in the financial industry (SIC code 6000-6999) and utilities (code 4900-4999), and we exclude REITs and firms with ADR whose stock is traded on a foreign market. We also exclude firm years if the assets or sales more than doubled or halved in that year. We require that firms have total assets of

[14] Morck et al. (1990) propose that an improved sentiment about a constrained firm, reflected in a rise in its stock price, can lead to increased investment. Although we control for the effect of a lagged rise in stock price by using $RET2_{j,t-1}$, a fall in illiquidity may be interpreted as a temporarily improved sentiment that leads to increased investment in constrained firms. These alternative explanations are not mutually exclusive and can all co-exist.

at least $10 million and share price of at least $1 at the beginning of the year, and we winsorize all variables at the 1% level on both tails of their distribution.

INSERT TABLE 1

Table 1 presents statistics for our data. (The table includes some variables whose construction is detailed below when employed in estimations.) Our sample includes 64,798 firm-years except for the data on $SPRD_{j,t-1}$ which includes 28,971 firm years.

INSERT TABLE 2

The estimation results of Model (1), presented in Table 2, strongly support our hypothesis that corporate investment is negatively related to lagged stock illiquidity. Panel A presents results for the entire sample period for NYSE-AMEX stocks. The coefficient of $ILLIQ_{j,t-1}$ is negative and significant, being -0.009 (t = -13.91) and -0.009 (t = -13.46) for $INV_{j,t} = CEx_{j,t}$ and $CExRD_{j,t}$, respectively. The economic significance of the estimated effects of illiquidity is illustrated as follows. A one-standard-deviation increase in *ILLIQ* (controlling for firm fixed effects)[15] lowers subsequent investment relative to assets, measured as either *CEx* or *CExRD*, by 0.015. This effect is sizable given that the mean of *CEx* is 0.076 and the mean of *CExRD* is 0.094, implying a decline of about 1/5 to 1/6 in investment in response to an increase of one standard deviation in *ILLIQ*. In Panel E we present estimation results of Model (1) by the Fama-MacBeth (1973) method, replacing the firm fixed-effects with industry fixed-effects. In this estimation, the coefficients of $ILLIQ_{j,t-1}$ are -0.004 (t = -12.54) and -0.008 (t = -14.61) for $INV_{j,t} = CEx_{j,t}$ and $CExRD_{j,t}$, respectively. By these estimates, a one-standard-deviation increase in *ILLIQ* across firms lowers investment measured as *CEx* by 0.010 and lowers *CExRD* by 0.020.

The results are similar for illiquidity measured by *SPRD* (logarithm of the average bid-ask spread): the coefficient of *SPRD* is negative and significant in all regressions, see Appendix Table A1. For example, the coefficient *b1* of $SPRD_{j,t-1}$ is -0.008 with t = -6.84 for $INV_{j,t} = CEx_{j,t}$. As noted, the data for *SPRD* which begins in 1994 includes less than a half of the years and the firm-years used for tests with *ILLIQ* as a measure of illiquidity. As for the economic effect of the estimates, a one-standard-deviation[16] increase in *SPRD* lowers *CEx* by 0.010, which is close in magnitude to the effect of *ILLIQ*.

[15] The standard deviation of *ILLIQ* after controlling for firm fixed effects is 1.71. For the annual cross-firm estimates in Panel E, the standard deviation of *ILLIQ* is calculated after controlling for year fixed effects; then, the standard deviations is 2.48.

[16] We use the standard deviation of *SPRD* after controlling for firm fixed effects, which is 1.24.

The control variables' coefficients have the predicted signs. $CF_{j,t}$ (cash flow) and $Q_{j,t-1}$ have positive and significant effects on investment as found by Fazzari et al. (1988). The effect of $VOL_{j,t-1}$—return volatility—is negative and significant, similar to the negative effect of $ILLIQ_{j,t-1}$. Both illiquidity and risk raise the firm's cost of capital and, thus, have negative effects on investment.[17] Investment is lower for larger firms (with higher $TA_{j,t-1}$) and higher for firms with better past stock performance (higher $RET2_{j,t-1}$), which captures expectations about future growth. The significant effects on investment of the control variables, which are correlated with $ILLIQ_{j,t-1}$, highlight the importance of not omitting them from a model that is intended to estimate the effect of $ILLIQ_{j,t-1}$.

In addition to the illiquidity's direct negative effect on investment, it negatively affects *Q* (Fang et al. (2009)), which in turn positively affects investment. In our estimation, the effect of $ILLIQ_{j,t-1}$ is already conditional on the contemporaneous $Q_{j,t-1}$. Here, we estimate separately this indirect channel of effect on *CEx* of *ILLIQ* through its prediction of *Q*. First, we estimate Model (1) with $Q_{j,t}$ as the dependent variable, omitting $Q_{j,t-1}$ from the right-hand side. The coefficient of $ILLIQ_{j,t-1}$ is -0.149 with t = -13.96. Since the coefficient *b3* (the effect of $Q_{j,t-1}$ on $CEx_{j,t}$) is 0.005, the indirect effect of *ILLIQ* on *CEx* through its negative effect on *Q* is -0.0007 (= 0.005*-0.149), which is substantially smaller than the direct effect of *ILLIQ* on *CEx*.

We replicate our analysis measuring investment by *dTA*, the annual change in total assets scaled by lagged total assets as do Chen et al. (2007), which reflects changes that may be voluntary or involuntary. The variable *dTA* is positive due to capital expenditures, investment in current assets and acquisitions, or it can be negative following a spinoff or asset sale when the proceeds are distributed to shareholders or used to redeem debt. An asset sale decision can possibly be affected by a rise in illiquidity, which raises the hurdle rate and leads the firm to divest. But *dTA* may be positive or negative for other reasons. It may be positive following an asset sale at a gain over book value, or it may be negative because of involuntary impairment of value. Not all these changes in asset values are driven by considerations related to stock illiquidity. We find that *dTA* < 0 for 27% of the firm years in our sample.

Estimating Model (1) with $INV_{j,t} = dTA_{j,t}$ we find again that illiquidity significantly lowers investment. The coefficient of $ILLIQ_{j,t-1}$ is -0.025 with t = -12.12. When measuring illiquidity by

[17] When adding to the model risk measured by β, using the estimates provided by CRSP for year t-1, its effect is positive while the coefficients of $ILLIQ_{j,t-1}$ and $SPRD_{j,t-1}$ remain negative and highly significant.

$SPRD_{j,t-}$, its coefficient is -0.038 with t = -6.79. We also replicate the analysis where $dTA_{j,t}$ includes only firm-years where $dTA_{j,t} \geq 0$, which is more likely to reflect voluntary action by firms. This constraint reduces the sample to 47,113 firm-years. We find that the coefficient of $ILLIQ_{j,t-1}$ is -0.019 with t = -9.12, again highly significant.

2.1. Robustness tests

2.1.1. Tests across industries

In Panel B of Table 2, we test whether the negative investment-illiquidity relation holds across industries by estimating Model (1) separately for each of the five major one-digit SIC code industries. While the firm fixed effects subsume the industry effects in terms of the level of investment, the slope coefficients may vary across industries. We use SIC codes 1 through 5, which are, respectively, mining and construction; two types of manufacturing; transportation, communication, electric, gas, and sanitary services; and retail and wholesale trade. Results are presented for *INV* = *CEx*. We find that *all* five coefficients of *ILLIQ* are negative and significant, varying between -0.006 (t = -8.80) and -0.019 (t = 5.64). We conclude that our result on the negative investment-illiquidity relationship applies to all five industry groups.

2.1.2. Consistency over time

In Panel C, we examine the consistency over time of the negative *INV-ILLIQ* relationship by splitting the sample into two subperiods and estimating the model separately for each subperiod. Also, given that firm fixed effects are assumed to control for time-invariant firm characteristics,[18] a shorter estimation period makes this assumption more reasonable because some firm characteristics may change over time. We find that the coefficient of *ILLIQ* is negative and significant in *both* subperiods. For *INV* = *CEx*, the coefficients of *ILLIQ* are -0.011 (t = -12.02) and -0.007 (t = -9.78) for the first and second subperiod, respectively. Similarly, for *INV* = *dTA* the coefficients of $ILLIQ_{j,t-1}$ for the first and second subperiods are -0.029 (t = -11.20) and -0.027 (t = -7.79), respectively. We conclude that the negative effect of illiquidity is consistent over time.

2.1.3. The effect on Nasdaq firms

In Panel D, we estimate the model for Nasdaq stocks. The data begins in 1998, after the

[18]See Roberts and Whited (2012).

Nasdaq market-making reform that enabled direct trading between stockholders in a way similar to that done on the NYSE and AMEX, which makes the estimated *ILLIQ* for Nasdaq similar to that for NYSE and AMEX. Notably, Nasdaq accommodates relatively younger firms in developing industries (such as high tech) that are different from those firms listed on NYSE\AMEX. Thus, a separate estimation of the investment-illiquidity relation for Nasdaq firms tests our hypothesis for a different type of firms.

The results in Panel D show the results for Nasdaq firms to be similar to those for NYSE\AMEX firms. The coefficient of *ILLIQ* is negative and highly significant. We also estimate the model for *INV* = *dTA* and find that the effect of *ILLIQ* is negative and highly significant. In Appendix Table A1, Panel B, we present the results for Nasdaq firms with *SPRD* replacing *ILLIQ*. There, too, we find that the *INV-SPRD* relationship is negative and significant.

2.1.4. Using industry fixed effects instead of firm fixed effects

We estimate Model (1) by replacing firm fixed effects with *industry* fixed effects that employ Fama and French's 49-industry classification.[19] The estimation is done by two methods: a panel regression and annual cross-section Fama-MacBeth regressions. Roberts and Whited (2013) propose performing model estimations with and without firm fixed effects and checking whether the estimated coefficients change in a meaningful way between the two models, which can indicate if a low-frequency, unobserved omitted variable affects the results. The authors also suggest that estimation without firm fixed effects may provide a better understanding of the cross-sectional effects of the variables, because a model with firm fixed effects estimates the within-firm variation rather than the cross-sectional variation that is of interest. Panel E presents the estimations of Model (1) which include *industry* fixed effects instead of firm fixed effects and employ both panel regressions and annual cross-section Fama-MacBeth (1973) regressions where the annual cross-section coefficients are averaged over the 57 sample years.[20]

We find that the coefficients of *ILLIQ* in these estimations are similar to those in Panel A in both magnitude and statistical significance. This finding suggests that the model is unlikely to

[19] Firms that are not assigned to an industry according to this classification (less than 0.5% of observations) are assigned to the "Other" industry.

[20] The standard errors in the panel regression are clustered by firm and by year. In the tests by the Fama-MacBeth procedure, the standard errors of the average coefficients employ the Newey-West (1987) procedure (with one lag) to account for possible serial correlation in the estimated coefficients.

omit an unobservable variable that affects the results.[21] For example, for *INV* = *CExRD*, the coefficient of *ILLIQ* in the panel regression here is -0.009 (t = -10.91) with industry fixed effects, compared with -0.009 (t = -13.46) in a model with firm fixed effects (Panel A). Results with illiquidity measured by *SPRD* are presented in Appendix Table A1, Panel C. There again, the effect of illiquidity is negative and significant and the magnitudes of the coefficients are similar to those in Panel A, where we use firm fixed effects. Employing the Fama-MacBeth estimation procedure, we again find that the coefficients of *ILLIQ* and *SPRD* are negative and highly significant with magnitudes that are close to those presented in Panel A for panel regressions with firm fixed effects. We also estimate the model with $INV_{j,t} = dTA_{j,t}$ and find similar results. For the Fama-MacBeth cross-section regressions procedure, with industry fixed effects, the coefficient of $ILLIQ_{j,t-1}$ is -0.012 with t = -10.14.

2.1.5. Estimating the model with *changes* in all variables

In this robustness test we convert all variables in Model (1) from levels to changes (first difference) and estimate the model without firm fixed effects.[22] We add to the model lagged changes in investment following Eberly, Rebelo, and Vincent's (2012, p. 370) suggestion that the "lagged-investment effect is empirically more important than the cash-flow and *Q* effects combined." Panel F of Table 2 presents the coefficients of $dILLIQ_{j,t-1}$ and those of the lagged investment changes; the coefficients of all the variables are presented in Appendix Table A2 with the prefix *d* indicating the first difference of the variable. The models include only year fixed effects.

We find that in the model with $dINV_{j,t} = dCEx_{j,t}$, the coefficient of $dILLIQ_{j,t-1}$ is negative and highly significant, being -0.008 with t = -11.58. The magnitudes of these estimates are close to those in Panel A for the levels of the variables in a model that includes firm fixed effects. When we add the lagged dependent variable $dINV_{j,t-1}$ to the model, the coefficient of $dILLIQ_{j,t-1}$ is -0.010 with t = -13.45. The coefficient of the lagged dependent variable $dINV_{j,t-1}$ is significantly negative, indicating partial reversals of investment, which is often bulky and changes intermittently in large increments. The coefficients of all other variables retain their sign and significance, as in Panel A.

[21] Roberts and Whited (2012) point out that in investment regressions, fixed effects rarely matter qualitatively, because investment is roughly the change in capital, so the fixed effect is differenced out.

[22] Roberts and Whited (2012) suggest this form of regression as a useful alternative to a panel regression with firm fixed effects when the model residuals are potentially correlated with unobserved characteristics.

2.1.6. Controlling for corporate liquidity: The level of cash and changes in cash

Corporate liquidity—cash and marketable securities—may affect investment and may also be correlated with stock liquidity. We, thus, re-estimate Model (1), augmenting it by including $Cash_{j,t-1}$, the level of cash and marketable securities, or $dCash_{j,t-1}$, the annual change in $Cash_{j,t-1}$, both scaled by lagged total assets.

We find in Panel G that the effect of *ILLIQ* on investment remains negative and highly significant. With $Cash_{j,t-1}$ as a control variable, the coefficient of $ILLIQ_{j,t-1}$ is -0.009 with t = -13.95, and it is negative and significant for each of the two subperiods. The coefficient of $Cash_{j,t-1}$ is -0.006 with t = -1.60. Similarly, when we add $dCash_{j,t-1}$ to Model (1), the coefficient of $ILLIQ_{j,t-1}$ remains negative and significant for the entire period and for the two subperiods, whereas the coefficient of $dCash_{j,t-1}$ is negative and significant for the entire period and for the first subperiod, and it is insignificant for the second subperiod; see Panel G.

Our results, thus, show that the effect of stock illiquidity on investment remains negative and highly significant after controlling for corporate liquidity. Below, we present findings that the negative investment-illiquidity sensitivity is similar when estimating the model separately for firms with high or low corporate liquidity.

2.1.7. Inventory investment

In standard inventory models, optimal inventory declines in its carrying cost that includes the cost of capital. We, thus, expect that inventory investment declines in illiquidity, which raises the cost of capital. Notably, Tobin's Q is not expected to affect inventory investment, and therefore, it is not included in the inventory investment models of Carpenter, Fazzari, and Petersen (1994) and of Jones and Tuzel (2013). Jones and Tuzel (2013) find that inventory growth is a declining function of the firm's implied cost of capital that is derived from projected future firm earnings based on analysts' expectations or earnings forecasting models.[23] They attribute their result to the effect of risk premium on the cost of capital. We test the effect of both illiquidity and risk on inventory investment and find that they both have negative and significant effects.

[23] Kashyap, Lamont, and Stein (1994) find that a firm's balance-sheet liquidity—cash and short-term investments divided by total assets—positively affects inventory investment. Carpenter et al. (1994) find that cash-flow liquidity positively affects inventory investment. Our analysis employs the market liquidity of the firm's claims.

We estimate Model (1) with $INV_{j,t} = dINVTRY_{j,t}$, the change in inventory in year t, scaled by lagged total assets. The model is augmented by $dSales_{j,t}$, the annual change in sales scaled by lagged total assets, following Carpenter et al.'s (1994, p. 76) suggestion that "inventory investment is positively correlated with contemporaneous sales shocks."

INSERT TABLE 3

In Table 3, we find that $ILLIQ_{j,t-1}$ has a negative effect on inventory, which is similar to its effect in the investment model of Table 2. The coefficient of $ILLIQ_{j,t-1}$ is -0.005 with t = -10.75 for the entire period, and it is -0.006 (t = -9.53) and -0.003 (t = -7.24) for the first and second subperiods, respectively. Notably, the effect of $Q_{j,t-1}$ is not robust, and its coefficient is altogether negative, as opposed to being positive and significant in the capital-investment model. The negative coefficient of $Q_{j,t-1}$ is significant for the entire period but insignificant for each of the two subperiods. The effect of past stock returns, *RET2*, which may predict better future prospects for the firm, is positive and significant. The effect of volatility, *VOL*, is negative and significant, which is consistent with Jones and Tuzel's (2013) results. The effects of $dSales_{j,t}$ and $Cash\ Flows_{j,t}$ are positive and significant, consistent with Carpenter et al. (1994). When we add $dSales_{j,t-1}$ to the model, its coefficient is 0.003 with t = 1.34, which is insignificant.

We re-estimate the model measuring illiquidity by $SPRD_{j,t-1}$ instead of $ILLIQ_{j,t-1}$ and find that the coefficient of $SPRD_{j,t-1}$ is -0.005 with t = -6.56.

We conclude that illiquidity has a negative and significant effect on inventory investment, similar to its effect on capital investment. In both cases, the negative effect of illiquidity can be explained by its effect on the firm's cost of capital, which negatively affects investment.

2.1.8. Using illiquidity lagged by two and three years

We estimate the effect on current investment of *ILLIQ* lagged by *two* years or *three* years relative to investment, which mitigates concerns about a simultaneous co-determination of investment and illiquidity. We estimate Model (1) replacing $ILLIQ_{j,\mathrm{t}-1}$ with its value lagged by two or three years, $ILLIQ_{j,\mathrm{t}-2}$ or $ILLIQ_{j,\mathrm{t}-3}$, while leaving all other variables at a one-year lag as before; $CF_{j,t}$ is contemporaneous. We find that the effect on investment of lagged *ILLIQ*, which is persistent, remains negative and significant when it is lagged further back by two or three years. For $INV_{j,\mathrm{t}} = CEx_{j,\mathrm{t}}$, we find:

(i) Two-year lag: The coefficient of $ILLIQ_{j,\mathrm{t}-2}$ is -0.006 with t = -9.29.

(ii) Three-year lag: The coefficient of $ILLIQ_{j,t-3}$ is -0.003 with t = -4.41.

The results are similar for $INV_{j,t} = CExRD_{j,t}$. We replicate this estimation for inventory investment, $dINVTRY_{j,t}$, using Model (1) augmented by $dSales_{j,t}$ and find that the negative effect of two- and three-year lagged illiquidity remains negative and significant:

(i) Two-year lag: The coefficient of $ILLIQ_{j,t-2}$ is -0.003 with t = -7.53.

(ii) Three-year lag: The coefficient of $ILLIQ_{j,t-3}$ is -0.002 with t = -4.28.

2.1.9. Investment in intangible assets

We now use as a dependent variable $InvInt_{j,t}$, the investment in intangible assets, in knowledge capital and in organizational capital. Following Peters and Taylor (2017), $InvInt_{j,t}$ is the sum of R&D spending plus a fraction of the firm's selling, general, and administrative (SG&A) expenditures,[24] scaled by $TA^{tot}_{j,t-1}$, the sum of the physical assets and the intangible assets at replacement cost (the cumulative past investment in intangible assets depreciated at an industry-specific rate) and the book value of property, plant and equipment (Compustat PPEGT item). We also estimate the determinants of $RDex_{j,t}$, the spending on R&D alone scaled by $TA^{tot}_{j,t-1}$. The explanatory variables include $TA^{tot}_{j,t-1}$, $Q^{tot}_{j,t-1}$, Peters and Taylor's (2017) Tobin's Q which accounts for intangible assets in the denominator, and cash flow $CF^{tot}_{j,t}$ defined as net income (before extraordinary items) plus depreciation and amortization scaled by $TA^{tot}_{j,t-1}$. Data for $Q^{tot}_{j,t}$ and the firm's intangible assets (at replacement cost) are obtained from Wharton Research Data Services (WRDS). The sample includes 46,151 firm-years between 1976 and 2017 after applying the sample selection criteria suggested by Peters and Taylor (2017).

The estimation results, presented in Appendix Table A3, show that the coefficient of $ILLIQ_{j,t-1}$ remains negative and highly significant. For $InvInt_{j,t}$ and $RDex_{j,t}$ as dependent variables, the coefficients of $ILLIQ_{j,t-1}$ for NYSE-AMEX stocks are, respectively, -0.006 (t = -11.64) and -0.001 (t = -7.38). The results are similar for Nasdaq stocks.

2.2. The information feedback effect

Another channel by which stock illiquidity may affect investment follows from the feedback effect proposed by Chen, Goldstein and Jiang (2007). Managers glean from their firm's

[24] SG&A expenditures include advertising and brand support, spending on customer relationships, employee training, and payments to strategy consultants.

stock price the information provided by the trading of informed traders and use it in their investment decision. "[A] positive relation between the investment sensitivity to stock price and the amount of private information incorporated into the price by speculators would imply that the private information in price is new to managers and that managers look at the price to learn this information and use it in their investment decisions" (p. 620). Chen et al. (2007) test whether corporate investment increases in $INFO_{j,t-1}*Q_{j,t-1}$, where $INFO_{j,t-1}$ is the private information in the stock price. They find a positive and significant effect of this interaction term, meaning that the investment-*Q* sensitivity increases in the extent of private information in prices.

For *INFO*, Chen et al. (2007) use two measures which are linked to stock illiquidity and largely reflect adverse selection cost due to information asymmetry between informed traders—those possessing private information—and liquidity traders who are uninformed. Glosten and Milgrom (1985) and Kyle (1985) propose that illiquidity, measured by the bid-ask spread or the price impact of trading, results from asymmetric information between informed and uninformed traders. Chen et al.'s first measure is the ratio of return idiosyncratic variance to the total variance. Benston and Hagerman (1974) find that the bid-ask spread increases in the idiosyncratic risk while not being affected by the systematic risk, and Ho and Stoll (1981) show theoretically that the bid-ask spread rises in idiosyncratic risk because of market makers' risk aversion. Evidence shows a positive correlation between idiosyncratic return variance and illiquidity measures including *ILLIQ*; see Spiegel and Wang (2005) and Han and Lesmond (2011).

The second measure of *INFO* used by Chen et al. (2007) is PIN, the probability of informed trading, derived from the asymmetry in the arrival rate of orders from informed and uninformed traders (Easley, Keifer and O'Hara (1996), Easley, Keifer, O'Hara and Paperman (1996)). Easley, Hvidkjaer, and O'Hara (2002) find that PIN is positively and significantly correlated with the bid-ask spread and Duarte and Young (2009) find that *ILLIQ* subsumes the effect of PIN, with which it is positively correlated, in explaining expected return. Ferreira, Ferreira and Raposo (2011) find that both PIN and *ILLIQ* have similar explanatory power as measures of stock price informativeness, and Balarkrishnan et al. (2017) find that PIN, *ILLIQ* and *SPRD* are similarly affected by corporate disclosure. Bakke and Whited (2010) propose that PIN captures liquidity. In summary, PIN is positively related to illiquidity both theoretically and empirically.[25]

[25] Bond et al. (2012, p. 353) point out that Chen et al. (2007) show that "the sensitivity of investment to price (or Tobin's Q) is stronger when there is more private information injected into the price in the trading process (based on

INSERT TABLE 4

We augment Model (1) by $INFO_{j,t-1}*Q_{j,t}$, where *INFO* is either *ILLIQ* or *SPRD*. By Chen et al. (2007), the coefficient of $INFO_{j,t-1}*Q_{j,t-1}$ is positive. Our estimation supports this hypothesis. For $INV_{j,t} = CEx_{j,t}$, the coefficient of $ILLIQ_{j,t-1}*Q_{j,t-1}$ is 0.001 with t = 4.12 and the coefficient of $SPRD_{j,t-1}*Q_{j,t-1}$ is 0.002 with t = 3.78. For $INV_{j,t} = CExRD_{j,t}$, the coefficient of $ILLIQ_{j,t-1}*Q_{j,t-1}$ is 0.001 with t = 2.62, and the coefficient of $SPRD_{j,t-1}*Q_{j,t-1}$ is 0.002 with t = 3.45. Throughout, the coefficients of $ILLIQ_{j,t-1}$ and $SPRD_{j,t-1}$ remain negative and highly significant. For example, for $INV_{j,t} = CEx_{j,t}$, the coefficient of $ILLIQ_{j,t-1}$ is -0.010 with t = -13.39. Thus the indirect positive feedback effect of $ILLIQ_{j,t-1}$ on $CEx_{j,t}$ offsets about 1/10 of the direct negative effect of $ILLIQ_{j,t-1}$ for Q =1.0. For $INV_{j,t} = dTA_{j,t}$, as used by Chen et al. (2007), we find that the coefficient of $ILLIQ_{j,t-1}*Q_{j,t-1}$ is 0.004 with t = 3.53 and the coefficient of $ILLIQ_{j,t-1}$ is -0.029 with t = -12.32. Here, the indirect positive feedback effect of $ILLIQ_{j,t-1}$ on $dTA_{j,t}$ offsets about 1/7 of the direct negative effect of $ILLIQ_{j,t-1}$ for Q = 1.0.

We add a falsification test to verify the learning channel. Cash flows are known to be positively correlated with Tobin's Q (since both are correlated with the firm's investment opportunity set) but do not incorporate informed traders' private information. Thus, showing that the results on the interaction effects of *INFO* (measured by illiquidity) with Tobin's Q do not replicate with cash flows would help support the learning channel. For that end, we re-estimate the model in Table 4, which is Model (1) augmented by $INFO_{j,t-1}*Q_{j,t-1}$, adding the term $INFO_{j,t-1}*CF_{j,t-1}$. The results, presented in Appendix Table A5, support the learning channel, since all the coefficients of $INFO_{j,t-1}*CF_{j,t-1}$ are insignificantly different from zero. Using $INV_{j,t} = CEx_{j,t}$, these coefficients for *INFO* = *ILLIQ* and SPRD are, respectively, 0.002 (t = 0.87) and 0.002 (t = 0.38). Using $INV_{j,t} = CExRD_{j,t}$, the respective coefficients are 0.001 (t = 0.36) and -0.001 (t = -0.06). At the same time, the coefficients of $ILLIQ_{j,t-1}*Q_{j,t-1}$ remain positive and significant for both measures of $INV_{j,t}$ and both measures of $INFO_{j,t}$. Also, the coefficients of $ILLIQ_{j,t-1}$ are negative and significant as before.

Our findings, thus, support two channels by which illiquidity affects investment: Investment declines in the cost of capital which rises in illiquidity, and investment is positively related to the extent of private information incorporated in stock prices, which is positively related

market microstructure measures)." *ILLIQ* and *SPRD* are market microstructure measures of asymmetry between private and public information.

to illiquidity.[26]

2.3. Financial constraint and the effect of illiquidity

We have proposed that illiquidity lowers investment, because it raises the hurdle rate on investment projects. Another explanation for the negative effect of stock illiquidity on investment is that illiquidity indicates financial constraint. Morck et al. (1990) and Bond, Edmans, and Goldstein (2012) propose that the stock market affects firms' investment behavior through its effect on the issuance of new securities to finance investment. The question is whether it follows that illiquidity more strongly affects investment in financially constrained firms.

Following the methodology of Fazzari et al. (1998), we divide firms in each year into three groups by lagged measures of financial constraint and estimate Model (1) separately for each group. First, we sort firms by Hoberg and Maksimovic's (2015) measure $Delaycon_{j,t-1}$, derived from textual analysis of the section of Managerial Discussion and Analysis in the 10-K report. It indicates that "firms with higher values are more similar to a set of firms known to be at risk of delaying their investments due to issues with liquidity." The data are available from the authors' website and include 15,917 firm-years for our sample between 1998 and 2016. We also sort firms by either stock illiquidity, *ILLIQ*, or by -1**Equity Capitalization*, which is positively correlated with *ILLIQ*. Higher values of *ILLIQ* and -1**Equity Capitalization* may indicate higher financial constraint. We estimate Model (1) using $INV_{j,t} = CEx_{j,t}$.

We propose that if the negative effect of $ILLIQ_{j,t-1}$ on investment is due to illiquidity reflecting financial constraint, its coefficient *b1* should be more negative for firms with greater financial constraint, while being negligibly small for firms that are unconstrained. However, if the channel by which illiquidity lowers investment is by raising the corporate cost of capital, *b1* should be negative and significant for both constrained and unconstrained firms.

INSERT TABLE 5

In Table 5.1 we find that the negative and significant investment-*ILLIQ* relation holds for all three groups sorted on *Delaycon*, *ILLIQ* or -1**Equity Capitalization*. To save space, we present only the coefficient of $ILLIQ_{j,t-1}$ and $CF_{j,t}$. For the constraint measures that span the entire sample

[26] Our finding that the investment-to-price sensitivity increases in measures of illiquidity is consistent with the finding in Goldstein et al. (2020). They show that following the implementation of the EDGAR system, which lowered illiquidity, there was a decline in the investment-to-price sensitivity..

period 1963-2019, we also present results for the two subperiods, 1963-1990 and 1991-2019, that examine whether our results are consistent over time. In Appendix Table A4, we present the complete results with coefficients for all the variables.

We find that for all classifications of firms by measures of constraint, the coefficient *b1* of $ILLIQ_{j,t-1}$ is negative and significant for all three financial-constraint groups, including for the group of the least constrained firms. For the first classification by Hoberg and Maximovic's (2015) $Delaycon_{j,t-1}$ measure of the need to delay investment, *b1* is more negative for more constrained firms: moving from low-constraint to high-constraint firms, *b1* is -0.005 with t = -4.09 and -0.009 and t = -4.40, respectively; the difference between the coefficients is insignificant.[27] However, for the classification by $ILLIQ_{j,t-1}$, the coefficient *b1* has an opposite pattern: Moving from the lowest-*ILLIQ* to the highest-*ILLIQ* group, *b1* is -0.015 (t = -9.69), -0.010 (t = -8.92), and -0.007 (t = -8.80), respectively, with the difference between the coefficients being statistically significant. The same pattern holds in each of the two subperiods, and it also holds when moving from big to small firms, that is, from the least constrained to the most constrained firms.

The more negative investment-*ILLIQ* sensitivity for financially-constrained firms, as observed for the *Delaycon* measure, as well as for some measures of constraint in Table 5.2 below, is consistent with the secondary market liquidity facilitating capital raising (Edmans et al., 2012). The greater investment-*ILLIQ* sensitivity for firms with the more liquid stocks is consistent with Amihud and Mendelson's (1986) theoretical prediction and empirical evidence on the greater positive effect of illiquidity costs on expected return for more liquid stocks,[28] which leads to a more negative effect on corporate investment for firms with liquid stocks.

In Table 5.2 we use seven other measures of financial constraint to split our sample and estimate Model (1) for each group. Three of these measures indicate the availability of corporate liquidity: *Cash Distribution* equals dividends plus stock purchases divided by market value of equity, following Fazzari et al. (1988); *Cash Flow* is income before extraordinary items plus depreciation divided by lagged total assets; and *Cash Balance* is cash and cash equivalents divided by total assets. For all these measures, a higher value means a lesser need for external financing

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[27] The test for the difference between b1 coefficients of the low and high constraint groups employs the estimated standard errors of the coefficients.

[28] Amihud and Mendelson (1986) propose that because more liquid stocks are held in equilibrium by frequently-trading investors, the required return on liquid stocks responds more strongly to a given increase in illiquidity costs, a prediction supported by empirical evidence. Their evidence shows that the positive effect of illiquidity cost (the bid-ask spread) on return is six times greater for the lowest-illiquidity stocks than it is for stocks with the highest illiquidity.

and a lower constraint. Next, following Hovakimian and Titman (2006), we use *Age*, the number of years from IPO, and *Firm Size*, measured by total assets, because younger and smaller firms are more financially constrained.[29] *Leverage* is the sum of long-term and short-term debt minus cash, divided by total assets; higher debt overhang may indicate constraint. Finally, *Whited-Wu* is a weighted average of the firm's characteristics using Whited and Wu's (2006) model and estimated weights. We multiply the last two measures by -1 so that lower value implies greater financial constraint, thus, making the presentation consistent with that of the other measures.

In Table 5.2 we find that *b1*, the coefficient of $ILLIQ_{j,t-1}$, is negative and highly significant for all three groups of financial constraint. In particular, *ILLIQ* negatively affects investment even for the least-constrained firms. The pattern of the coefficient *b1* is not consistent across the three terciles for all measures of constraint. For some measures, *b1* decreases with financial constraints, for others, it increases and for some, there is no monotonic pattern across the constraint terciles. In particular, *b1* is significantly more negative and less negative for constraint measured by *Firm Size* and by *Leverage*, respectively.

For the *dINVTRY-ILLIQ* sensitivity, results are presented in Table 5.3 using Model (1) augmented by $dSales_{j,t}$ as we do in the model estimated in Table 3. For sake of parsimony, we present results for five measures of financial constraint: *Delaycon*, *Cash Distribution*, *Age*, *Firm Size*, and *Whited-Wu*. *Delaycon* and *Whited-Wu* are multiplied by -1 to make their ranking consistent with that of the other variables. We find that the coefficient *b1*— the *dINVTRY-ILLIQ* relation—is negative and significant for both financially-constrained and financially-unconstrained firms. For *Delaycon*, *b1* is more negative for the least constrained firms while for *Firm Size* and *Whited-Wu*, *b1* is significantly more negative for more constrained firms. For the other measures there is no clear pattern across the constraint terciles.

In summary, even for unconstrained firms that can raise funds more easily or that have available internal resources, illiquidity has a significant negative effect on investment in capital assets and in inventory. This finding supports our view that the channel by which illiquidity affects investment is through its effect in raising the expected return required by investors and the firm's cost of capital.

3. Controlling for endogeneity

[29] We identify the IPO year as the first year in which share price is available on annual Compustat data.

We account for potential endogeneity of illiquidity in two ways. We study the differential effect across firms of two exogenous liquidity-improving events—the decimalization of quotes in 2001 and the Nasdaq reform of 1997—and we employ an instrumental variables (IV) method to conduct a 2SLS estimation of Model (1), testing whether the instrumented *ILLIQ* has a negative effect on investment.

3.1. The effect of decimalization

The 2001 decimalization of quoted stock prices enabled trading at minimum price increments of $0.01 compared to $1/16 or $0.0625 beforehand. Consequently, the minimum bid-ask spread could decline from $0.0625 to $0.01, leading to lower trading costs. Decimalization started on January 29, 2001 for NYSE-AMEX stocks and on April 9, 2001 for Nasdaq stocks.

Bessembinder (2003) finds that the decline in quoted and effective dollar bid-ask spreads after decimalization was greater for stocks that initially had narrower spreads for which decimalization relaxed the lowest bound constraint of $0.0625 on the dollar spread. We thus expect that stocks whose initial spread was more often quoted at the minimum tick experienced a greater decline in their expected return or in their cost of capital. Also, the decline in the cost of capital should be stronger for firms with a narrower spread based on Amihud and Mendelson's (1986) theory and evidence that the expected return-illiquidity sensitivity is greater for more liquid stocks. By the investors' clientele effect, stocks with a lower bid-ask spread are held by frequently trading stockholders who value liquidity more and, thus, more liquid stock should realize a greater decline in required return for any given decline in the bid-ask spread.

We propose that there was a greater increase in investment for firms with narrower pre-decimalization bid-ask spreads. Our test is based on Model (1), employing the methodology suggested by Roberts and Whited (2012) and Becker and Stromberg (2012). We estimate the following model over the years 1999-2003 that straddle the decimalization year 2001, skipping the decimalization year 2001.

$$INV_{j,t} = \boldsymbol{b1*Post*SPD_j} + b2*CF_{j,t} + b3*Q_{j,t-1} + b4*TA_{j,t-1} + b5*VOL_{j,t-1} + b6*RET2_{j,t-1} + \text{Firm FE} + \text{Year FE} \qquad (2)$$

Post is a dummy variable that equals 1 for the two post-decimalization years 2002-2003. SPD_j captures the "treatment" variable, using either of the following two variables that are based on the *pre*-decimalization quoted dollar bid-ask spread of the firm's stock:

(i) $P625_j$ is the proportion of quoted dollar spread at 6.25 cents or $1/16 during the period. Spreads of stocks with a higher value of $P625_j$ were more often constrained before decimalization by the minimum tick of $1/16.

(ii) $LoSP_j$ is a dummy variable which equals 1 if the average quoted dollar spread of stock *j* is in the bottom quartile, and zero otherwise. Stocks with $LoSP_j = 1$ are viewed as "treated" stocks whose liquidity was more likely to improve after decimalization.

The variables are calculated for each stock over the period January-July[30] of 2000 using the TAQ database.[31] The variables $P625_j$ and average spread are calculated daily using data between 9:30 am and 4:00 pm, and then, we average the variables across the trading days from January 1 to July 31 of 2000. The mean of $P625_j$ is 0.248, the interquartile range is 0.129-0.335 with a standard deviation of 0.16, and the lowest quartile of the average bid-ask spread is $0.132. The sample includes 1,348 NYSE-AMEX and Nasdaq firms that satisfy data requirements and have data for the two pre-Decimalization years, 1999 and 2000, and for at least one year in the post-Decimalization, 2002-03. There are 5,252 firm-years in the sample.

We expect that $b1 > 0$. This means that following decimalization, firms whose stocks were quoted with narrower bid-ask spread increased investment by more because their bid-ask spread declined by more, which induced a greater decline in their cost of capital.

INSERT TABLE 6

The results are presented in Table 6. In Panel A, which shows estimates for model (2), the coefficient *b1* is positive and significant for both measures of SPD_j. For $INV_{j,t} = CEx_{j,t}$ (columns (1)-(2)), the estimated *b1* for $P625_j$ and $LoSP_j$ is, respectively, 0.024 (t = 2.78) and 0.006 (t = 2.01).[32] For $INV_{j,t} = CExRD_{j,t}$, the respective values of *b1* are 0.034 (t = 3.32) and 0.010 (t = 2.81). By the results in Column (2), the firms with the more liquid stocks—those in the lowest quartile of bid-ask spread—whose liquidity improved more by the decimalization increased their investment by 0.006 compared with the more illiquid stocks. This is economically meaningful,

[30] We end in July because a few NYSE stocks participated in the SEC experiment at the end of 2000, and also delete one stock that had average quoted spread of less than 6.25 cents before the end of July from the sample.
[31] We use National Best Bid and Offer (NBBO) data compiled from TAQ by Wharton Research Data Services (WRDS) and delete quotes with zero or missing bid or ask price or bid or ask size, quotes in which the bid price is greater than or equal to the ask, and quoted spreads greater than $5. Similar quote exclusion criteria are used by Holden and Jacobsen, (2014).
[32] Standard errors are clustered by firm given the paucity of clusters in this regression that includes only four years. See a discussion on this issue in Cameron and Miller (2015).

given that the average $CEx_{j,t}$ over the two pre-decimalization years is 0.079. For $INV_{j,t} = CExRD_{j,t}$, the increase in investment for firms in the lowest quartile of bid-ask spread was 0.010, which is meaningful relative to 0.122, its pre-decimalization average level.

We conduct a falsification test by estimating Model (2) over two sets of time periods that follow the 2001 decimalization event. In Set 1, the "pre" and "post" two-year periods are 2002-2003 and 2005-2006 (skipping 2004), respectively, and in Set 2, the respective "pre" and "post" periods are 2003-2004 and 2006-2007 (skipping 2005). SPD_j, which indicates a lower dollar spread is either mSP_j, which is minus the average spread, or $LoSP_j$ that equals 1 for stocks whose average spread is in the lowest quartile, as before. The dollar spread is estimated over January-July of 2003 for Set 1 and over January-July of 2004 for Set 2. In the decimalization test, a lower dollar spread—higher *SPD*—in the "pre" period predicts a higher investment in the "post" period, captured by $b1 > 0$. The results for the falsification test are different. In Appendix Table A6 we find that the coefficient *b1* is mostly insignificantly different from zero and in one case it is negative and significant. Thus, in the falsification test, a lower dollar spread in the "pre" period does not predict a higher investment in the "post" period.

The adjustment speed of investment to the to the exogenous decline in illiquidity following the decimalization is tested by the following model:

$$CEx_j = b11*Yr00*SPD_j + b12*Yr02*SPD_j + b13*Yr03*SPD_j + Control\ variables$$
$$+ \text{Firm FE} + \text{Year FE}. \qquad (2.1)$$

Yr00, *Yr02* and *Yr03* are dummy variables that equal 1 in 2000 (the year before decimalization), 2002 and 2003, respectively. Model (2.1)[33] estimates the investment response compared to the base year 1999 (two years before decimalization) for the stocks that benefited more from decimalization. We expect that both *b12* and *b13* are positive, meaning that investment in the two post-decimalization years is higher than in 1999 for treated firms.

The estimation results of Model (2.1) are presented in Figure 1. Both *b12* and *b13* are positive and significantly greater than zero, indicating an increase in investment (relative to that in 1999) for treated firms after decimalization, while *b11* that accounts for the pre-decimalization year is insignificant (the tests use a 0.10 confidence interval).[34] These results suggest a sustainable

[33] The methodology follows that of Giroud (2013).

[34] Setting a confidence interval of 0.10 is a stringent parallel-trends test since it leads to a more frequent rejection of $b11 = 0$.

and significant rise in investment following decimalization for firms whose stock was quoted at a narrower spread before decimalization, which made them benefit more from the decline in the lower bound on the spread's quoted value.

INSERT FIGURE 1

For inventory investment, the effect of decimalization is similar. We estimate Model (2) with $INV_j = dINVTRY_j$, with the control variables as in Table 3. For $SPD_j = P625_j$ and $LoSP_j$, the coefficient $b1$ is, respectively, 0.039 (t= 4.74) and 0.012 (t = 4.59), suggesting that firms that benefited more from the exogenous improvement in liquidity increased more of their inventory investment.

3.2. The effect of the Nasdaq reform

We test the effect of the 1997 Nasdaq reform on investment of Nasdaq firms, following evidence that the reform lowered the bid-ask spreads in this market. Christie and Schultz (1994, 1999) find that Nasdaq dealers avoided quoting odd-eighths prices, which resulted in the inside bid-ask spreads being at least $0.25 (or multiples of $0.25) for some Nasdaq stocks, suggesting a tacit collusion to inflate the spreads. They also find that when dealers in a stock started using odd-eighth quotes routinely, there was a decline in inside spread of that stock. The Nasdaq reform enabled all investors to display their limit orders which competed with the dealers' quotes, leading to narrower bid-ask spreads. Barclay, Christie, Harris, Kandel and Schultz (1999, Table II) find that following the reform, inside bid-ask spreads declined for stocks whose bid and ask prices were both quoted in even-eighths prices beforehand. They conclude (p. 14): "… the decline in the avoidance of odd-eighth quotes has a significant and dramatic impact on the width of average inside spreads." Therefore, we expect a greater improvement in liquidity—a greater decline in the bid-ask spread—for stocks that were more frequently quoted in even-eighths before the reform.

We estimate the following model:

$$INV_{j,t} = \boldsymbol{b1*Post*f(Even8_j)} + b2*CF_{j,t} + b3*Q_{j,t-1} + b4*TA_{j,t-1} + b5*VOL_{j,t-1} + b6*RET2_{j,t-1} + \text{Firm FE} + \text{Year FE} \quad (3)$$

$Even8_j$ is the proportion of quotes where *both* bid and ask prices are even-eighths prices. $Even8_j$ is estimated from June to December of 1996, just before the reform. We consider all quoted prices between 9:30 am and 4:00 pm on each trading day using the TAQ database and define as $Even8_j$ the average of the daily proportion of quotes where both bid and ask prices are at even-eighths between June 1 and December 31 of 1996.[35] For *f*($Even8_j$) we use either $LEven8_j = \ln(1 + Even8_j)$ or $HiEven8_j$ that equals 1 if $Even8_j$ is above the median and 0 otherwise. A higher value of *f*($Even8_j$) implies a greater likelihood of a decline in the bid-ask spread after the reform. *Post* is a dummy variable that equals 1 in the two post-reform years 1998 and 1999 and it equals 0 in the two pre-reform years 1995 and 1996, skipping the reform year of 1997. The sample consists of 599 Nasdaq stocks and 2,286 firm-years. The much smaller number of firm-years in this analysis is expected to reduce statistical significance. The estimation results are presented in Table 7.

INSERT TABLE 7

We find higher investment for firms with higher *f*($Even8_j$), that is, for firms whose stock's inside bid-ask spread was more likely to decline after the Nasdaq reform. Investment increased by 0.013 with t = 2.16, which is significant,[36] for stocks with $HiEven8_j$. This increase is economically meaningful given that the average CEx_j was 0.095 during the two pre-reform years. For $CExRD_j$, the coefficient of $HiEven8_j$ is 0.017 with t = 2.17, which is nearly 1/10 the average $CExRD_j$ during the two pre-reform years, which is 0.155. The coefficients for $LEven8_j$ are similarly positive and significant, being 0.031 (t = 1.87) and 0.049 (t = 2.48) for CEx_j and $CExRD_j$, respectively.

We conduct a falsification test by estimating Model (3) over two sets of time periods that follow the 1997 Nasdaq reform. In Set 1, the "pre" and "post" two-year periods are, respectively, 1998-1999 and 2000-2001 (skipping 2000), and in Set 2, the respective "pre" and "post" periods are 1999-2000 and 2002-2003 (skipping 2001). As before, *f*($Even8_j$) is either $LEven8_j$ or $HiEven8_j$. The values of $Even8_j$ are estimated over June-December of 1999 for Set 1 and over June-December of 2000 for Set 2.[37] In the Nasdaq reform test, the coefficient *b1* of *Post*f*($Even8_j$) is positive and significant, implying a higher post-reform investment for firms whose stock's bid and ask prices were both quoted more often at even-eighths before the reform. This is not the case for the falsification tests; see the results in Appendix Table A7. In none of these tests is the coefficient *b1* significantly different from zero.

[35] We use the same quote exclusion criteria as in our decimalization analysis, and delete quotes with zero or missing bid (ask) price or bid (ask) size, quotes in which the bid price is greater than or equal to the ask, and quoted spreads greater than $5; see footnote 31 above.
[36] Standard errors are clustered by firm, see footnote 32 above.
[37] The mean *Even8* is 0.115 and 0.103 for Set 1 and Set 2, respectively, and the respective values of *Even8* for the third quartile are 0.173 and 0.140. During the periods of the falsification test, the minimum tick size was reduced to $1/16 and then to $0.01.

We estimate the speed of adjustment of investment to the exogenous decline in illiquidity by the following model:

$$CEx_j = b11*Yr96*f(Even8_j) + b12*Yr98*f(Even8_j) + b13*Yr99*f(Even8_j) + \textit{Control variables} + \text{Firm FE} + \text{Year FE}. \quad (3.1)$$

Yr96, *Yr98* and *Yr99* are dummy variables that equal 1 in 1996 (the year before the reform), 1998 and 1999, respectively. We expect that both *b12* and *b13* are positive, meaning that investment in the two post-reform years is higher than in 1995 for treated firms.

The estimation results, presented in Figure 2, support our hypothesis. Both *b12* and *b13* are positive and significantly greater than zero, indicating a higher investment that was sustainable over the two post-reform years by firms whose stock liquidity improved more by the Nasdaq reform. The coefficient *b11* for the pre-reform year is insignificantly different from zero.

INSERT FIGURE 2

Finally, we test the effect on inventory investment of the liquidity improvement after the Nasdaq reform by estimating Model (3) with INV_j = $dINVTRY_j$ with $dSales_{j,t-1}$ added to the explanatory variables. We find that the coefficient of $LEven8_j$ is 0.049 with t = 3.41, and the coefficient of $HiEven8_j$ is 0.019 with t = 3.37, suggesting that firms whose stock liquidity benefited more from the reform had a greater increase in inventory investment.

3.3. Instrumental variable (IV) estimation

We employ an IV estimation as another way to deal with endogeneity. We instrument *ILLIQ* by the concentration of institutional investors' holdings of the firm's stock, denoted *CIH*. While *CIH* strongly explains *ILLIQ*, there is no theory or evidence suggesting that *CIH* affects investment. This satisfies the exclusion restriction as proposed by Edmans, Goldstein and Jiang (2012).[38]

Theory and evidence suggest that *CIH* positively affects *ILLIQ*. Bolton and von Thadden (1998) propose that *CIH* is associated with a lower level of market making activity and with a greater information asymmetry, which both lead to lower liquidity. Rubin (2007, p. 221) proposes

[38] Edmans, Goldstein, and Jiang (2012, p. 935) state that "any variable that is directly associated with the firm's characteristics or management would not qualify as an instrument since it is directly related to both the price and the probability of a takeover [.]" which in their research are the explanatory variable and the dependent variable, respectively. The instrument "satisfies the exclusion restriction—the econometric requirement of being correlated with the [price] discount but not directly with the probability of a takeover." (The addition in brackets is ours.)

that "ownership concentration proxies for information asymmetry as ownership concentration measures quantify the incentives of few shareholders to obtain, analyze, and trade on information," and finds that stock illiquidity is rising in *CIH*. Blume and Keim (2012) propose that an "increase in the number of institutional holders of a stock decreases the average number of shares of the stock held by individual institutions and, thereby, reduces the potential size of a trade and its accompanying liquidity-induced impact."[39]

We measure *CIH* by two variables: (i) *HHI*, the Herfindahl-Hirschman index of institutional investors' holdings, calculated as the sum of the squared values of the fraction of each institutional holding of the total share outstanding; and (ii) *Breadth*, following Chen, Hong and Stein (2002), is the ratio of the number of institutions holding the stock to the number of all institutional investors in the sample at that time. Goldstein et al. (2020) propose that a broader investor base attracts liquidity to the secondary market. We obtain from Thomson Reuters Institutional Holdings data on institutional ownership reported by the 13F filing for the last quarter of each year. If the number of shares outstanding is missing on Thomson, we use the shares outstanding reported on CRSP for December of that year. We exclude cases where the total number of shares owned by institutional investors exceeds the number of shares outstanding. Both *HHI* and *Breadth* are in logarithm and we use -*Breadth* so that the effects of both *HHI* and -*Breadth* on *ILLIQ* are in the same direction. Valid values of $HHI_{j,t}$ and $Breadth_{j,t}$ are available for 31,448 firm-years for the period 1979-2019. The two variables are naturally related. In a regression of $HHI_{j,t}$ on $-Breadth_{j,t}$, in a model that includes firm and year fixed effects, the coefficient of $-Breadth_{j,t}$ is 0.700 with t = 61.57, and the partial R^2 is 0.126.

In the first stage of the 2SLS analysis, we estimate Model (1) with $ILLIQ_{j,t-1}$ as the dependent variable (instead of it being among the explanatory variables), adding to the explanatory variables $CIH_{j,t-1}$ which is either $HHI_{j,t-1}$ or $-Breadth_{j,t-1}$. The results are presented in columns (1) and (4), respectively, of Table 8. The coefficients of $HHI_{j,t-1}$ and $-Breadth_{j,t-1}$ are both positive and significant being, respectively, 0.499 with t = 13.29 and 0.538 with t = 11.01, which is consistent with both theory and evidence.[40]

[39] In addition, Heflin and Shaw (2000) find that block holdings by non-manager investors increase illiquidity while illiquidity does not affect block holding. Velury and Jenkins (2006) find that concentrated institutional ownership lowers earnings quality, which raises information asymmetry and illiquidity.

[40] The high correlations that we find in this estimation between the explanatory variables and *ILLIQ* highlight the importance of controlling for these variables in estimating the effect of *ILLIQ* on *INV* lest their effect would be confounded with that of *ILLIQ*.

INSERT TABLE 8

In the second stage, we estimate Model (1) replacing $ILLIQ_{j,t-1}$ with $FILLIQ_{j,t-1}$, the fitted value of $ILLIQ_{j,t-1}$ from the first-stage regression. The results in Table 8 show that $FILLIQ_{j,t-1}$, the instrumented value of $ILLIQ_{j,t-1}$, has a negative and significant effect on investment. For $CEx_{j,\text{t-1}}$,we find that for $CIH_{j,\text{t-1}} = HHI_{j,t-1}$ (column 2) , the coefficient of $FILLIQ_{j,t-1}$ is -0.013 with t = -6.26 and for $CIH_{j,t-1}$ = -$Breadth_{j,t-1}$ (column 5), the coefficients of $FILLIQ_{j,t-1}$ is -0.013 with t = -6.02. The results are similar for $CExRD_{j,t}$.

For inventory investment, $dINVTRY_{j,\text{t}}$, we follow the same procedure using Model (1) that is augmented by $dSales_{j,\text{t}}$ and the instrument $CIH_{j,\text{t-1}}$. We find that the coefficient $FILLIQ_{j,t-1}$ for $CIH_{j,\text{t-1}}$, being $HHI_{j,t-1}$ and -$Breadth_{j,t-1}$, is, respectively, -0.006 with t = -4.12 and -0.006 with t = -3.37. The results thus show that instrumented *ILLIQ* has a negative and significant effect on investment in capital assets and in inventory.

4. The effect of illiquidity on the firm's production process

We present a novel link between the stock market and the firm's production process. We propose that market illiquidity makes firms select production processes that are less capital intensive because illiquidity lowers capital investment. Specifically, greater stock illiquidity induces the following outcomes:

1) Higher marginal revenue productivity of capital.
2) Higher labor/capital marginal rate of substitution and higher labor/capital ratio.
3) Lower operating leverage or the extent of fixed costs in production, which includes fixed costs due to all types of investment.

<u>Test 1</u>: Marginal revenue productivity of capital

We hypothesize that illiquidity raises the marginal revenue productivity of capital, MRPK. A profit-maximizing firm sets the level of capital input such that MRPK equals its cost of capital. A higher cost of capital due to illiquidity induces lower usage of capital so as to equate the value of its marginal productivity, which is decreasing in capital, to its higher cost. Therefore, MRPK increases in illiquidity. We test this hypothesis in two ways. In the first test, we estimate a model where MRPK is measured as the change in sales relative to the change in capital:

$$dSales_{j,t} = b1*ILLIQ_{j,t-1} + b2*dTA_{j,t} + \boldsymbol{b3*ILLIQ_{j,t-1}*dTA_{j,t}} + b4*Q_{j,t-1} + b5*TA_{j,t-1}$$

$$+ b6*VOL_{j,t-1} + b7*RET2_{j,t-1} + firm\ FE + year\ FE\ , \quad (4)$$

where $dSales_{j,t}$ and $dTA_{j,t}$ are the annual change in sales and in total assets, respectively, both scaled by lagged total assets, and $MRPK_{j,t} = b2 + b3*ILLIQ_{j,t-1}$. Ignoring illiquidity, $MRPK_{j,t}$ is measured by *b2* which is obviously positive. We test whether $b3 > 0$, that is, whether illiquidity raises MRPK.

INSERT TABLE 9

The estimation results of Model (4) in Table 9, Panel A support our hypothesis. We find that *b3* is 0.046 with $t = 9.01$ and that it is positive and significant in each of the two subperiods. For robustness, we estimate the model without firm fixed effects and find that $b3 = 0.048$ with $t = 9.03$. The results are similar when replacing the firm fixed effects with industry fixed effects. These results support our proposition that higher illiquidity, which raises the cost of capital, makes the firm select a production process with a higher marginal revenue productivity of capital.

As an alternative measure for MRPK we use Hsieh and Klenow's (2009) model that allows for friction in capital markets, which raises the cost of capital. They assume a Cobb-Douglas production function with constant returns to scale, $Y = AK^{\alpha}L^{(1-\alpha)}$, where Y, L and K are output, labor and capital, respectively, and A is a constant. The firm's profit is $\Pi = PY - wL - (1+c_K)*rK$, where P is output price, w is market labor cost, r is the market cost of capital, and c_K is an assumed cost of friction in the capital market, which raises the firm's cost of capital. In our case, c_K indicates the firm-specific illiquidity premium required by capital providers—the holders of its capital claims—that increases in illiquidity. The firm optimally sets its output so that the marginal revenue productivity of capital MRPK is $\alpha*PY/K = (1+c_K)*r$. Thus, for a given production function, the firm's MRPK, which is proportional to the revenue/capital ratio PY/K, increases in c_K. Intuitively, a higher cost of capital due to illiquidity induces producing more output per unit of capital.

We test whether MRPK is an increasing function of *ILLIQ* by estimating Model (1) with the dependent variable $Sales_{j,t}/TA_{j,t}$, which is proportional to $MRPK_{j,t}$.[41] We hypothesize that $b1 > 0$ meaning that $Sales_{j,t}/TA_{j,t}$, the output value per unit of capital, increases in $ILLIQ_{j,t-1}$. The estimation results in Panel B of Table 9 support our hypothesis. The coefficient *b1* of $ILLIQ_{j,t-1}$ is

[41] An alternative variable to *Sales* is value added which equals sales minus purchased inputs such as raw materials; however, these data are unavailable hence we assume that purchased inputs are proportional to *Sales* for a given firm. Our panel estimation with firm fixed effects tests the effect of illiquidity for a given firm over time.

0.023 with t = 5.45 for the entire sample period, and it is positive and significant for each of the two subperiods, indicating consistency over time.

We employ the decimalization event of 2001 to test the effect of an exogenous change in stock liquidity on the firm's production process. We estimate Model (2) with the dependent variable being $Sales_{j,t}/TA_{j,t}$. For $SPD_j = P625_j$, the coefficient of $Post*SPD_j$ is -0.114 (t= -2.71), indicating that firms whose liquidity improved by decimalization increased the capital intensity of production, which lowered output per unit of capital. For $SPD_j = LoSP_j$, the coefficient of $Post*SPD_j$ is negative, -0.021, but insignificant, t = -1.26.

Testing the effect of the Nasdaq reform on the firm's production process we estimate Model (3) with the dependent variable being $Sales_{j,t}/TA_{j,t}$. We again expect that the coefficient of $f(Even8_j)$ is negative. We find for $f(Even8_j) = LEven8_j$ and $HiEven8_j$ that the coefficient of $Post*f(Even8_j)$ is, respectively, -0.065 with t = -0.78 and -0.051 with t = -1.79, (significant at the 0.10).

In both cases, the results suggest that firms, whose liquidity improved by decimalization or by the Nasdaq reform increased the capital intensity of production, reflected in lower output per unit of capital.

<u>Test 2</u>: The change in labor input relative to change is assets

We propose that firms with higher stock illiquidity substitute labor for capital because of their higher cost of capital. Employing again Hsieh and Klenow's (2009) model, the firm's optimal labor input is given by $L = [(1-\alpha)r(1+c_K)/\alpha w]*K$. Thus, $dL/dK = (1-\alpha)r/\alpha w + c_K(1-\alpha)r/\alpha w$, which increases in c_K. Therefore, the marginal rate of substitution between labor and capital in production—the increase in labor input for a given increase in capital—is positively related to the illiquidity premium in the cost of capital, which increases in c_K. And, the labor/capital ratio is increasing in c_K.

We test whether dL/dK increases in illiquidity by estimating Model (4) with the dependent variable $dLabor_j$, the annual change in the number of employees scaled by lagged total assets. Then, $dL/dK = b2 + b3*ILLIQ_{j,t-1}$, where $ILLIQ$ is positively related to c_K. Naturally, $b_2 > 0$ since the marginal rate of substitution between labor and capital is $\alpha r/(1-\alpha)w > 0$. We test whether $b3 > 0$, that is, whether firms with a higher illiquidity premium realize a greater increase in labor input for a given increase in capital because the higher cost of capital induces firms to select a production process that is less capital intensive.

INSERT TABLE 10

The estimation results are presented in Table 10, Panel A. Naturally, $b2 > 0$ meaning that labor input rises to match an increase in capital. Importantly, $b3 > 0$ as we hypothesize, which means that illiquidity raises the increase in labor input for a given increase in capital. We find that $b3 = 1.201$ with $t = 7.60$. The results are consistent across the two subperiods, being $b3 = 1.478$ with $t = 7.82$ and $b3 = 0.371$ with $t = 9.23$ for the first and second subperiods, respectively.[42]

As a robustness test, we estimate the model for each of the five one-digit SIC code industries, because production functions differ across industries. We find that *b3* is positive and significant for *all* five industries; see Panel B of Table 10.

Panel C of Table 10 presents a second test of the effect of illiquidity on the labor/capital ratio. We estimate Model (1) with the dependent variable being $LaborTA_{j,t}$, the ratio of the number of employees to total assets in year *t*, in logarithm. We expect a positive coefficient of $ILLIQ_{j,t-1}$, meaning that as illiquidity raises the cost of capital, the firm selects a higher labor/capital ratio, thus, reducing the capital intensity in production. The results support our hypothesis. The coefficient of $ILLIQ_{j,t-1}$ is 0.010 with $t = 2.14$ for the entire period, and it is 0.014 ($t = 3.06$) and 0.009 ($t = 1.98$) for the first and second subperiods, respectively.

We test the effect of the 2001 decimalization on labor/capital ratio, estimating Model (2) with the dependent variable $LaborTA_{j,t}$. We expect the coefficient of $Post*SPD_j$ to be negative ($b1 < 0$), implying a reduction in the labor/capital ratio after decimalization for firms with a greater improvement in liquidity (given that beforehand their spreads were quoted more often at the minimum tick), that is, such firms adopted a production process that was less labor-intensive. We find that the coefficients for SPD_j that equals $P625_j$ and $LoSP_j$ are, respectively, -0.148 with $t = -3.71$ and -0.015 with $t = -1.02$.

Testing the effect of the 1997 Nasdaq reform on labor/capital ratio, we estimate Model (3) with the dependent variable $LaborTA_{j,t}$. We find that the coefficient of $Post*f(Even8_j)$ for $f(Even8_j) =$

[42] For robustness, we estimate the model without firm fixed effects. We find that $b3 = 1.249$ with $t = 7.52$. The results are similar when we add industry fixed effects to the model. Further, we re-estimate the model employing annual cross-section Fama-MacBeth regressions with industry fixed effects, using Fama and French's 49-industry classification. We find again that $b3 = 0.180$ with and $t = 5.26$.

$LEven8_j$ and $HiEven8_j$ is, respectively, -0.028 (t = -1.00) and -0.028 (t = -0.35), both negative as expected though, insignificant.

<u>Test 3</u>: Operating leverage

We test the effect of illiquidity on the firm's operating leverage, *OL*, the extent of fixed costs in the total cost of production. This test supplements our analysis on the effect of illiquidity on investment and accounts for alternatives to investing in assets such as leasing them.[43] If switching from buying to leasing assets is a costly endeavor driven by higher illiquidity that would not have been done otherwise, it means that illiquidity imposes a cost that may inhibit the use of capital assets. Reducing the use of capital induces firms to adopt production processes that rely less on fixed costs and more on variable costs. We test this hypothesis below.[44]

Lev (1974) and Mandelker and Rhee (1984) estimate *OL* from a regression model of the firm's total cost on its sales. Greater cost-sales sensitivity implies greater reliance on *variable* costs and lower operating leverage. We test whether the firm's cost-sales sensitivity is a function of stock illiquidity by estimating the following model:

$$Cost_{j,t} = b1*ILLIQ_{j,t-1} + b2*Sales_{j,t} + \mathbf{b3*ILLIQ_{j,t-1}*Sales_{j,t}} + b4*Q_{j,t-1} + b5*TA_{j,t-1} + b6*VOL_{j,t-1} + b7*RET2_{j,t-1} + firm\ FE + year\ FE. \qquad (5)$$

$Cost_{j,t}$ and $Sales_{j,t}$ are contemporaneous, whereas $ILLIQ_{j,t-1}$ is lagged. $Cost_{j,t}$, defined as $Sales_{j,t} - EBIT_{j,t}$ (earnings before interest and taxes), includes all costs, both variable and fixed.[45] Its main components are cost of goods sold, selling general and administrative costs, R&D costs, and depreciation. $Sales_{j,t}$ and $Cost_{j,t}$ are scaled by lagged assets.

Operating leverage is defined as $OL = 1\text{-}b2$, following Lev (1974). Here, operating leverage is $OL = 1\text{-}b2\text{-}b3*ILLIQ$. We hypothesize that $b3 > 0$, that is, higher illiquidity reduces operating leverage, inducing greater reliance on variable costs in production.

INSERT TABLE 11

The estimation results of Model (5), presented in Table 11, support our hypothesis: $b3$ = 0.001 with t = 2.61. The estimated coefficient $b3$ is consistent in the two subperiods in both

[43] Sharpe and Nguyen (1995) find that capital-constrained firms are more likely to lease their assets.
[44] In addition, operating leverage that measures costs that are unrelated to current sales may reflect investment in intangible assets, such as fixed expenditures on employee training or research and development projects.
[45] See Aboody, Levi, and Weiss (2017) for this definition.

magnitude and in statistical significance: For the first and second period *b3* is 0.002 (t = 2.20) and 0.002 (t = 2.28), respectively.

Employing the decimalization event of 2001 to test the effect of an exogenous change in stock liquidity, we estimate the following model that combines Model (2) with Model (5):

$$Cost_{j,t} = b1*Post*SPD_j + b2*Sales_{j,t} + b3*Post*SPD_j*Sales_{j,t}, + Control\ variables + Firm\ FE + Year\ FE. \quad (5.1)$$

We expect that $b3 < 0$ meaning that stocks with a narrower bid-ask spread, for which liquidity improved the most, increased their operating leverage and relied less on variable costs that normally rise with sales. For $SPD_j = P625_j$ and $LoSP_j$, we find that the coefficient *b3* is negative and significant, being respectively -0.029 (t = -3.02) and -0.012 (t = -1.95). The negative *b3* implies that $OL = 1\text{-}b2\text{-}b3 > 1\text{-}b2$. That is, operating leverage has increased for the lower-spread firms whose liquidity improved more by decimalization.

We test the effect of the Nasdaq reform by estimating Model (5.1) with $f(Even8_j)$ replacing SPD_j. We again expect $b3 < 0$ meaning that firms whose bid-ask spread was likely to decline by more increased their reliance on fixed costs in production. We find for $f(Even8_j)$ that equals $LEven8_j$ and $HiEven8_j$ the coefficient *b3* is respectively -0.024 with t = -1.73 and -0.007 with t = -1.00.[46]

5. Concluding remarks

This paper presents a channel by which Wall Street affects Main Street: the secondary market liquidity affects corporate investment and production decisions. Because illiquidity raises the expected return required by stockholders, it raises the firm's opportunity cost of capital and consequently lowers corporate investment. The negative investment-illiquidity relation holds even for firms that are not financially constrained or are in no need to raise capital, suggesting that the effect of illiquidity on investment is through the secondary market rather than through the primary market. Because illiquidity inhibits capital investment, it induces firms to economize on the use of capital in production. Firms with higher illiquidity have higher output per unit of capital and rely relatively more on labor input in production. Generally, their costs consist less of fixed costs and more of variable costs.

[46] The power of the test is lower for the Nasdaq reform because the sample is smaller, being less than half of the decimalization-test sample.

Our results provide a broad interpretation of Chen et al.'s (2007) proposition of a feedback effect from the secondary market to the real economy, by which firms' investment decisions employ information learned from secondary market prices. In our context, managers learn about their firm's stock liquidity and cost of capital from market prices and trading activity and use this information in their investment decisions. Just as most managers use their firm's β risk and risk premium derived from market price data to calculate the cost of capital by the CAPM (Graham and Campbell, 2001), managers learn from the secondary market about their firm's stock illiquidity and its premium and use this information to estimate the expected return required by investors, which is used to determine the investment hurdle rate. Managers can employ asset pricing models to estimate the illiquidity premium (see Amihud et al., 2013) or learn about the illiquidity effect from the price/earnings multiple which declines in illiquidity (Loderer and Roth, 2005). This analysis is consistent with Bond al.'s (2012) proposed feedback from secondary market price information to the real economy.

Our results suggest that firms may benefit from spending resources on improving their stock liquidity, which would in turn reduce their cost of capital. Liquidity can improve by improved disclosure of corporate information, by security design that makes the corporate claims more liquid and by increasing the company float (see Amihud and Mendelson, 1988). Balakrishnan, Billings, Kelly, and Ljungqvist (2016) find that stock liquidity increased in firms that increased voluntary disclosure by providing timely and informative earnings guidance. Amihud, Mendelson, and Uno (1999) find a rise in stock liquidity and stock price after firms reduce their stock's minimum trading unit, and allow smaller investors to invest in their stock. And Amihud, Lauterbach, and Mendelson (2003) find that stock liquidity rises after firms eliminate fragmented trading in their equity securities by consolidating them.

Our results suggest that reforms in the secondary market trading procedures which improve market liquidity, such as the 1997 Nasdaq market-making reform and the 2001 decimalization, are beneficial to the real economy by affecting investment and production. More generally, government policies and regulations that increase the information available to traders, reduce asymmetric information and increase liquidity are expected to have a similar effect. For example, mandating periodic disclosure of accounting information and setting a uniform and comprehensive format of disclosure improves liquidity and lowers the cost of capital. Leuz and Verrecchia (2000) find that liquidity improved for firms in Germany that switched to an international reporting regime (IAS or U.S. GAAP). Similarly, transparency of trading in the market improves liquidity, as seen for example when corporate bond trading started to be reported on the TRACE system (see Bessembinder, Maxwell and Venkatamaran, 2006). Henry (2000) finds that broad stock market liberalizations, which allowed foreigners to purchase shares in the country's stock market and increased net capital inflows, lead to private investment booms. Among the explanations for this finding, Henry (2000) proposes that increased capital inflow increases market liquidity, which following Amihud and Mendelson (1986), lowers the equity premium. Our analysis focuses on liquidity-related market reforms, showing how they raise investment.

Macroeconomic analysis by Naes, Skjeltorp, and Odegaard (2011) finds that aggregate stock market liquidity positively affects growth in aggregate private real investment. Our analysis provides microeconomic firm-level evidence that is consistent with the positive macroeconomic relationship between stock market liquidity and investment.

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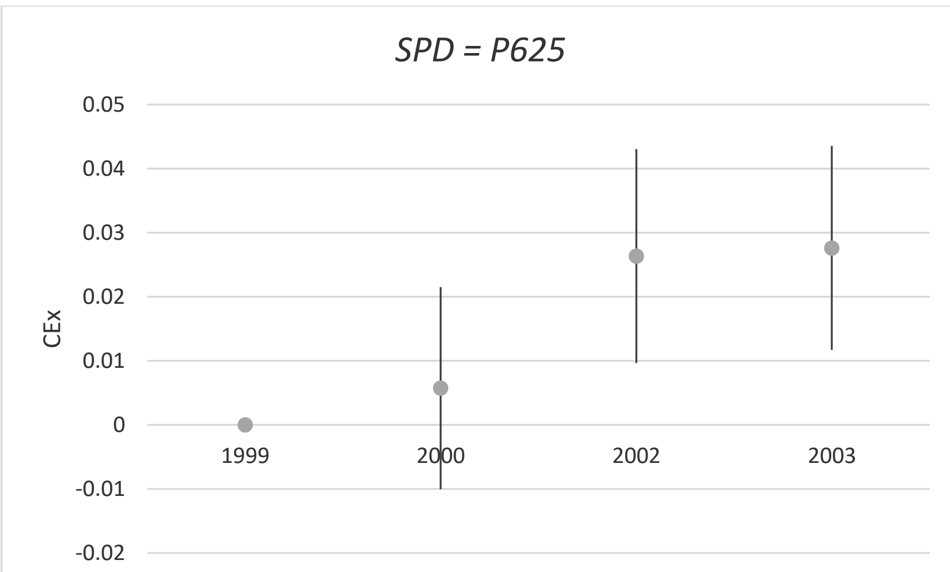
Figure 1: Change in investments around the Decimalization of 2001

$$CEx_{j,t} = b11*Yr00*SPD_j + b12*Yr02*SPD_j + b13*Yr03*SPD_j + \\ +Control\ variables + firm\ FE + year\ FE\ , \qquad (2.1)$$

Yr00, *Yr02*, and *Yr03* are indicator variables that equal 1 in 2000 (the year before decimalization), 2002, and 2003 respectively. SPD_j takes two values based on the quoted bid-ask spreads for the firm's stock during the months January-July of 2000 (source: TAQ): (i) $P625_j$, the proportion of quoted spread at 6.25 cents ($1/16), and (ii) $LoSP_j$, a dummy variable that equals 1 for firms in the lowest quartile of the average quoted bid-ask spread. The sample includes 1,348 firms that satisfy data requirements and are traded on NYSE-AMEX and Nasdaq. The estimation period is 1999-2003, skipping the decimalization year of 2001. There are 5,252 firm-years. The *t*-statistics employ standard errors that are clustered by firm. The graph shows the coefficients *b11*, *b12*, and *b13* and their confidence interval (for p = 0.10).



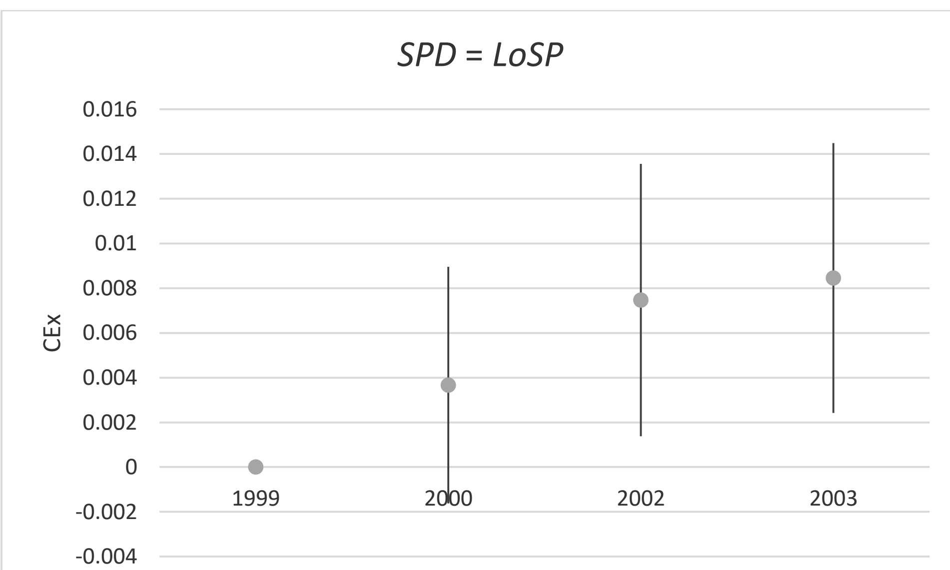


Figure 2: Change in investments around the Nasdaq reform of 1997

We estimate the speed of adjustment of investment to the exogenous decline in illiquidity in the following model:

$$CEx_j = b11*Yr96*f(Even8)_j + b12*Yr98*f(Even8)_j + b13*Yr99*f(Even8_j)$$
$$+ \textit{Control variables} + \text{Firm FE} + \text{Year FE} . \qquad (3.1)$$

Yr96, *Yr98* and *Yr99* are indicator variables that equal 1 in 1996 (the year before the reform), 1998 and 1999, respectively. $Even8_j$ is the proportion of bid and ask quotes where both are even-eighths prices during the period June 1996-December 1996. *f(Even8)* is either $LEven8_j = \ln(1+ Even8_j)$ or $HiEven8_j$, a dummy variable that equals 1 for firms with above-median $Even8_j$ (0 otherwise). The sample includes 599 Nasdaq stocks that satisfy data requirements. The estimation period is 1995-1999, skipping the Nasdaq reform year of 1997. There are 2,286 firm-years. The *t*-statistics employ standard errors that are clustered by firm. The graph shows the coefficients *b11*, *b12*, and *b13* and their confidence interval (for p = 0.10).

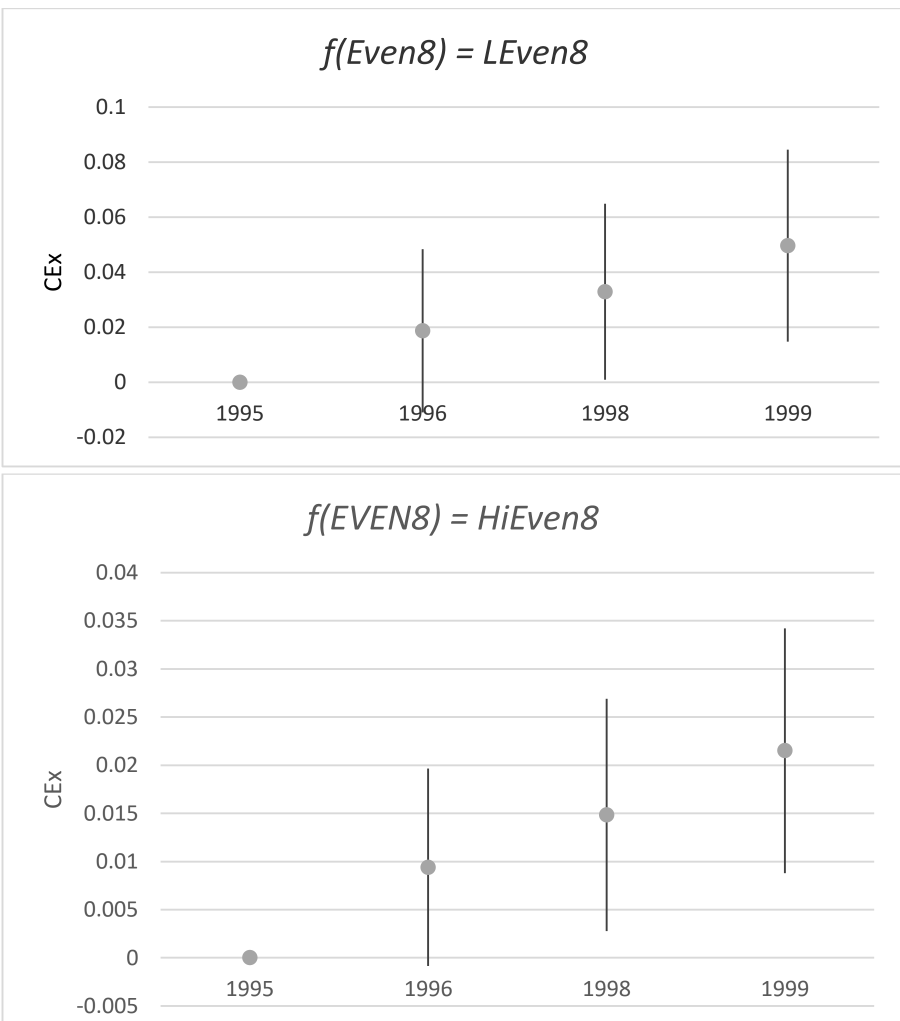


Table 1: Descriptive statistics

The sample includes data of NYSE and AMEX firms for 1963-2019 and excludes financial stocks (SIC 6000-6999), utility firms (SIC 4900-4999), stocks with share code other than 10 and 11, firms with share price of less than $1 and total assets lower than $10 million, and firms whose total assets or sales doubled or were halved from year *t*-1 to year *t*. Investment is either capital expenditures, *CEx*, or *CExRD*, the sum of *CEx* and *R&D* (research and development expenses). These variables are scaled by lagged total assets. Illiquidity measures are *ILLIQ*, the annual average ratio of daily absolute return to dollar volume, or *SPRD*, the annual average of the end-of-day quoted bid-ask spread relative to price. Both variables are in logarithms. Data for the illiquidity variables are from CRSP; for *SPRD*, data begin in 1993. *CF* is cash flow, defined as net income (before extraordinary items) plus depreciation and amortization divided by lagged total assets. *Q* is total firm's market value (market value of equity plus book value of assets minus book value of equity and balance-sheet deferred taxes) divided by the book value of assets. *TA* is total assets in logarithm. *dTA* is the annual change in total assets scaled by lagged total assets. *VOL* is equity volatility, the standard deviation of the weekly stock return during the year, and *RET2* is the cumulative stock return over the last two years. *Sales* is total revenues scaled by lagged total assets and *dSales* is the annual change in revenues scaled by lagged total assets. *dLabor* is the annual change in the number of employees scaled by lagged total assets. *Cost* is total revenues minus earnings before interest and taxes, scaled by lagged total assets.

Variable	*N*	*Mean*	*Std. Dev.*	*Q1*	*Median*	*Q3*
CEx_t	64,798	0.076	0.074	0.029	0.055	0.096
$CExRD_t$	64,798	0.094	0.086	0.039	0.071	0.121
$ILLIQ_{t-1}$	64,798	-16.99	3.198	-19.39	-16.77	-14.56
$SPRD_{t-1}$	28,971	-5.462	1.81	-7.002	-5.141	-3.974
CF_t	64,798	0.094	0.101	0.059	0.1	0.142
Q_{t-1}	64,798	1.50	0.958	0.951	1.212	1.695
TA_{t-1}	64,798	6.064	1.923	4.61	5.96	7.406
dTA_t	64,798	0.105	0.25	-0.008	0.068	0.163
$RET2_{t-1}$	64,798	0.346	1.007	-0.191	0.179	0.625
VOL_{t-1}	64,798	0.057	0.027	0.038	0.051	0.068
$Sales_t$	64,798	1.467	0.927	0.874	1.303	1.809
$dSales_t$	64,798	0.117	0.278	-0.005	0.083	0.212
$dLabor_t$	64,798	0.852	5.385	-0.332	0.068	1.136
$Cost_t$	64,798	1.359	0.902	0.782	1.191	1.675

Table 2: Investment as a function of illiquidity

Estimation results for the model:

$$INV_{j,t} = \boldsymbol{b1*ILLIQ_{j,t-1}} + b2*CF_{j,t} + b3*Q_{j,t-1} + b4*TA_{j,t-1} + b5*VOL_{j,t-1} + b6*RET2_{j,t-1} + firm\ FE + year\ FE. \quad (1)$$

Investment of firm *j* in year *t*, $INV_{j,t}$, is either $CEx_{j,t}$ or $CExRD_{j,t}$. The variables are described in Table 1. Filters for the data and the variables apply. The sample includes NYSE and AMEX firms unless otherwise indicated. To save space, we present in Panels B-E only the coefficient of $ILLIQ_{j,t-1}$; the models include all control variables and fixed effects. Standard errors are clustered by firm and year. *, **, and *** indicate significance at the 0.10, 0.05, and 0.01 level, respectively.

Panel A: Estimation over the entire period, 1963-2019

	Dependent Variable	
	$CEx_{j,t}$	$CExRD_{j,t}$
$ILLIQ_{j,t-1}$	-0.009	-0.009
	(-13.91)***	(-13.46)***
$CF_{j,t}$	0.124	0.114
	(11.17)***	(8.38)***
$Q_{j,t-1}$	0.005	0.008
	(5.68)***	(6.89)***
$TA_{j,t-1}$	-0.019	-0.023
	(-14.18)***	(-14.77)***
$VOL_{j,t-1}$	-0.084	-0.09
	(-3.95)***	(-3.52)***
$RET2_{j,t-1}$	0.005	0.006
	(4.92)***	(4.80)***
R^2	60.1%	62.2%

Panel B: Separate estimations by industry, using one-digit SIC code.

The Dependent Variable is $CEx_{j,t}$. The five industries are, respectively, mining and construction; two types of manufacturing; transportation, communication, electric, gas, and sanitary services; and retail and wholesale trade. The model includes control variables and firm and year fixed effects.

	One-Digit SIC Industry Code				
	SIC=1	SIC=2	SIC=3	SIC=4	SIC=5
$ILLIQ_{j,t-1}$	-0.013 (-5.71)***	-0.007 (-7.24)***	-0.006 (-8.80)***	-0.019 (-5.64)***	-0.008 (-6.79)***
R^2	67.3%	51.1%	52.0%	54.6%	62.0%
N	5,754	14,473	23,346	3,613	9,407

Panel C: Estimations over two subperiods. There are 31,991 firm-years in the first period and 32,807 firm-years in the second period. The model includes control variables and firm and year fixed effects.

	1963-1990		1991-2019	
	$CEx_{j,t}$	$CExRD_{j,t}$	$CEx_{j,t}$	$CExRD_{j,t}$
$ILLIQ_{j,t-1}$	-0.011 (-12.02)***	-0.011 (-11.48)***	-0.007 (-9.78)***	-0.008 (-8.77)***
R^2	59.7%	62.6%	67.5%	68.5%

Panel D: Estimations for Nasdaq firms, 1998-2019. There are 31,477 firm-years. The model includes control variables and firm and year fixed effects.

	Dependent Variable	
	$CEx_{j,t}$	$CExRD_{j,t}$
$ILLIQ_{j,t-1}$	-0.004 (-9.02)***	-0.005 (-6.29)***
R^2	65.7%	79.7%

Panel E: Estimations using industry fixed effects instead of firm fixed effects, employing Fama and French's 49-industry classification. The estimations are either by a panel regression with industry and year fixed effects, or by the Fama-MacBeth procedure of annual cross-section regressions with industry fixed effects. For the latter estimation, the table presents the average coefficients and their *t*-statistics. The models include all control variables. The calculations of the standard errors of the annual coefficients employ the Newey-West (1987) procedure with one lag.

	Panel Regressions		Fama-MacBeth Regressions	
	$CEx_{j,t}$	$CExRD_{j,t}$	$CEx_{j,t}$	$CExRD_{j,t}$
$ILLIQ_{j,t-1}$	-0.005	-0.009	-0.004	-0.008
	(-9.48)***	(-10.91)***	(-12.54)***	(-14.61)***
R^2	31.7%	26.2%	37.3%	34.8%

Panel F: Estimations using first difference of all variables. The variables in Model (1) are replaced by their first difference indicated by the prefix *d*. Panel F1 includes the variables in Model (1), and in Panel F2, the model is extended by adding the lagged change in investment ($dCEx_{j,t}$ or $dCExRD_{j,t}$, consistent with the dependent variable). Both panels include the first difference of all control variables and year fixed effects. There are 57,084 firm-years.

The complete results presenting the coefficients of all the variables are in Appendix Table A2.

	Panel F1		Panel F2	
	$dCEx_{j,t}$	$dCExRD_{j,t}$	$dCEx_{j,t}$	$dCExRD_{j,t}$
$dILLIQ_{j,t-1}$	-0.008	-0.009	-0.010	-0.011
	(-11.58)***	(-11.50)***	(-13.45)***	(-13.40)***
$dINV_{j,t-1}$			-0.210	-0.217
			(-13.67)***	(-15.66)***
R^2	9.7%	9.9%	13.9%	14.3%

Panel G: Adding $Cash_{j,t-1}$ and $dCash_{j,t-1}$, the changes in $Cash_{j,t-1}$, as control variables.

Estimations of Model (1) adding the following control variables: $Cash_{j,t-1}$, the sum of cash and cash-equivalent investments scaled by lagged total assets; or $dCash_{j,t-1}$, the change in the sum of cash and cash equivalents scaled by lagged total assets. The dependent variable is $CEx_{j,t}$. To save space, we present only the coefficient of $ILLIQ_{j,t-1}$ and those of the added variables. The regressions include control variables and firm and year fixed effects.

		Subperiods			Subperiods	
	1963-2019	1963-1990	1991-2019	1963-2019	1963-1990	1991-2019
$ILLIQ_{j,t-1}$	-0.009 (-13.95)***	-0.011 (-12.00)***	-0.007 (-9.86)***	-0.009 (-13.94)***	-0.010 (-12.03)***	-0.007 (-9.78)***
$Cash_{j,t-1}$	-0.006 (-1.60)	-0.002 (-0.39)	-0.004 (-0.87)			
$dCash_{j,t-1}$				-0.013 (-2.84)***	-0.021 (-3.17)**	-0.005 (-0.87)
N	64,798	31,991	32,807	64,798	31,991	32,807
R^2	60.1%	59.7%	67.5%	60.1%	59.8%	67.5%

Table 3: Inventory investment as a function of illiquidity

The dependent variable is $dINVTRY_{j,t}$, the change in inventory scaled by lagged total assets. The estimation employs Model (1) augmented by $dSales_{j,t}$, the change in sales scaled by lagged total assets. The regressions include firm and year fixed effects. There are 59,699 firm-years for the entire period and 30,865 and 28,834 firm-years for the first and second subperiods, respectively. Standard errors are clustered by firm and year. *, **, and *** indicate significance at the 0.10, 0.05, and 0.01 level, respectively.

		Subperiods	
	1963-2019	1963-1990	1991-2019
$ILLIQ_{j,t-1}$	-0.005	-0.006	-0.003
	(-10.75)***	(-9.53)***	(-7.24)***
$CF_{j,t}$	0.063	0.153	0.040
	(7.63)***	(11.11)***	(5.53)***
$Q_{j,t-1}$	-0.001	-0.001	-0.0003
	(-1.88)*	(-0.88)	(-0.45)
$TA_{j,t-1}$	-0.012	-0.017	-0.011
	(-13.32)***	(-9.60)***	(-10.07)***
$VOL_{j,t-1}$	-0.043	-0.059	-0.064
	(-2.11)**	(-2.21)**	(-2.52)**
$RET2_{j,t-1}$	0.003	0.003	0.002
	(5.79)***	(4.29)***	(3.93)***
$dSales_{j,t}$	0.105	0.103	0.097
	(29.52)***	(20.23)***	(19.72)***
R^2	41.4%	44.2%	42.3%

Table 4: Investment, illiquidity and the feedback effect

The dependent variable $INV_{j,t}$ is either $CEx_{j,t}$ or $CExRD_{j,t}$. The estimations employ Model (1) (used in Table 2), augmented by $INFO_{j,t-1}*Q_{j,t-1}$, where *INFO* = *ILLIQ* or *SPRD*. The model includes firm and year fixed effects. There are 64,798 firm-years for *INFO* = *ILLIQ* and 28,971 firm-years for *INFO* = *SPRD*. Standard errors are clustered by firm and year. *, **, and *** indicate significance at the 0.10, 0.05, and 0.01 level, respectively.

	$INV_{j,t} = CEx_{j,t}$		$INV_{j,t} = CExRD_{j,t}$	
	INFO = ILLIQ 1963-2019	*INFO = SPRD* 1994-2019	*INFO = ILLIQ* 1963-2019	*INFO = SPRD* 1994-2019
$INFO_{j,t-1}$	-0.010	-0.011	-0.010	-0.012
	(-13.39)***	(-8.08)***	(-12.68)***	(-7.02)***
$CF_{j,t}$	0.125	0.077	0.115	0.055
	(11.22)***	(10.67)***	(8.43)***	(5.39)***
$Q_{j,t-1}$	0.022	0.018	0.022	0.024
	(5.18)***	(6.10)***	(3.97)***	(6.35)***
$INFO_{j,t-1}*Q_{j,t-1}$	0.001	0.002	0.001	0.002
	(4.12)***	(3.78)***	(2.62)***	(3.45)***
$TA_{j,t-1}$	-0.018	-0.015	-0.023	-0.022
	(-13.81)***	(-7.73)***	(-14.63)***	(-9.20)***
$VOL_{j,t-1}$	-0.089	-0.109	-0.093	-0.116
	(-4.11)***	(-4.09)***	(-3.65)***	(-3.54)***
$RET2_{j,t-1}$	0.005	0.002	0.005	0.002
	(4.82)***	(2.62)***	(4.69)***	(2.17)**
R^2	60.1%	69.2%	62.2%	69.9%

Table 5: The effect of financial constraint on the *INV-ILLIQ* relation

Estimations of Model (1) with $INV_{j,t} = CEx_{j,t}$. Firms are sorted in each year t into three groups by measures of financial constraint for the previous year and Model (1) is estimated for each group. The sample generally includes 64,798 firm-years with approximately 21,600 firm-years in each of the three subsamples except in Panel A of Tables 5.1 and 5.3 that covers the years 1998-2016 and includes 15,917 firm-years, approximately 5,300 firm-years in each subsample. Filters for the data and the variables apply. Standard errors are clustered by firm and year. *, **, and *** indicate significance at the 0.10, 0.05, and 0.01 level, respectively.

Table 5.1. In Panel A, firms are sorted by Hoberg and Maximovic's (2015) constraint measure $Delaycon_{j,t-1}$ by which "firms with higher values are more similar to a set of firms known to be at risk of delaying their investments due to issues with liquidity." In Panels B and C firms are sorted by $ILLIQ_{j,t-1}$ and by -1*$Equity\ Capitalization_{j,t-1}$, respectively. To save space, we report only the coefficient of $ILLIQ_{j,t-1}$ and $CF_{j,t}$. Appendix Table A4 presents the complete table with estimated coefficients for all variables.

Period	Variable	Low value = **Low constraint**	Medium	High value = **High constraint**
		Panel A: Sorting by $Delaycon_{j,t-1}$		
1998-2016	$ILLIQ_{j,t-1}$	-0.005	-0.006	-0.009
		(-4.09)***	(-4.68)***	(-4.40)***
	$CF_{j,t}$	0.072	0.086	0.094
		(5.79)***	(5.56)***	(6.76)***
		Panel B: Sorting by $ILLIQ_{j,t-1}$		
1963-2019	$ILLIQ_{j,t-1}$	-0.015	-0.010	-0.007
		(-9.69)***	(-8.92)***	(-8.80)***
	$CF_{j,t}$	0.135	0.141	0.097
		(8.28)***	(9.35)***	(10.16)***
1963-1990	$ILLIQ_{j,t-1}$	-0.016	-0.011	-0.008
		(-7.80)***	(-6.53)***	(-5.71)***
	$CF_{j,t}$	0.259	0.232	0.182
		(9.70)***	(6.90)***	(8.86)***
1991-2019	$ILLIQ_{j,t-1}$	-0.011	-0.009	-0.006
		(-5.80)***	(-5.81)***	(-6.44)***
	$CF_{j,t}$	0.077	0.097	0.064
		(6.68)***	(7.31)***	(7.63)***
		Panel C: Sorting by $-1*Equity\ Capitalization_{j,t-1}$		
1963-2019	$ILLIQ_{j,t-1}$	-0.012	-0.008	-0.007
		(-9.74)***	(-8.88)***	(-9.39)***
	$CF_{j,t}$	0.131	0.150	0.094
		(7.22)***	(9.77)***	(10.24)***
1963-1990	$ILLIQ_{j,t-1}$	-0.015	-0.010	-0.008
		(-8.45)***	(-7.91)***	(-6.00)***
	$CF_{j,t}$	0.253	0.252	0.182
		(8.54)***	(7.95)***	(8.51)***
1991-2019	$ILLIQ_{j,t-1}$	-0.008	-0.005	-0.006
		(-5.73)***	(-4.90)***	(-7.47)***
	$CF_{j,t}$	0.071	0.101	0.065
		(5.62)***	(9.09)***	(7.89)***

Table 5.2. The effects of financial constraint on the coefficient of $ILLIQ_{j,t\text{-}1}$ in Model (1)

Firms are sorted in each year by the lagged values of measures that indicate financial constraint and then divided into three groups. Model (1) is estimated for each group. The table reports only the coefficients of $ILLIQ_{j,t\text{-}1}$ (to save space). The measures of financial constraint are the following. *Cash Distribution* is dividends plus stock purchases divided by market value of equity. *Cash Flow* is income before extraordinary items plus depreciation divided by lagged total assets. *Cash Balance* is cash and cash equivalents divided by lagged total assets. *Age* is the number of years from IPO. *Firm Size* is total assets. *Leverage* is short-term and long-term debt minus cash, divided by total assets. *Whited-Wu* is a weighted average of the firm's characteristics using the coefficient from Whited and Wu (2006). The last two measures are multiplied by -1 so that a low value represents a high constraint.

Measure of constraint by which sorting is done	Low value = **High constraint**	Medium	High value = **Low constraint**
A: $Cash\ Distribution_{j,t\text{-}1}$	-0.009 (-11.02)***	-0.007 (-8.38)***	-0.008 (-10.07)***
B: $Cash\ Flow_{j,t\text{-}1}$	-0.006 (-9.19)***	-0.007 (-9.80)***	-0.007 (-6.10)***
C: $Cash\ Balance_{j,t\text{-}1}$	-0.007 (-7.09)***	-0.008 (-10.45)***	-0.008 (-10.84)***
D: $Age_{j,t\text{-}1}$	-0.010 (-11.25)***	-0.010 (-10.03)***	-0.008 (-9.01)***
E: $Firm\ Size_{j,t\text{-}1}$	-0.008 (-11.77)***	-0.010 (-11.89)***	-0.012 (-10.61)***
F: $-Leverage_{j,t\text{-}1}$	-0.009 (-8.84)***	-0.007 (-7.99)***	-0.006 (-8.97)***
G: $-1*Whited\text{-}Wu_{j,t\text{-}1}$	-0.009 (-11.77)***	-0.009 (-10.10)***	-0.011 (-10.86)***

Table 5.3. Inventory investment: The effect of financial constraint on the coefficient of $ILLIQ_{j,t-1}$ in an augmented Model (1)

The dependent variable is $dINVTRY_{j,t}$, the change in inventory scaled by lagged total assets. The estimation model in Model (1) that is augmented by $dSales_{j,t}$, the change in sales scaled by lagged total assets. The estimation procedure is as in Table 5.1 and 5.2. To save space, we present only results for financial constraint classification by -1*$Delaycon_{j,t-1}$ and characteristics A, D, E and G in Table 5.2.

Measure of constraint by which sorting is done	Variable	Low value = High constraint	Medium	High value = Low constraint
A: -1*$Delaycon_{j,t-1}$	$ILLIQ_{j,t-1}$	-0.004	-0.002	-0.006
		(-3.15)***	(-1.78)*	(-5.12)***
	$CF_{j,t}$	0.051	0.041	0.043
		(3.27)***	(2.67)***	(2.27)**
B: *Cash Distribution*$_{j,t-1}$	$ILLIQ_{j,t-1}$	-0.005	-0.005	-0.005
		(-7.49)***	(-6.47)***	(-6.94)***
	$CF_{j,t}$	0.063	0.071	0.062
		(6.06)***	(5.71)***	(4.79)***
C: $Age_{j,t-1}$	$ILLIQ_{j,t-1}$	-0.005	-0.006	-0.004
		(-8.27)***	(-8.11)***	(-5.12)***
	$CF_{j,t}$	0.082	0.084	0.042
		(6.25)***	(6.28)***	(3.93)***
D: *Firm Size*$_{j,t-1}$	$ILLIQ_{j,t-1}$	-0.006	-0.006	-0.003
		(-8.47)***	(-8.39)***	(-4.67)***
	$CF_{j,t}$	0.082	0.072	0.040
		(7.10)***	(6.28)***	(2.99)***
E: -1**Whited-Wu*$_{j,t-1}$	$ILLIQ_{j,t-1}$	-0.006	-0.005	-0.003
		(-9.25)***	(-7.59)***	(-4.62)***
	$CF_{j,t}$	0.082	0.063	0.073
		(7.38)***	(5.04)***	(5.54)***

Table 6: The 2001 decimalization and the effect of illiquidity on investment

The estimated model is:

$$INV_{j,t} = \mathbf{b1*Post*SPD_j} + b2*CF_{j,t}+b3*Q_{j,t-1}+ b4*TA_{j,t-1} + b5*VOL_{j,t-1} + b6*RET2_{j,t-1} + \text{firm FE} + \text{year FE} . \quad (2)$$

Post = 1 for the two post-decimalization years 2002-2003. The estimation includes the two pre-decimalization years 1999-2000, skipping the decimalization year 2001. SPD_j is the "treatment" variable, based on the quoted bid-ask spreads for the firm's stock during the months January-July of 2000 (source: TAQ): (i) $P625_j$ is the proportion of quoted spread at 6.25 cents (\$1/16) during the period; (ii) *LoSP* is an indicator variable that equals 1 for firms with average bid-ask spread in the lowest quartile. The sample includes 1,348 firms that satisfy data requirements, traded on NYSE-AMEX and Nasdaq. There are 5,252 firm-years. The *t*-statistics employ standard errors that are clustered by firm. *, **, and *** indicate significance at the 0.10, 0.05, and 0.01 level, respectively.

	$INV_{j,t} = CEx_{j,t}$		$INV_{j,t} = CExRD_{j,t}$	
	$SPD_j = P625_j$	$SPD_j = LoSP_j$	$SPD_j = P625_j$	$SPD_j = LoSP_j$
	(1)	(2)	(3)	(4)
$\mathbf{Post*SPD_j}$	**0.024**	**0.006**	**0.034**	**0.01**
	(2.78)***	**(2.01)****	**(3.32)*****	**(2.81)*****
$CF_{j,t}$	0.059	0.059	0.038	0.038
	(4.46)***	(4.44)***	(1.48)	(1.46)
$Q_{j,t-1}$	0.006	0.006	0.012	0.012
	(4.40)***	(4.26)***	(5.92)***	(5.81)***
$TA_{j,t-1}$	-0.028	-0.029	-0.061	-0.061
	(-7.36)***	(-7.38)***	(-10.24)***	(-10.23)***
$VOL_{j,t-1}$	-0.125	-0.128	-0.148	-0.152
	(-3.79)***	(-3.89)***	(-3.15)***	(-3.24)***
$RET2_{j,t-1}$	0.002	0.002	0.001	0.001
	(1.32)	(1.29)	(0.49)	(0.44)
R^2	73.1%	73.0%	80.8%	80.7%

Table 7: The 1997 Nadsaq reform and the effect of illiquidity on investment

The estimated model is:

$$INV_{j,t} = \mathbf{b1*Post*f(Even8_j)} + b2*CF_{j,t}+b3*Q_{j,t-1}+ b4*TA_{j,t-1} + b5*VOL_{j,t-1} + b6*RET2_{j,t-1} + \text{firm FE} + \text{year FE}, \quad (3)$$

where *Post* = 1 for the two post-reform years 1998 and 1999. The estimation includes the two pre-reform years 1995 and 1996, skipping the reform, year 1997. $Even8_j$ is the proportion of quotes where both bid and ask prices are even-eighths prices during the period June 1996-December 1996 (source: TAQ). $f(Even8_j)$ is either $LEven8_j$ = ln(1+$Even8_j$) or *HiEven8*, a dummy variable that equals 1 for firms with above-median $Even8_j$ (0 otherwise). The sample includes 599 stocks that satisfy data requirements, traded on Nasdaq. There are 2,286 firm-years. The *t*-statistics employ standard errors that are clustered by firm. *, **, and *** indicate significance at the 0.10, 0.05, and 0.01 level, respectively.

	$INV_{j,t} = CEx_{j,t}$		$INV_{j,t} = CExRD_{j,t}$	
	$f(Even8_j)=$ $LEven8_j$	$f(Even8_j)=$ $HiEven8_j$	$f(Even8_j)=$ $LEven8_j$	$f(Even8_j)=$ $HiEven8_j$
	(1)	(2)	(3)	(4)
$\boldsymbol{Post*f(Even8_j)}$	**0.031**	**0.013**	**0.049**	**0.017**
	(1.87)*	**(2.16)****	**(2.48)****	**(2.17)****
$CF_{j,t}$	0.021	0.021	-0.034	-0.034
	(1.18)	(1.15)	(-0.83)	(-0.83)
$Q_{j,t-1}$	0.008	0.008	0.01	0.011
	(2.86)**	(2.93)***	(2.68)***	(2.75)**
$TA_{j,t-1}$	-0.042	-0.042	-0.085	-0.084
	(-5.71)***	(-5.75)***	(-7.04)***	(-6.99)***
$VOL_{j,t-1}$	-0.183	-0.18	-0.201	-0.194
	(-2.26)**	(-2.21)**	(-2.09)**	(-2.01)***
$RET2_{j,t-1}$	0.012	0.012	0.014	0.014
	(4.93)***	(4.94)***	(5.04)***	(5.01)***
R^2	69.9%	69.9%	75.8%	75.7%

Table 8: Instrumental variable estimation (2SLS)

This table presents results for the 2SLS model:

Stage 1: $ILLIQ_{j,t-1} = b1{*}CF_{j,t} + b2{*}Q_{j,t-1} + b3{*}TA_{j,t-1} + b4{*}VOL_{j,t-1} + b5{*}RET2_{j,t-1} + \mathbf{b6{*}CIH_{j,t-1}} + \text{firm FE} + \text{year FE},$

Stage 2: $INV_{j,t} = \mathbf{b1{*}FILLIQ_{j,t-1}} + b2{*}CF_{j,t} + b3{*}Q_{j,t-1} + b4{*}TA_{j,t-1} + b5{*}VOL_{j,t-1} + b6{*}RET2_{j,t-1} + \text{firm FE} + \text{year FE},$

The instrumental variable *CIH* is the institutional investors' concentration, measured by (i) *HHI*, the Herfindahl-Hirschman index of institutional investors' holdings, the sum of the squared values of the fraction of each institutional holding of the total share outstanding; or (ii) *Breadth*, following Chen, Hong and Stein (2002), the ratio of the number of institutions holding the stock to the number of all institutional investors at that time. The variables are in logarithm and we use -*Breadth* = -1**Breadth* to indicate concentration. Investment of firm *j* in year *t*, $INV_{j,t}$, is $CEx_{j,t}$ or $CExRD_{j,t}$. The variables are described in the legend of Table 1. Filters for the data and the variables apply. The sample includes 31,448 firm-years between 1979 and 2019. Standard errors are clustered by firm and year. *, **, and *** indicate significance at the 0.10, 0.05, and 0.01 level, respectively.

	CIH = HHI			*CIH = -Breadth*		
	Stage 1	Stage 2		Stage 1	Stage 2	
	$ILLIQ_{j,t-1}$	$CEx_{j,t}$	$CExRD_{j,t}$	$ILLIQ_{j,t-1}$	$CEx_{j,t}$	$CExRD_{j,t}$
	(1)	(2)	(3)	(4)	(5)	(6)
$\mathbf{FILLIQ_{j,t-1}}$		**-0.013**	**-0.015**		**-0.013**	**-0.016**
		(-6.26)*	**(-6.23)***		**(-6.02)***	**(-6.48)***
$CF_{j,t}$	-0.947	0.097	0.081	-0.925	0.096	0.08
	(-6.86)***	(9.13)***	(5.72)***	(-6.51)***	(9.12)***	(5.64)***
$Q_{j,t-1}$	-0.416	0.004	0.007	-0.374	0.004	0.007
	(-11.50)***	(2.49)**	(3.77)***	(-10.63)***	(2.17)**	(3.38)***
$TA_{j,t-1}$	-1.216	-0.028	-0.036	-1.081	-0.029	-0.038
	(-39.91)***	(-8.91)***	(-9.56)***	(-27.90)***	(-8.69)***	(-10.10)***
$VOL_{j,t-1}$	6.363	-0.049	-0.046	6.378	-0.045	-0.038
	(7.30)***	(-1.80)*	(-1.44)	(7.32)***	(-1.64)	(-1.19)
$RET2_{j,t-1}$	-0.067	0.004	0.003	-0.075	0.004	0.003
	(-3.74)***	(3.12)***	(2.65)***	(-4.22)***	(3.16)***	(2.64)***
$\mathbf{HHI_{j,t-1}}$	**0.499**					
	(13.29)*					
$\mathbf{-Breadth_{j,t-1}}$				**0.538**		
				(11.01)*		
R^2	96.1%	64.9%	68.1%	96.1%	64.9%	68.1%

Table 9: Illiquidity effect on the marginal revenue productivity of capital

Panel A: The effect of illiquidity on sales growth relative to capital change

This table presents results for the model:

$$dSales_{j,t} = \mathbf{b1*ILLIQ_{j,t-1}} + b2*dTA_{j,t} + b3*ILLIQ_{j,t-1}*dTA_{j,t} + b4*Q_{j,t-1} + b5*TA_{j,t-1} + b6*VOL_{j,t-1} + b7*RET2_{j,t-1} + \text{firm FE} + \text{year FE}. \quad (4)$$

$dSales_{j,t}$ is the annual change in sales scaled by lagged total assets, and $dTA_{j,t}$ is the annual change in total assets scaled by lagged total assets. See Table 1 for details on the variables. The sample includes 64,798 firm-years for the entire period and 31,991 and 32,807 firm-years for the first and second subperiod, respectively. In all panels, *t*-statistics (in parentheses) are based on standard errors clustered by firm and year. *, **, and *** indicate significance at the 0.10, 0.05, and 0.01 level, respectively.

		Subperiods	
	1963-2019	1963-1990	1991-2019
$ILLIQ_{j,t-1}$	0.013 (6.09)***	0.020 (5.48)***	0.015 (5.34)***
$dTA_{j,t}$	1.312 (13.34)***	1.668 (13.23)***	0.874 (12.26)***
$\mathbf{ILLIQ_{j,t-1}*dTA_{j,t}}$	**0.046** **(9.01)*****	**0.061** **(9.45)*****	**0.026** **(6.33)*****
$Q_{j,t-1}$	0.021 (8.25)***	0.018 (4.14)***	0.025 (7.72)***
$TA_{j,t-1}$	0.000 (-0.08)	0.010 (1.58)	0.003 (0.51)
$VOL_{j,t-1}$	-0.300 (-2.85)***	-0.023 (-0.16)	-0.340 (-2.40)**
$RET2_{j,t-1}$	0.021 (6.01)***	0.022 (3.99)***	0.019 (4.50)***
R^2	48.9%	53.2%	48.6%

Panel B: The effect of illiquidity on the Sales/Assets ratio

We estimate Model (1) with the dependent variable $MRPK_{j,t} = Sales_{j,t}/TA_{j,t}$, which is proportional to the marginal revenue productivity of capital. To save space, we report only the coefficients of *ILLIQ*. The regressions include firm and year fixed effects. The sample includes 64,798 firm-years for the entire period and 31,991 and 32,807 firm-years for the first and second subperiod, respectively.

		Subperiods	
	1963-2019	1963-1990	1991-2019
$ILLIQ_{j,t-1}$	0.023	0.027	0.017
	(5.45)***	(5.49)***	(3.87)***
Including control variables and firm and year fixed effects			
R^2	85.6%	89.9%	87.1%

Table 10: The effect of illiquidity on the labor/capital marginal rate of substitution

This table presents results for Model (4) (see Table 9, Panel A) with the dependent variable $dLabor_{j,t}$, the annual change in number of employees scaled by lagged total assets. The regressions include firm and year fixed effects. The sample includes 64,798 firm-years for the entire period and 31,991 and 32,807 firm-years for the first and second subperiod, respectively. In both panels below, *t*-statistics (in parentheses) are based on standard errors clustered by firm and year. *, **, and *** indicate significance at the 0.10, 0.05, and 0.01 level, respectively.

Panel A: *Estimations of Model (4)* with $dLabor_{j,t}$ as the dependent variable *for the entire sample*

		Subperiods	
	1963-2019	1963-1990	1991-2019
$ILLIQ_{j,t-1}$	-0.140	-0.055	-0.026
	(-3.74)***	(-0.89)	(-1.14)
$dTA_{j,t}$	27.67	37.37	10.05
	(8.26)***	(9.60)***	(12.04)***
$\boldsymbol{ILLIQ_{j,t-1}*dTA_{j,t}}$	**1.201**	**1.478**	**0.371**
	(7.60)***	**(7.82)*****	**(9.23)*****
$Q_{j,t-1}$	0.123	0.409	0.053
	(1.67)*	(2.72)***	(1.88)*
$TA_{j,t-1}$	-0.691	-1.542	-0.150
	(-6.47)***	(-6.56)***	(-2.79)***
$VOL_{j,t-1}$	1.391	4.877	-1.738
	(0.94)	(1.54)	(-1.80)*
$RET2_{j,t-1}$	0.165	0.233	0.083
	(3.64)***	(2.24)**	(3.06)***
R^2	33.2%	38.1%	42.5%

Panel B: *Estimation of the model by industry*.

	One-Digit SIC Industry Code				
	SIC=1	SIC=2	SIC=3	SIC=4	SIC=5
$ILLIQ_{j,t-1}$	-0.036	-0.170	-0.049	-0.162	-0.281
	(-0.62)	(-1.85)*	(-0.75)	(-2.17)**	(-3.05)***
$dTA_{j,t}$	9.598	38.001	32.621	12.739	30.568
	(5.07)***	(7.03)***	(7.53)***	(4.23)***	(6.78)***
$\boldsymbol{ILLIQ_{j,t-1}*dTA_{j,t}}$	**0.410**	**1.717**	**1.389**	**0.529**	**1.247**
	(4.44)***	**(6.76)*****	**(7.04)*****	**(3.54)*****	**(5.47)*****
The regressions include control variables and firm and year fixed effects.					
N	5,754	14,473	23,346	3,613	9,407
R^2	21.4%	30.6%	37.4%	38.1%	39.0%

Panel C: *The effect of illiquidity on the Labor/Assets ratio*

Estimation of Model (1) with the dependent variable being $LaborTA_{j,t}$, the ratio of the number of employees to total assets (in logarithm). The sample includes 64,798 firm-years for the entire period and 31,991 and 32,807 firm-years for the first and second subperiod, respectively. The model includes firm and year fixed effects.

		Subperiods	
	1963-2019	1963-1990	1991-2019
$ILLIQ_{j,t-1}$	0.010	0.014	0.009
	(2.14)**	(3.06)***	(1.98)**
Including control variables and firm and year fixed effects			
R^2	94.5%	93.8%	93.9%

Table 11: The effect of illiquidity on operating leverage

This table presents results for the model:

$$Cost_{j,t} = b1*ILLIQ_{j,t-1} + b2*Sales_{j,t} + \mathbf{b3*ILLIQ_{j,t-1}*Sales_{j,t}} + b4*Q_{j,t-1} + b5*TA_{j,t-1} + b6*VOL_{j,t-1} + b7*RET2_{j,t-1} + firm\ FE + year\ FE. \quad (5)$$

$Sales_{j,t}$ are total revenues and $Cost_{j,t} = Sales_{j,t} - EBIT_{j,t}$, where $EBIT_{j,t}$ is earnings before interest and taxes. These variables are scaled by lagged total assets. *ILLIQ* is illiquidity, defined in Table 1, in logarithm. Operating leverage is $1 - b2 - b3*ILLIQ_{j,t-1}$. The regressions include firm and year fixed effects. The sample includes 64,798 firm-years for the entire period and 31,991 and 32,807 firm-years for the first and second subperiod, respectively. The *t*-statistics (in parentheses) are based on standard errors clustered by firm and year. *, **, and *** indicate significance at the 0.10, 0.05, and 0.01 level, respectively.

		Subperiods	
	1963-2019	1963-1990	1991-2019
$ILLIQ_{j,t-1}$	0.005	0.002	0.003
	(3.93)***	(1.20)	(1.66)*
$Sales_{j,t}$	0.947	0.948	0.940
	(112.1)***	(67.62)***	(70.59)***
$\mathbf{ILLIQ_{j,t-1}*Sales_{j,t}}$	**0.001**	**0.002**	**0.002**
	(2.61)* **	**(2.20)** **	**(2.28)** **
$Q_{j,t-1}$	-0.033	-0.031	-0.028
	(-13.13)***	(-8.88)***	(-9.38)***
$TA_{j,t-1}$	0.003	0.004	-0.005
	(1.51)	(1.18)	(-1.64)
$VOL_{j,t-1}$	-0.010	-0.014	-0.007
	(-5.66)***	(-8.76)***	(-3.69)***
$RET2_{j,t-1}$	0.294	0.121	0.308
	(6.57)***	(2.13)**	(5.45)***
R^2	99.5%	99.7%	99.3%

Appendix

Table A1: Investment as a function of *SPRD*, the relative quoted bid-ask spread

This table presents results for the model:

$$INV_{j,t} = b1*SPRD_{j,t-1} + b2*CF_{j,t} + b3*Q_{j,t-1} + b4*TA_{j,t-1} + b5*VOL_{j,t-1} + b6*RET2_{j,t-1} + firm\ FE + year\ FE. \quad (1)$$

$SPRD_{j,t}$ is the (logarithm of the) average daily relative quoted bid-ask spread (the dollar spread divided by the quote's mid-point) in year t. Data for *SPRD* are available from CRSP since 1993, thus the sample size is smaller. Investment of firm j in year t, $INV_{j,t}$, is $CEx_{j,t}$ or $CExRD_{j,t}$. Filters for the data and the variables apply. Errors are clustered by firm and year. The sample includes NYSE and AMEX firms unless otherwise indicated. To save space, we present in Panels B and C only the coefficient of $SPRD_{j,t-1}$; the models include all control variables. The t-statistics (in parentheses) are based on standard errors clustered by firm and year. *, **, and *** indicate significance at the 0.10, 0.05, and 0.01 level, respectively.

Panel A: Estimations over the period 1994-2019

	Dependent Variable	
	$CEx_{j,t}$	$CExRD_{j,t}$
$SPRD_{j,t-1}$	-0.008	-0.009
	(-6.84)***	(-5.61)***
$CF_{j,t}$	0.076	0.054
	(10.65)***	(5.31)***
$Q_{j,t-1}$	0.010	0.014
	(8.71)***	(9.79)***
$TA_{j,t-1}$	-0.015	-0.022
	(-7.93)***	(-9.39)***
$VOL_{j,t-1}$	-0.107	-0.113
	(-4.07)***	(-3.49)***
$RET2_{j,t-1}$	0.003	0.002
	(2.72)***	(2.31)**
Firm FE	Yes	Yes
Year FE	Yes	Yes
N	28,971	28,971
R^2	69.1%	69.8%

Panel B: Estimations for Nasdaq firms, 1998-2019

	Dependent Variable	
	$CEx_{j,t}$	$CExRD_{j,t}$
$SPRD_{j,t-1}$	-0.005	-0.007
	(-4.90)***	(-4.71)***
Including control variables and firm and year fixed effects		
N	31,477	31,477
R^2	65.6%	79.6%

Panel C: Estimation with industry fixed effects instead of firm fixed effects. See legend in Table 2 Panel E.

	Panel Regressions		Fama-MacBeth Regressions	
	$CEx_{j,t}$	$CExRD_{j,t}$	$CEx_{j,t}$	$CExRD_{j,t}$
$SPRD_{j,t-1}$	-0.005	-0.005	-0.006	-0.009
	(-3.51)***	(-2.91)***	(-4.18)***	(-2.93)***
Including control variables and firm and year fixed effects				
R^2	36.6%	28.7%	39.9%	33.9%

Table A2: *Changes* in investment as a function of *changes* in the explanatory variables

This table presents results of panel regressions of the model:

$$dINV_{j,t} = b1*dILLIQ_{j,t-1} + b2*dCF_{j,t} + b3*dQ_{j,t-1} + b4*dTA_{j,t-1} + b5*dVOL_{j,t-1} + b6*dRET2_{j,t-1} + b7*dINV_{j,t-1} + year\ FE.$$

The prefix *d* indicates the first difference in each year of the variable used in Panel A of Table 2. The *t*-statistics (in parentheses) are based on standard errors clustered by firm and year. *, **, and *** indicate significance at the 0.10, 0.05, and 0.01 level, respectively.

	Dependent Variable			
	$dCEx_{j,t}$	$dCExRD_{j,t}$	$dCEx_{j,t}$	$dCExRD_{j,t}$
$dILLIQ_{j,t-1}$	-0.008	-0.009	-0.010	-0.011
	(-11.58)***	(-11.50)***	(-13.45)***	(-13.40)***
$dCF_{j,t}$	0.064	0.049	0.061	0.047
	(8.01)***	(4.17)***	(7.88)***	(4.19)***
$dQ_{j,t-1}$	0.008	0.01	0.008	0.011
	(6.75)***	(7.60)***	(6.92)***	(7.86)***
$dTA_{j,t-1}$	-0.065	-0.081	-0.052	-0.066
	(-14.28)***	(-18.37)***	(-13.69)***	(-18.12)***
$dVOL_{j,t-1}$	-0.084	-0.096	-0.084	-0.094
	(-3.01)***	(-3.06)***	(-2.95)***	(-2.98)***
$dRET2_{j,t-1}$	0.003	0.003	0.003	0.003
	(3.97)***	(3.67)***	(4.04)***	(3.81)***
$dINV_{j,t-1}$			-0.21	-0.217
			(-13.67)***	(-15.66)***
N	57,084	57,084	57,084	57,084
R^2	9.7%	9.9%	13.9%	14.3%

Table A3: Investment in intangible assets and in R&D as a function of illiquidity

Estimations of Model (1) with variables that follow Peters and Taylor's (2017) method of accounting for intangible assets. $InvInt_{j,t}$, investment in intangible capital, equals the R&D expense plus 0.3 times sales, general and administrative (SG&A) expense, divided by lagged TA^{tot}, the firm's total assets, the sum of intangible assets (at replacement cost) according to Peters and Taylor (2017) plus book value of property, plant and equipment (Compustat PPEGT item). $RDex_{j,t}$ is the R&D expense divided by lagged TA^{tot}. CF^{tot} is cash flow, defined as net income (before extraordinary items) plus depreciation and amortization divided by lagged TA^{tot}. $Q^{tot}_{j,t-1}$, is Peters and Taylor's (2017) estimation of Tobin's Q which accounts for intangible assets. Data for Q^{tot} and firm's intangible assets (at replacement cost) are obtained from Wharton Research Data Services (WRDS). The regressions include firm and year fixed effects. The sample includes 46,151 firm-years between 1976 and 2017 for NYSE-AMEX and 23,591 firm-years between 1998 and 2017 for Nasdaq after applying the sample selection criteria suggested by Peters and Taylor (2017). The *t*-statistics (in parentheses) are based on standard errors clustered by firm and year. *, **, and *** indicate significance at the 0.10, 0.05, and 0.01 level, respectively.

	NYSE-AMEX		Nasdaq	
	$IntInv_{j,t}$	$RDex_{j,t}$	$IntInv_{j,t}$	$RDex_{j,t}$
$ILLIQ_{j,t-1}$	-0.006	-0.001	-0.010	-0.004
	(-11.64)***	(-7.38)***	(-15.44)***	(-10.16)***
$CF^{tot}_{j,t}$	0.038	-0.004	-0.039	-0.046
	(5.67)***	(-1.94)*	(-5.46)***	(-7.41)***
$Q^{tot}_{j,t-1}$	0.006	0.002	0.009	0.004
	(6.85)***	(6.53)***	(10.18)***	(11.29)***
$TA^{tot}_{j,t-1}$	-0.022	-0.003	-0.051	-0.020
	(-15.71)***	(-6.72)***	(-16.62)***	(-10.92)***
$VOL_{j,t-1}$	0.016	0.008	0.042	0.040
	(0.85)	(1.14)	(2.70)***	(2.92)***
$RET2_{j,t-1}$	0.000	0.000	-0.001	-0.001
	(1.19)	(-1.34)	(-3.48)***	(-3.00)***
R^2	84.4%	86.8%	87.1%	89.8%

Table A4: Complete results for Model (1) to accompany Table 5.1

This table presents the complete estimation of Model (1) for each of the three groups of firms sorted in each year by $Delaycon_{j,t-1}$, $ILLIQ_{j,t-1}$ and by -1*$Equity\ Capitalization_{j,t-1}$ as indicators of financial constraint. It complements Table 5.1 that presents only the coefficients of $ILLIQ_{j,t-1}$ and of $CF_{j,t}$. The estimations are for the period 1963-2019 for analyses that use $ILLIQ_{j,t-1}$ and -1*$Equity\ Capitalization_{j,t-1}$, and for the period 1998-2016 for analyses that use $Delaycon_{j,t-1}$. The *t*-statistics (in parentheses) are based on standard errors clustered by firm and year. *, **, and *** indicate significance at the 0.10, 0.05, and 0.01 level, respectively.

	Sorting by $Delaycon_{j,t-1}$			Sorting on $ILLIQ_{j,t-1}$			Sorting on $-1*Equity\ Capitalization_{t-1}$		
	Low value= Low constraint	Medium	High value= High constraint	Low value= Low constraint	Medium	High value= High constraint	Low value= Low constraint	Medium	High value= High constraint
$ILLIQ_{j,t-1}$	-0.005	-0.006	-0.009	-0.015	-0.010	-0.007	-0.012	-0.008	-0.007
	(-4.09)***	(-4.68)***	(-4.40)***	(-9.69)***	(-8.92)***	(-8.80)***	(-9.74)***	(-8.88)***	(-9.39)***
$CF_{j,t}$	0.072	0.086	0.094	0.135	0.141	0.097	0.131	0.150	0.094
	(5.79)***	(5.56)***	(6.76)***	(8.28)***	(9.35)***	(10.16)***	(7.22)***	(9.77)***	(10.24)***
$Q_{j,t-1}$	0.008	0.008	0.011	0.003	0.006	0.006	0.003	0.006	0.006
	(3.42)***	(4.25)***	(5.47)***	(2.35)**	(3.85)***	(4.04)***	(2.10)**	(3.35)***	(3.85)***
$TA_{j,t-1}$	-0.019	-0.021	-0.018	-0.021	-0.021	-0.022	-0.019	-0.026	-0.021
	(-5.13)***	(-6.86)***	(-2.92)***	(-9.02)***	(-9.75)***	(-14.00)***	(-8.70)***	(-9.47)***	(-13.94)***
$VOL_{j,t-1}$	-0.005	-0.018	-0.050	-0.066	-0.187	-0.085	-0.031	-0.100	-0.086
	(-0.11)	(-0.44)	(-1.10)	(-1.41)	(-5.24)***	(-3.58)***	(-0.66)	(-2.65)***	(-3.78)***
$RET2_{j,t-1}$	0.001	0.000	0.001	0.008	0.004	0.005	0.008	0.003	0.004
	(0.94)	(0.40)	(0.58)	(5.73)***	(2.95)***	(6.09)***	(5.34)***	(2.52)**	(5.47)***
N	5,298	5,313	5,306	21,582	21,617	21,599	21,582	21,617	21,599
R^2	75.2%	79.7%	81.0%	68.2%	67.6%	60.0%	69.4%	66.9%	58.2%

Table A5. A falsification test of the feedback effect, employing cash flows

This table replicates Table 4, augmenting the model by $INFO_{j,t-1}*CF_{j,t-1}$, where $INFO = ILLIQ$ or $SPRD$. Standard errors are clustered by firm and year. *, **, and *** indicate significance at the 0.10, 0.05, and 0.01 level, respectively.

	$INV_{j,t} = CEx_{j,t}$		$INV_{j,t} = CExRD_{j,t}$	
	$INFO = ILLIQ$	$INFO = SPRD$	$INFO = ILLIQ$	$INFO = SPRD$
	1963-2019	1994-2019	1963-2019	1994-2019
$\boldsymbol{INFO_{j,t-1}}$	**-0.010**	**-0.011**	**-0.010**	**-0.012**
	(-13.52)*	**(-8.13)***	**(-12.78)***	**(-7.04)***
$CF_{j,t}$	0.159	0.088	0.133	0.053
	(3.89)***	(3.11)***	(2.57)***	(1.32)
$\boldsymbol{INFO_{j,t-1}*CF_{j,t-1}}$	**0.002**	**0.002**	**0.001**	**-0.001**
	(0.87)	**(0.379)**	**(0.364)**	**(-0.06)**
$Q_{j,t-1}$	0.021	0.018	0.021	0.024
	(4.84)***	(5.53)***	(3.65)***	(5.55)***
$\boldsymbol{INFO_{j,t-1}*Q_{j,t-1}}$	**0.001**	**0.001**	**0.001**	**0.002**
	(3.72)*	**(3.15)***	**(2.32)**	**(2.80)***
All regressions include control variables and firm and year fixed effects				
R^2	60.1%	69.2%	62.2%	69.9%

Table A6. A falsification test of the 2001 Decimalization effect, using other periods

Replications of the tests in Table 6 over sample periods that follow the 2001 decimalization. The estimated model is:

$$INV_{j,t} = \mathbf{b1*Post*SPD_j} + b2*CF_{j,t} + b3*Q_{j,t-1} + b4*TA_{j,t-1} + b5*VOL_{j,t-1} + b6*RET2_{j,t-1} + \text{firm FE} + \text{year FE} . \quad (2)$$

The regression is estimated separately for two subsample sets. In Set 1, *Post* = 1 for the years 2005-2006 and the "pre" years are 2002-2003, skipping the year 2004. In Set 2, *Post* = 1 for the years 2006-2007 and the "pre" years are 2003-2004, skipping the year 2005. *SPD* equals either *mSP*, which is minus the average bid-ask spread, or *LoSP* which equals 1 for firms with average bid-ask spread in the lowest quartile. *SPD* is estimated for Set 1 over January-July of 2003, and for Set 2 over January-July of 2004. Set 1 includes 5,896 firm-years, and Set 2 includes 5,773 firm-years. The *t*-statistics employ standard errors that are clustered by firm. *, **, and *** indicate significance at the 0.10, 0.05, and 0.01 level, respectively.

	$INV_{j,t} = CEx_{j,t}$		$INV_{j,t} = CExRD_{j,t}$	
	$SPD_j = mSP_j$	$SPD_j = LoSP_j$	$SPD_j = mSP_j$	$SPD_j = LoSP_j$
	(1)	(2)	(3)	(4)
Set 1: *Post* = 1 for 2005-2006. The "pre" years are 2002-2003				
$Post*SPD_j$	-0.007	-0.005	-0.001	-0.002
	(-0.83)	(-2.19)**	(-0.18)	(-0.75)
All regressions include the control variables and firm and year fixed-effects				
R^2	78.1%	78.1%	81.8%	81.9%
Set 2: *Post* = 1 for 2006-2007. The "pre" years are 2003-2004				
$Post*SPD_j$	-0.009	-0.000	-0.005	0.005
	(-0.68)	(-0.07)	(-0.24)	(1.64)
All regressions include the control variables and firm and year fixed-effects				
R^2	78.1%	78.1%	81.8%	81.9%

Table A7. A falsification test of the 1997 Nasdaq reform effect using other periods

Replications of the tests in Table 7 over sample periods that follow the 1997 Nasdaq reform. The estimated model is:

$$INV_{j,t} = \boldsymbol{b1*Post*f(Even8_j)} + b2*CF_{j,t}+b3*Q_{j,t-1}+ b4*TA_{j,t-1} + b5*VOL_{j,t-1} + b6*RET2_{j,t-1} + \text{firm FE} + \text{year FE}, \quad (3)$$

The regression is estimated separately for two subsample sets. In Set 1, *Post* = 1 for the years 2001-2002 and the "pre" years are 1998-1999, skipping the year 2000. In Set 2, *Post* = 1 for the years 2002-2003 and the "pre" years are 1999-2000, skipping the year 2001. $Even8_j$ is the proportion of quotes where both bid and ask prices are even-eighths prices. $f(Even8_j)$ is either $LEven8_j$ = ln(1+$Even8_j$) or *HiEven8*, a dummy variable that equals 1 for firms with above-median $Even8_j$ (0 otherwise). *Even8* is estimated for Set 1 over June-December of 1999, and for Set 2 over June-December of 2000. Set 1 includes 2,714 firm-years, and Set 2 includes 2,735 firm-years. The *t*-statistics employ standard errors that are clustered by firm. *, **, and *** indicate significance at the 0.10, 0.05, and 0.01 level, respectively.

	$INV_{j,t} = CEx_{j,t}$		$INV_{j,t} = CExRD_{j,t}$	
	$f(Even8_j)=$ $LEven8_j$ (1)	$f(Even8_j)=$ $HiEven8_j$ (2)	$f(Even8_j)=$ $LEven8_j$ (3)	$f(Even8_j)=$ $HiEven8_j$ (4)
Set 1: *Post* = 1 for 2001-2002. The "pre" years are 1998-1999				
$Post*f(Even8_j)$	-0.009	-0.001	-0.005	-0.001
	(-0.35)	(-0.15)	(-0.16)	(-0.17)
All regressions include the control variables and firm and year fixed-effects				
R^2	71.1%	71.1%	80.4%	80.4%
Set 2: *Post* = 1 for 2002-2003. The "pre" years are 1999-2000				
$Post*f(Even8_j)$	-0.039	-0.002	-0.026	-0.001
	(-1.20)	(-0.53)	(-0.67)	(-0.24)
All regressions include the control variables and firm and year fixed-effects				
R^2	70.4%	70.4%	80.8%	80.8%