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 decisions. Illiquidity raises the required return and the firm's cost of capital and thus negatively affects investment in fixed assets, in R&D and in inventory. The negative investment-illiquidity relation holds even for firms that are not financially constrained. Consequently, illiquidity induces firms to adopt a production process that is less capital intensive. Illiquid firms have higher marginal productivity of capital, more labor input for a given increase in capital, and lower operating leverage that means a lesser reliance on fixed costs. These effects hold after controlling for endogeneity by the instrumental variables method and for an exogenous liquidity event, the 2001 decimalization.

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"The Stock Market and Investment: Is the Market a Sideshow?"
Morck, Shleifer and Vishny (1990)

1. Introduction

We propose that stock market illiquidity has negative effect on corporate investment and consequently affects the extent of capital intensity in the firm's production process. This is because, following Amihud and Mendelson (1986),[1] illiquidity raises the expected return required by investors as compensation for higher transaction costs. Consequently, corporate managers apply a higher opportunity cost of capital when evaluating investment projects which reduces their value for any given future cash flows, thus reducing investment. Put differently, the firm's price/earnings ratio is lower for more illiquid stocks for any given expected earnings, risk and growth.[2] This is akin to the negative effect of risk on investment since risk raises the expected return required by risk-averse investors thus raising the firm's cost of capital.

We find that stock illiquidity has negative and significant effect on corporate investment in panel regressions with firm fixed effects or with industry fixed effects. The negative investment-illiquidity relation holds over time and across all major industries. Our results remain qualitatively unchanged after we account for potential endogeneity by employing instrumental variable regressions. And, testing the effect of an exogenous liquidity-increasing event, the 2001 decimalization, we find that firms whose stock liquidity benefitted most from decimalization invested significantly more.

We propose that the channel by which illiquidity affects investment is its effect on the cost of capital, which is similar to the effect of risk. Consequently, the negative illiquidity-investment effect should hold regardless of whether the firm is financially constrained, that is, regardless of whether the firm uses available cash for investment or whether it needs to raise capital. Corporate managers should select investment projects which generate sufficiently high return to satisfy stockholders' required return even if they have the necessary funds. We thus test whether the negative investment-illiquidity sensitivity is related to financial constraint and find that it does not. Following the methodology of Fazzari, Hubbard and Petersen (1988) we divide firms into three groups by nine measures of financial constraint and estimate the investment-

[1] Amihud and Mendelson (1986), Brennan and Subrahmanyam (1996) and other studies show that expected stock return is an increasing function of stock illiquidity. Similarly, bond illiquidity raises the required yield on corporate bonds (Chen, Lesmond and Wei, 2007). See a review in Amihud, Mendelson and Pedersen (2013).

[2] See evidence in Loderer and Roth (2005). Damodaran (2002) proposes, in the valuation of illiquid firms, to apply lower multiple of cash flow when valuing illiquid firms.

illiquidity sensitivity separately for each group. We find that the negative illiquidity-investment sensitivity is about equally strong for all groups including that of unconstrained firms. In particular, illiquidity has a strong negative effect on investment even in firms with the highest level of corporate liquidity (cash and marketable securities). We also find that the negative investment-illiquidity sensitivity is strongly significant after controlling for the level of corporate liquidity or the change in this level.

The firm's production process is also affected by stock illiquidity. We propose that because illiquidity inhibits investment it makes firms select a production process that is less capital intensive. And because illiquidity raises the cost of capital relative to labor cost, it raises the labor/capital rate of substitution in production. We find that illiquidity raises the marginal productivity of capital measured by the output-to-capital ratio and by the increase in output for a given increase in capital. And, we find that illiquidity raises the labor input for a given increase in capital. This result holds across the major industries. Finally, we find that the firm's operating leverage declines with illiquidity meaning that production relies more on variable costs and less on fixed costs which reflects broader definition of investment.

We test the effect of lagged illiquidity on investment measured by capital expenditures or by capital expenditures plus investment in research and development (R&D) scaled by lagged assets, as well as on investment measured by changes in total assets or by changes in inventory 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 for both measures of investment and for both measures of illiquidity. The estimation model includes firm (or industry) fixed effects and year fixed effects as well as control variables that have been shown to affect investment. Following Fazzari et al. (1988) we control for current cash flow and lagged Tobin's *Q*, calculated as the ratio of market-to-book value of assets. The control variables also include lagged total assets, return volatility and two-year stock return, all found to significantly affect investment. The models are estimated over a period of 54 years, 1963 through 2016 and for robustness we replicate the estimations for two equal subperiods of 27 years, 1963-1989 and 1990-2016.[3] All results are consistent for both subperiods. Our results on the negative and highly significant effect of illiquidity on investment remain the same when we estimate the

[3] Our models include firm fixed effects (or industry fixed effects) that control for unobserved characteristics. Because some of these characteristics may change over the long run, a shorter estimation period provides an additional check.

models with industry fixed effects replacing the firm fixed effects, using cross-section panel regressions or the Fama and Macbeth (1973) cross-section regression method. The negative and significant investment-illiquidity relation is not unique to any one industry; we show that it holds when estimating the model separately for each of five major industries using one-digit SIC code (excluding financials and utilities). We also find that *changes* in illiquidity have negative and significant effect on *changes* in investment; this relation is unaffected when including lagged changes in investment.

We deal with possible endogeneity of illiquidity in three ways. First, we employ an instrumental variable (two-stage least square) estimation of the model using institutional holdings as instrument. Institutional holdings are known to be negatively related to illiquidity as we indeed find in our estimates. We find that the instrumented *ILLIQ* has negative and significant effect on investment.

Second, to reduce concern about *contemporaneous* effects of shocks on both investment and illiquidity we estimate the effect on investment of *ILLIQ* that is lagged by two years or three years relative to investment instead of by one year (all other explanatory variables remain lagged by one year). We find that the negative and highly significant effect of *ILLIQ* persists even when it is lagged by two or three years.

Third, we employ an exogenous liquidity-improving event – the decimalization of quoted prices in the U.S. exchanges in 2001 – to test how a change in illiquidity affects investment. Quote decimalization enabled price increments of 1 cent instead of the minimum tick of 6.25 cents ($1/16) beforehand and was found to increase the liquidity of the most liquid stocks (Bessembiner, 2003). We find that following decimalization, investment increased significantly more in firms whose stock benefitted most from the increased liquidity – those with a narrower initial bid-ask spread which was more constrained by the minimum tick of 6.25 cents.[4]

Using lagged *Q* as an explanatory variable of capital investment may preclude using other explanatory variables given 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 positive effect of *Q* on investment there are significant effects of all explanatory variables – cash flow and lagged values of illiquidity, total assets, return volatility,

[4] Amihud and Mendelson (1986) prove that a given decline in trading costs reduces expected return more for stocks that are more liquid.

and past stock return. This may be because we use the standard average Q instead of marginal Q which the model demands. While the two are equal when financing is frictionless and profits are linear in capital (Hennessy, Levi and Whited, 2007), frictionless financing is inconsistent with illiquidity, which is the focus of our analysis. Also, Q is measured with error given that its calculation employs assets' book value instead of their replacement value and it does not include intangible capital. We replicate our tests using Peters and Taylor's (2017) "total Q" whose calculation accounts for intangible assets such as capitalized research and development expenditures and part of selling, general and administrative expenditures. Still, our results on the negative effect of illiquidity on investment remain practically unchanged.

While Q is expected to affect capital investment, inventory investment is not theoretically affected by Q. Yet, both inventory investment and capital investment are negatively affected by the firm's cost of capital which increases with illiquidity and risk. Therefore, inventory investment should decline in both illiquidity and risk. Our test results support this prediction. Stock illiquidity has a significant negative effect on inventory investment after controlling for Q and all the other variables used in the capital investment model as well as for the change in sales. This is consistent with the negative effect of illiquidity on capital expenditures. Here, Q has an insignificant negative effect on inventory investment which is unlike its positive and significant effect on capital investment.

We study whether the negative investment-illiquidity sensitivity is driven by illiquidity representing financial constraint, which inhibits investment in financially constrained firms with insufficient cash flow as suggested by Fazzari et al. (1988). This follows the proposition in Morck, Shleifer and Vishny (1990) and Bond, Edmans and Goldstein (2012) that the secondary market affects real activity through its effect on the issuance of new securities, which is more important for financially constrained firms. This channel of the effect of illiquidity on investment may coexist with the channel that we propose by which the positive effect of illiquidity on the firm's cost of capital affects investment regardless of the firm's financial constraint.

We test this by estimating the investment-illiquidity relation across firms with different level of financial constraint. We sort firms by nine measures of financial constraint – equity size, firm asset size, stock illiquidity, cash distribution, cash flow, cash balances, age, leverage, and the Whited-Wu (2006) measure – and divide them into three groups. We estimate our model for each of these groups and find that the negative and highly significant effect of illiquidity on investment holds for all groups, even for firms that are not financially constrained. The results hold for both capital expenditures and inventory investment. This supports our view that the negative investment-illiquidity relation is due to the illiquidity effect on the firm's cost of capital. Higher illiquidity induces managers to set a higher hurdle rate for investments so that they can generate higher expected return to accommodate stockholders who are averse to illiquidity in the same way that they are to risk and demand compensation for both.

We next test how the firm's production process is affected by stock illiquidity. The negative effect of illiquidity on capital investment induces firms to lower capital intensity in production. We find the following three results.

(i) Illiquidity raises the marginal productivity of capital measured by the sales-to-assets ratio or by the increase in output per unit increase in capital.

(ii) Illiquidity raises labor input for a given increase in capital, that is, it induces a higher labor/capital rate of substitution in production. These results hold for all main industries.

(iii) Illiquidity lowers the firm's operating leverage measured by the use of fixed cost in production which reflects investment in fixed assets and other fixed costs.

We find these results in panel regressions with control variables and with firm and year fixed effects. We also find these results when illiquidity is replaced by its instrumented value, employing a 2SLS procedure. We also employ the decimalization event as an exogenous shock to illiquidity to test these results. Our results thus propose that illiquidity depresses investment and induces firms to adopt production processes that deviate from those selected by their liquid counterparts. This can provide another channel by which illiquidity depresses firm value, documented by Fang Noe and Tice (2009).

Our firm-level evidence on the negative illiquidity-investment relation supports the documented macroeconomic effect of market liquidity on investment. Naes, Skjeltorp and Odegaard (2011) find that quarterly growth in aggregate private real investment is negatively affected by aggregate stock market illiquidity for the period 1947-2008, using several measures of illiquidity and controlling for macroeconomic variables.[5] The two sets of results are consistent.[6]

Our findings suggest that firms can benefit from improving their stock and bond liquidity, as suggested by Amihud and Mendelson (1986, 1988). This includes primarily going public, which makes the firm's stock liquid. For public firms, illiquidity can improve by enhanced voluntary disclosure, which reduces information asymmetry and improves liquidity; having standardized claims, increasing the float and facilitating trading in the firm's stock, especially for small investors. For example, Balakrishnan, Billings, Kelly, Ljungqvist (2016) find that firm stock liquidity improves following voluntary disclosure by firms that provide more timely and informative earnings guidance. Amihud, Mendelson and Uno (1999) find that stock liquidity improved and stock price increased when firms reduced the minimum trading unit of their stock, thus making it more accessible to small investors. Amihud, Lauterbach and Mendelson (2003) find that stock liquidity and stock prices increase when firms eliminate fragmented trading in its equity securities by consolidating them.

We now briefly review the theory and evidence on the effect of illiquidity on the cost of capital. Amihud and Mendelson (1986) propose that expected return is an increasing function of the illiquidity of the firm's securities because investors require compensation for higher cost of trading. This prediction is supported empirically by a great number of studies for both stocks and bonds. Illiquidity also increases the firm's cost of raising capital through higher underwriter fees and greater price discount on the stock and bonds that the firm is selling. This translates into a higher required return on investment projects financed by external financing. Butler, Grullon and Weston (2005) and Gao and Ritter (2010) find that in seasoned equity offerings (SEOs), investment banking fees increase in the firm's stock illiquidity, especially for large equity issues, and Asem, Chung, Cui and Tian (2016) find that illiquidity induces greater price discounts at

[5] In our analysis, we control for macroeconomic effects by including time fixed effects.

[6] Some studies find inconsistent results on the relation between firm investment and changes in liquidity due to addition to or deletion from stock indexes. This may be because these additions of stocks to an index or deletions from it, which are non-random, reflect information on the firm's prospects, thus on its investment. Becker-Blease and Paul (2008) find that firms whose stock is added to the S&P500 index increase their capital investment and enjoy subsequent increase in liquidity, while Gregoriou and Nguyen (2010) find that firms whose stock was deleted from the FTSE 100 index in the U.K. had no reduction in investment or stock liquidity. Asker, Farre-Mensa and Ljungqvist (2015) find that private firms invest more than public ones, which are more liquid, suggesting that public firms are subject to short-termism pressures that distort investment decisions. In our analysis, all firms are public and are subject to capital market pressures.

SEOs. This is why firms prefer to do SEOs after their stock liquidity has improved, which lowrs expected return; see Lin and Wu (2013). Bond illiquidity similarly raises the required yield on corporate bonds (Chen, Lesmond and Wei, 2007), increases the borrowing cost on new debt and reduces the firms' propensity to issue debt (Davis, Masler and Roseman, 2017). Over time and across world markets, higher stock market illiquidity negatively affects equity issuance (Hanselaar, Stulz and van Dijk, 2016).

The paper proceeds as follows. In Section 2 we present evidence on the effect of the firm's stock illiquidity on investment. In Section 3 we present evidence on the effect of stock decimalization in 2001 on investment. Section 4 includes tests on the effects of stock illiquidity on a number of production features of the firm. Concluding remarks are offered in Section 5.

2. The effect of illiquidity on corporate investment

We estimate the effect of stock illiquidity on the firm's investment using Fazzari et al.'s (1988) model which explains the firm investment by cash flow and Tobin's *Q* with firm fixed effects and time fixed effect. We augment the model by adding some lagged explanatory variables.

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

$INV_{j,t}$ is investment of firm *j* in year *t*, for which we use *CExp*, capital expenditures, or *CExpRD*, the sum of *CExp* and investment in research and development (R&D), both scaled by lagged total assets. *CExpRD* is called "total investment" by Babenko et al. (2011) and is used by Becker and Stromberg (2012). Our analysis employs annual values over a period of 54 years, 1963-2016.

We focus on the effect of illiquidity, measured by Amihud's (2002) *ILLIQ*. We hypothesize that $b1 < 0$, that is, the firm investment is a declining function of its stock illiquidity. $ILLIQ_{j,t}$ is the (logarithm of the) average for each stock *j* over year *t* of the daily ratio of absolute return to dollar volume. This measure is shown by Amihud (2002) to be highly correlated with Kyle's (1985) theoretical measure of illiquidity, λ, the price impact of trades and with the fixed cost of trading. Hasbrouck (2009) and Goyenlo et al. (2009) find that it is the most highly correlated low-frequency measure of illiquidity with Kyle's (1985) λ. In international crosscountry studies, Lesmond (2005) finds that *ILLIQ* is among the best low-frequency measures of illiquidity that estimate the bid-ask spread plus commissions, and Fong, Holden and Trzcinka (2017) find that *ILLIQ* is among the best low-frequency estimates of λ. 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, and price of at least $1 at the beginning of the test year. To avoid outliers, we delete 1% of the daily observations with the highest values of *ILLIQ* in each stock-year. As a robustness test we replace $ILLIQ_{j,t}$ by another measure of illiquidity, the bid-ask spread, denoted $SPRD_{j,t}$. It is the (logarithm of the) average daily quoted relative bid-ask spread (the dollar spread divided by the quote's mid-point) in year *t*. Data for *SPRD* are available from CRSP since the end of 1992 and thus we use the 1993 average spread for cross-section analysis that begins in 1994. Consequently, the sample size is smaller. The results for estimations that use $SPRD_{j,t-1}$ are presented in the appendix.

The control variables include contemporaneous cash flow, *CF*, following Myers and Majluf (1984) and Fazzari et al. (1988) who propose that firms invest first from available internal resources. *CF* equals net income (before extraordinary items) plus depreciation and amortization and it is scaled by total assets. The other explanatory variables are lagged by one year. *Q* (an estimate of Tobin's *q*) is the market value of assets divided by book value of assets, where the market value of assets is defined as market value of equity plus book value of assets minus book value of equity minus balance sheet deferred taxes (following the definition in Fang et al. 2009). This variable commonly reflects growth opportunities. *TA* is total assets (in logarithm) which measure the firm's total size. *VOL* is the standard deviation of weekly stock return calculated over the year, which measures the firm's risk. Volatility or risk 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 market expectations about investment opportunity and thus its coefficient is expected to me positive. The inclusion of the control variables *TA*, *VOL*, and *RET2* is important 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. Thus, their omission may lead to the "missing variable problem" by which their effect on investment is erroneously attributed to that of *ILLIQ* with which they are correlated. *RET2* also controls for the effect of 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.[7]

Our sample includes firms whose stock traded on the New York Stock Exchange (NYSE) and the American Stock Exchange (AMEX) during 1963-2016. We conduct a separate analysis for firms whose stock traded on Nasdaq during a shorter period, 1998-2016, 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 counted twice reflecting both 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 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 62,102 firm-years except for the data on $SPRD_{j,t-1}$ that include 26,242 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. In Panel A we present results for the entire sample period for NYSE-AMEX stocks. The coefficient of $ILLIQ_{j,t-1}$ is negative and significant for all four investment variables. Specifically, the coefficients *b1* of $ILLIQ_{j,t-1}$ for the model with $INV_{j,t} = CEx_{j,t}$ and $CExRD_{j,t}$ are, respectively, -0.008 (t = -13.05) and -0.009 (t = -12.54), highly significant.

In Appendix Table A1 we present estimation results with illiquidity measured by *SPRD*, the logarithm of the relative quoted bid-ask spread. The results are qualitatively similar to those when illiquidity is measured by *ILLIQ*. In all regressions, illiquidity measured by the bid-ask spread has negative and highly significant effect on corporate investment. For example, the

[7] 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. While we control for the effect of 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.

coefficient *b1* of $SPRD_{j,t-1}$ for the model with $INV_{j,t} = CEx_{j,t}$ is -0.008 with t = -6.64, highly significant. As pointed out above, because of data availability, tests using *SPRD* begin in 1994 and include less than a quarter of the years and less than half the firm-years used for tests with *ILLIQ* as a measure of illiquidity.

The economic significance of the estimated effects of illiquidity is illustrated as follows. By the estimates in Table 2, Panel A, one standard deviation increase in *ILLIQ* over time lowers subsequent investment (relative to assets) measured as *CEx* by 1.3% and lowers *CExRD* by 1.5%. Using the cross-section results in Panel E by the Fama-Macbeth method, one standard deviation increase in *ILLIQ* across firms lowers investment measured as *CEx* by 1.2% and lowers *CExRD* by 1.7%. These estimations are similar in magnitude and are economically meaningful relative to the mean values of *CEx* and *CExRD* that are 7.7% and 9.5%, respectively.[8]

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 as is the effect of $ILLIQ_{j,t-1}$. This is reasonable since both risk and illiquidity raise the required return.[9] Investment is lower for larger firms (those with higher $TA_{j,t-1}$) and higher for firms with better past performance (higher $RET2_{j,t-1}$). The significant effects on investment of the last three variables, which are also correlated with $ILLIj_{,t-1}$, highlight the importance of not omitting them from a model that focuses on the effect of $ILLIQ_{j,t-1}$.

We replicate our test using another measure of investment, the change in total assets, *dTA*, scaled by lagged total assets. The variable *dTA* reflects changes in all the firm's assets due to capital expenditures as well as investment in current assets and acquisitions of companies. However, *dTA* may include accounting revaluation of assets which raises asset value without the firm making an investment, or *dTA* may be negative because of capital losses including involuntary impairment of value. Voluntary decline in total assets includes spinoffs and split-offs, which are driven by economic considerations that are unrelated to stock liquidity. Or, a firm

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[8] For the estimates of Panel A that include firm fixed effects, the standard deviation of *ILLIQ* is calculated after controlling for firm fixed effects. For the annual cross-firms estimates in Panel E, the standard deviation of *ILLIQ* is calculated after controlling for time fixed effects. These standard deviations are 1.68 and 2.49, respectively.

[9] Adding to the model lagged β that is estimated from monthly return over 36 months does not affect the coefficient of $ILLIQ_{j,t-1}$.

may sell assets and distribute the proceeds to stockholders through stock repurchase and special dividend. Altogether, $dTA < 0$ for 27% of the firm years in our sample which reflects both voluntary and involuntary declines in total assets that are unrelated to stock liquidity.

We estimate Model (1) with $INV_{j,t} = dTA_{j,t}$ and find that the results are similar to those reported in Table 2, that is, illiquidity reduces investment. The coefficients of $ILLIQ_{j,t-1}$ is -0.024 with t = -11.83, highly significant. In conclusion, stock illiquidity has negative and highly significant effect on investment defined as change in total assets. When using $SPRD_{j,t-1}$ as a measure of illiquidity with $INV_{j,t} = dTA_{j,t}$, its coefficient is -0.041 with t = -8.36, highly significant. 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 reduces the sample to 45,278 firm-years. We find that the coefficient of $ILLIQ_{j,t-1}$ is -0.018 with t = -8.88, which is again highly significant.

2.1. Robustness tests

2.1.1. Tests across industries

In Panel B we test whether the negative investment-illiquidity relation holds across industries. We do industry-level estimations of Model (1) for five one-digit SIC code industries. While the firm fixed effects subsume the industry effects in terms of the level of investment, a separate estimation for each industry allows for the slope coefficients to vary across industries. We use industries codes 1 to 5 which are, respectively, mining and construction; two types of manufacturing; transportation, communication, electric, gas and sanitary services; and retail and wholesale trade. We present results for $INV = CEx$. We find that all five coefficients of $ILLIQ$ are negative and significant, varying between -0.005 to -0.014 which is of the same order of magnitude. We conclude that our result on the negative investment-illiquidity relation applies to all industry groups.

2.1.2. Consistency over time

In Panel C, we examine whether the negative investment-illiquidity relation is consistent over time by splitting the sample into two equal subperiods of 27 years each, and estimating the model for each subperiod. Given that firm fixed effects are assumed to control for time-invariant firm characteristics,[10] a shorter estimation period makes this assumption more reasonable. We

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[10]See Roberts and Whited (2013).

find that the coefficient of *ILLIQ* is negative and significant in *both* subperiods. For example, for the *INV* = *CEx* equation, the coefficients of *ILLIQ* are -0.011 (t = -12.87) and -0.007 (t = -9.31) for the first and second subperiod, respectively.

We find similar results for $INV_{j,t} = dTA_{j,t}$. The coefficients of $ILLIQ_{j,t-1}$ are similar in magnitude and significance for both subperiods, being -0.029 (t = 11.57) and -0.025 (t = 8.13) for subperiods I and II, respectively. Thus, 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 with data that begin in 1998, the year after the Nasdaq reform. It enabled direct trading between stockholders in a way similar to that done on NYSE and AMEX, making *ILLIQ* similar to that estimated for NYSE and AMEX. Notably, accommodates relatively younger firms in newly-developing industries (such as high tech) that were different from those listed on NYSE\AMEX. Thus, a separate estimation of the investment-illiquidity relation for Nasdaq firms enables to test our hypothesis for a different group of firms.

The results in Panel D show that the results for Nasdaq firms are similar to those for NYSE\AMEX firms. The coefficient of *ILLIQ* is negative and highly significant. We also estimate the model for $INV_{j,t} = dTA_{j,t}$ and find that he effect of *ILLIQ* is negative and highly significant. In the Appendix Table A1, Panel B, we present the results with *SPRD* replacing *ILLIQ*.

2.1.4. Replacing firm fixed effects by industry fixed effects

We now estimate Model (1) in cross-section regressions using industry fixed effects instead of firm fixed effects, employing two estimation methods: a panel regression and annual cross-section Fama-Macbeth regressions. Roberts and Whited (2013) propose to do model estimation with and without firm fixed effects and check whether the estimated coefficients change in a meaningful way between the two methods. This procedure could indicate if there is a low frequency, unobserved omitted variable that affects the results. They also suggest that estimation without firm fixed effects provides a better understanding of the cross-sectional effects of the variables since a model with firm fixed effects estimates the within-firm variation rather than the cross-sectional variation that is of interest. In Panel E we replicate the estimation of Panel A *without* firm fixed effects using instead *industry* fixed effects that employ Fama and French's 49-industry classification. We use both panel regressions and annual cross-section Fama-Macbeth regressions where the annual coefficients are averaged over the 54 sample years.[11]

We find that the coefficients of *ILLIQ* are similar in these estimations to those in Panel A in both magnitude and statistical significance. This suggests that the model is unlikely to omit an unobservable variable that affects the results.[12] For example, the coefficient of *ILLIQ* in the panel regression here with *CExRD* as dependent variable is -0.008 (t = -10.59) with industry fixed effect compared with -0.009 (t = -12.54) with firm fixed effects in Panel A. Results with illiquidity measured by *SPRD* are presented in the Appendix Table A1, Panel C. There again, the effect of illiquidity is negative and significant and the magnitude of the coefficients is similar as those in Panel A where we use firm fixed effect. Employing the Fama-MacBeth estimation procedure, we again find that the coefficients of *ILLIQ* and *SPRD* are negative and highly significant with their magnitude being close to those presented in Panel A where we employ panel regressions with firm fixed effect.

For $INV_{j,t} = dTA_{j,t}$ we find similar results. In the cross-section regressions using the Fama-Macbeth procedure (as we do in Panel E) with industry fixed effects, the coefficient of $ILLIQ_{j,t-1}$ is -0.011 with t = -10.11.

2.1.5. Using a *Q* value that accounts for intangible assets

We do two robustness tests that change the variables in the model. The first test accounts for possible error in the calculation of $Q_{j,t-1}$, replacing it by Peters and Taylor's (2017) "total *Q*" denoted $Q^{tot}_{j,t-1}$ which takes into account intangible assets. The calculation of Q^{tot} employs R&D expenditures and part of selling, general and administrative (SG&A) expenditures which are

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[11] In the panel regression, standard errors are clustered by firm and by year. In the tests by the Fama-Macbeth procedure, the estimated 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.
[12] Roberts and Whited (2013) 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.

capitalized instead of expensed and then depreciated over an assumed number of years. A more precisely measured Q may better predict investment and weaken the predictive effect of *ILLIQ*.

The data source for Q^{tot} is Luke Taylor's web site which provides firm-level data. Q^{tot} includes capitalized R&D investment and a fraction of Selling General & Administrative (SGA) costs which include spending on organizational capital through advertising and brand support, spending on distribution systems, employee training, and payments to strategy consultants.

The results show that the coefficient of $ILLIQ_{j,t-1}$ remains negative and highly significant when $Q^{tot}_{j,t-1}$ replaces $Q_{j,t-1}$. For the model with the dependent variable $INV_{j,t} = CEx_{j,t}$ ($INV_{j,t} = CEx_{j,t}$), the coefficient of $\mathrm{ILLIQ}_{j,t-1}$ is -0.008 with t = -13.68 (-0.010 with t = -13.84, respectively), which are similar to the coefficients in Panel A of Table 2. The coefficients of $Q^{tot}_{j,t-1}$ for the models with $INV_{j,t} = CEx_{j,t}$ and $INV_{j,t} = CEx_{j,t}$ are, respectively, 0.004 with t = 5.66 and 0.005 with t = 5.15.

2.1.6. 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. This is a useful alternative to the panel regression with firm fixed effects when the model residuals are potentially correlated with unobserved low-frequency characteristics. We also estimate the model with lagged changes in investment, accommodating 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." We present in Panel F of Table 2 the coefficients of $dILLIQ_{j,t-1}$ and of the lagged changes investment; the coefficients of all variables are presented in the Appendix Table A2.

We find that the coefficients of the changes in all explanatory variables are similar in sign and significance to those presented in Panel A. In particular, the coefficient of $dILLIQ_{j,t-1}$ is negative and highly significant regardless of whether the model includes the lagged change in investment. For $dINV_{j,t} = dCEx_{j,t}$, the coefficient of $dILLIQ_{j,t-1}$ is -0.008 with t = -10.53. The result is similar when replacing the firm fixed effects with industry fixed effects. Adding to this model industry fixed effects does not change the results.

Adding to the model lagged dependent variable, $dINV_{j,t-1}$, the results are unchanged. The coefficient of $dILLIQ_{j,t-1}$ remains negative and highly significant. In a model that includes $dCEx_{j,t-1}$, the coefficient of $dILLIQ_{j,t-1}$ is -0.010 with t = -12.01 which is similar in magnitude and in significance to the coefficient of $ILLIQ_{j,t-1}$ in Panel A of this table. The coefficient of $dINV_{j,t-1}$ is highly significant and it is negative indicating partial reversals in 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 of Table 2.

2.1.7. Controlling for corporate liquidity: the level of cash and changes in cash

Corporate liquidity – cash and marketable securities – may facilitate investment and at the same time may reduce stock illiquidity. Thus omitting corporate liquidity from the model could cause an observed negative effect of illiquidity on investment. We therefore re-estimate Model (1) which is augmented by the lagged level or change in corporate liquidity. We add to the model the explanatory variables $Cash_{j,t-1}$, the level of cash and marketable securities, or $dCash_{j,t}$, the change in $Cash_{j,t}$, both scaled by lagged total assets.

We find in Panel G1 that the effect of *ILLIQ* on investment remains negative and highly significant for the entire period and for each of the two subperiods while the effect of corporate liquidity is not robust. The coefficient of $ILLIQ_{j,t-1}$ is -0.008 with t = -13.10 and the coefficient of $Cash_{j,t-1}$ is negative, -0.008 with t = -1.93, marginally significant. But while the coefficient of $ILLIQ_{j,t-1}$ is negative and highly significant for each of the two subperiods, the coefficient of $Cash_{j,t-1}$ is insignificantly different from zero in both subperiods. Similarly, when $dCash_{j,t-1}$ is added 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 G2.

Our results thus show that the negative and highly significant effect of stock liquidity (*ILLIQ*) on investment remains after controlling for the effect of corporate liquidity. Below, we present (in Table 4.2) additional findings that the negative investment-illiquidity sensitivity is unaffected by whether it is estimated separately for firms with high or low level of corporate liquidity.

2.1.8. Inventory investment

We test the effect of stock illiquidity on investment in inventory. By standard models, optimal inventory declines in the carrying cost of inventory that includes the cost of capital. We therefore expect that illiquidity, which raises the cost of capital, has negative effect on inventory investment. Notably, Tobin's *Q* is not expected to affect inventory investment. While Fazzari, Hubbard and Petersen (1988) include lagged *Q* in their capital investment estimation model, the inventory investment models of Carpenter, Fazzari and Petersen (1994) and of Jones and Tuzel (2013) do not include *Q* as an explanatory variable. Jones and Tuzel (2013) find that inventory growth is a declining function of the firm's implied cost of capital that is derived from projections of future firm earnings (using analysts' expectations or earnings forecasting models) and equity prices.[13] 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 both variables have negative and significant effect on inventory investment.

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

INSERT TABLE 3

The results in Table 3 show that $ILLIQ_{j,t-1}$ has a strongly negative effect on inventory investment and its coefficient is of the same order of magnitude as that in the investment model of Table 2. The coefficient of $ILLIQ_{j,t-1}$ is -0.005 with t = -11.12 for the entire period and it is -0.007 (t = -10.09) and -0.004 (t = -8.13) for the first and second subperiod, respectively. Importantly, $Q_{j,t-1}$ does not have a robustly significant effect on inventory and its coefficient is altogether negative as opposed to being positive and significant in the fixed investment model. While the coefficient of $Q_{j,t-1}$ is negative and significant for the entire period, it is insignificantly different from zero for each of the two subperiods. Past stock returns which may predict better future prospects for the firm have positive and significant effect on inventory investment.

[13] Kashyap, Lamont and Stein (1994) find that firm's balance sheet liquidity – cash and short-term investments divided by total assets – positively affect 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.

The effect of volatility, *VOL*, is negative and significant which is similar to the negative and significant effect of *VOL* on *ILLIQ*. The negative effect of risk on inventory investment is consistent with Jones and Tuzel's (2013) results. As in Carpenter et al. (1994), $dSales_{j,t}$ and $Cash\ Flows_{j,t}$ have positive and significant effects on inventory investment. When adding to the model lagged change in sales, $dSales_{j,t-1}$, its coefficient is 0.0016 with t = 0.70, insignificant.

We again re-estimate the model using $SPRD_{j,t-1}$, the bid-ask spread, instead of $ILLIQ_{j,t-1}$. The results are qualitatively similar. The coefficient of $SPRD_{j,t-1}$ is -0.005 with t = -10.37.

We conclude that illiquidity has negative effect on inventory investment in the same way that it negatively affects corporate investment in fixed assets and in R&D. The negative effect of illiquidity can be traced to its effect on the firm's cost of capital which negatively affects optimal inventory since firm's value or Tobin's *Q* has no robust significant effect on this type of investment.

2.2. Financial constraint and the effect of illiquidity

We have proposed that illiquidity lowers investment because it raises the corporate cost of capital. Corporate managers accommodate stockholders demand for higher expected return in less liquid stocks by raising the hurdle rate on investment projects in firms with higher stock illiquidity. This is similar to the basic tenet in finance that the hurdle rate is increasing in risk given stockholders' risk aversion. Another explanation for the negative effect of stock illiquidity on investment could be that illiquidity indicates a financial constraint. Then, by Fazzari et al. (1998) the effect of stock illiquidity should be more important for constrained firms. Also, there should be greater investment-cash flow sensitivity in firms with more illiquid stocks because the higher cost of raising capital makes constrained firm more reliant on their internally-generated funds. Morck et al. (1990) and Bond, Edmans and Goldstein (2012) propose that the stock market affects firm's investment behavior through its effect on the issuance of new securities which firms undertake to raise capital for investment.

Following the methodology of Fazzari et al. (1998), we first divide firms in each year into three groups by lagged measures of financial constraint, using here stock illiquidity, *ILLIQ* and -1**Equity Capitalization* which is positively correlated with *ILLIQ*. The variable -1**Equity Capitalization* is considered an instrument because lagged *ILLIQ* includes transitory variations which reflect recent events in the firm or estimation errors (noise). Higher values of *ILLIQ* and -1**Equity Capitalization* could indicate higher financial constraint.

Then we estimate Model (1) for each of the three group using $INV_{j,t} = CEx_{j,t}$. We propose the following. If the negative investment-illiquidity relation is due financial constraint indicated by to illiquidity, the coefficient *b1* of $ILLIQ_{j,t-1}$ should be close to zero for unconstrained firms and more negative for firms with higher *ILLIQ* or -1**Equity Capitalization* (smaller size). However, if the channel by which illiquidity lowers investment is through it raising the corporate cost of capital, *b1* should be negative and significant for both unconstrained and constrained firms.

INSERT TABLE 4

We find that the negative investment-illiquidity relation is not driven by financial constraint. The results are presented in Table 4.1; to save space, we present only the coefficient of $ILLIQ_{j,t-1}$ and $CF_{j,t}$. We present results for the entire period, 1973-2016, and for the two subperiods, 1973-1989 and 1990-2016. In the Appendix Table A3 we present the complete results with coefficients for all the variables.

We find that *b1* is negative and significant for all three groups including the group of the least constraint firms, those with the lowest illiquidity and biggest size. We observe a clear pattern in the coefficient *b1* of $ILLIQ_{j,t-1}$. Moving from the group with the lowest to the group with the highest illiquidity, the coefficients *b1* are, respectively, -0.015 (t = -9.43), -0.010 (t = -9.12) and -0.006 (t = -7.77), respectively. The values of *b1* for the high-illiquidity and low-illiquidity groups are more than two standard errors apart. This pattern holds in each of the two subperiods, and it also holds when we move from the biggest-size to the smallest-size firms.

The evidence thus shows that the investment-illiquidity sensitivity is greater for firms with the most liquid stocks. This result can be explained based on Amihud and mendelson's (1986) theory and evidence on the effect of illiquidity, measured by transaction costs (such as the bid-ask spread) on expected return. They propose that in equilibrium, more liquid (lower illiquidity) stocks are more likely to be held by investors with a shorter expected holding period who price illiquidity cost more dearly. Consequently, for more liquid stocks, a given change in trading costs has greater effect on the required expected return for the most liquid stocks. Empirical evidence supports the existence of a greater expected return-illiquidity cost relationship.[14] Consequently, we expect that illiquidity will have a greater effect on corporate investment for firms with the most liquid stocks.

Our evidence does not support Fazzari et al.'s (1988) hypothesis on the effect of financial constraint on the investment-cash flow sensitivity. We do not find a systematic relation between the coefficient of $CF_{j,t}$ across the financial constraint groups. This is consistent with Kaplan and Zingales's (1997, 2000) claim that this sensitivity is not a valid measure of financing constraint.

We further use seven measures of financial constraint to test whether the negative investment-illiquidity relation is affected by financial constraint. Following Fazzari et al. (1988) we use *Cash Distribution* that equals dividends plus stock purchases divided by market value of equity. Following Hovakimian and Titman (2006) we use *Age*, the number of years from IPO, and *Firm Size*, measured by total assets, since younger and smaller firms are likely to be financially constrained. We use two measures of availability of cash; low values of these variables may indicate a need for external financing. *Cash Flow* is income before extraordinary items plus depreciation divided by total assets. *Cash Balance* is cash and cash equivalents divided by total assets. For all these measures, higher value means lower constraint. *Leverage* is the sum of long-term and short-term debt minus cash, divided by total assets. Higher leverage and debt overhang may inhibit the raising of new capital and thus may indicate constraint. And, Nini, Smith and Sufi (2009) find widespread restrictions on capital expenditures in loan agreements of highly levered firms. Finally, *Whited-Wu* is a weighted average of firm's characteristics using Whited and Wu's (2006) model and estimated weights. For the last two measures, higher values indicate higher financial constraint therefore we multiply them by -1 to make the presentation consistent with that of the other measures for which lower value implies higher financial constraint.

The results in Table 4.2 show 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. While for the constraint measures in Panels A, B and F *b1* is significantly more negative for the most financially constrained firms, the pattern is

[14] Amihud and Mendelson (1986, Table 7) show that the positive impact of the bid-ask spread on expected return is six times greater for stocks with the narrowest bid-ask spread that it is for stocks with the widest spread. This is because frequently trading investors, who hold in equilibrium the stocks with the narrowest spread are more sensitive to changes in trading costs than investors that trade infrequently and hold in equilibrium stocks with wide spread.

the opposite in Panel C where constraint is measured by *Firm Size*, that is, the effect of *ILLIQ* on investment is more negative for unconstrained (larger) firms. For the other four measures of financial constraint, there is no significant difference in the estimated coefficient *b1* across the financial constraint terciles and in some there is no consistent pattern as we move from high to low constraint.

Estimates for inventory investment, $dINVTR_{j,t}$, are presented in Table 4.3 using an Model (1) that is augmented by the contemporaneous change in sales, $dSales_{j,t}$, similar to the model estimated in Table 3. For sake of parsimony we present results for firms grouped by the first three measures of financial constraint – *Cash Distribution*, *Age* and *Firm Size* – and by the Whited-Wu measure, corresponding to items A, B, C and G in Table 4.2.

We illiquidity has negative and significant effect on inventory investment for all three groups of firms sorted on financial constraint, including for unconstrained firms. For financial constraint defined by *Cash Distribution* and *Age* there is no significant pattern in the coefficient of $ILLIQ_{j,t-1}$ across the three groups while for financial constraint defined by *Firm Size* and -1**Whited-Wu*, the coefficient of $ILLIQ_{j,t-1}$ is less negative for unconstrained firms, yet it is still highly significant. This indicates that for these measures of financial constraint, illiquidity matters less. Consistent with Fazzari et al. (1988), the coefficient of $Cash\ Flow_{j,t}$ is positive and significantly lower for unconstrained firms when constraint is proxied by *Firm Size* or *Cash Distribution*. The coefficient of $Q_{j,t-1}$ is insignificantly different from zero for most groups.

In summary, even unconstrained firms exhibit a significant negative effect of illiquidity on capital investment and on inventory investment. This supports our view that the negative effect of illiquidity on investment is through its effect on expected return required by investors and in turn on the firm's cost of capital.

2.3. Instrumental variable estimation

We account for potential endogeneity of illiquidity by employing an instrumental variables (IV) method and two stage least squares (2SLS) in estimating Model (1). For example, a favorable firm-specific economic shock may improve stock liquidity and at the same time induce capital investment. We control for such shocks by including in the model lagged return (*RET2*) and lagged value (*Q*), but there may still be a residual effect. The IV method accounts for causes that affect illiquidity and employs the instrumented value of illiquidity in estimating its effect on investment.

Our instrument is institutional holdings in firm *j* in year *t*, denoted $IH_{j,t}$, which is known to be negatively related to illiquidity, see Rubin (2007) and Blume and Keim (2012). Institutional investors prefer liquid stocks because of the large size of their investments and their needs to rebalance their portfolios due to information or clients' redemptions. We too find that institutional holding is negatively association with illiquidity with very high significance while it is insignificantly associated with investment. When adding $IH_{j,t-1}$ to Model (1) with $INV_{j,t} = CEx_{j,t}$, its coefficient is positive with $t = 1.62$, insignificant.[15] Data on institutional ownership is based on 13F filing. We use the database of Thomson Reuters Institutional Holdings, in particular the last quarter's 13F filings for each year. $IH_{j,t}$ is calculated by adding up all the shares held by institutions and dividing that by the number of shares outstanding. If the number of shares outstanding is not available on Thomson, we use the shares outstanding reported on CRSP for December of that year. We exclude cases where $IH_{j,t} \geq 1.0$ which we consider an error. Valid values of $IH_{j,t}$ are available for 29,740 firm-years during the period 1980-2016.

In our 2SLS analysis we first estimate a model similar to Model (1) with $ILLIQ_{j,t-1}$ as the dependent variable, adding $IH_{j,t-1}$ to the explanatory variables. The results are presented in columns (1) of Table 5. As expected, the coefficient of $IH_{j,t-1}$ is negative and highly significant, being -1.452 with $t = -12.17$. Good news such as higher cash flow (*CF*), higher value (*Q*) and lagged returns (*RET2*) significantly lower illiquidity while volatility (*VOL*) significantly raises it. Firms with higher size (*TA*) have significantly lower illiquidity.[16] Altogether, this model fits the data well with $R^2 = 95.4\%$.

INSERT TABLE 5

In the second stage we estimate Model (1) replacing $ILLIQ_{j,t-1}$ by $FILLIQ_{j,t-1}$, the fitted value of $ILLIQ_{j,t-1}$ from the first-stage regression. The results are presented in Table 5, columns (2) and (3). We find that $FILLIQ_{j,t-1}$, the instrumented value of $ILLIQ_{j,t-1}$, has a negative and

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[15] The negative illiquidity-institutional holdings relation is highly significant after controlling for past performance (*RET2*) and past valuation (*Q*) in a model that includes firm and year fixed effects. Given Titman, Wei and Xie (2004) find that capital investment is followed by negative excess stock returns, rational institutional investors are unlikely to increase their holdings in firms whose investment is expected to rise.

[16] The high correlation of these variables with *ILLIQ* means that it is important not to omit them from the estimation of *INV* as a function of *ILLIQ* lest their effect be wrongly attributed to *ILLIQ*.

significant effect on investment. The coefficients of $FILLIQ_{j,t-1}$ for $INV_{j,t} = CEx_{j,t}$ and $INV_{j,t} = CExRD_{j,t}$, are, respectively, -0.010 with t = -4.29 and -0.011 with t = -4.09. These results show that the negative effect of illiquidity on investment is robust.

We replicate this procedure for inventory investment, $dINVTR_{j,t}$ using Model (1) that is augmented by $dSales_{j,t}$ and the instrument $IH_{j,t}$. We find that in the coefficient of the instrumented illiquidity, $FILLIQ_{j,t-1}$, in the second-stage regression is negative as expected, being -0.003 with t = -1.65, which is significant at 10%.

2.4. Lagging illiquidity by two and three years

Our model is predictive in that illiquidity in one year predicts investment in the following year. We now replicate our estimation of Model (1) with *ILLIQ* lagged by two years or three years relative to investment while all the other explanatory variables (except Cash Flow) remain lagged by one year. This reduces the concern about endogeneity that results from some unobserved factors affecting contemporaneously both investment and illiquidity. Lagging *ILLIQ* by two or three years put it to a higher test by making it less likely that both illiquidity and investment are affected contemporaneously by some factor.

We estimate Model (1) replacing $ILLIQ_{j,t-1}$ by $ILLIQ_{j,t-2}$ or $ILLIQ_{j,t-3}$ while leaving all other explanatory variables lagged by one year as before (except for $CF_{j,t}$ which is contemporaneous). Because illiquidity is a persistent stock characteristic, its effect on investment is expected to hold even when it is observed further back. However, a longer lag is expected to attenuate the estimated effect of *ILLIQ* because of a greater error-in-the-variables problem which biases its coefficient towards zero. Ideally we would like to use the illiquidity level observed by managers when making investment decision. This illiquidity, which is unobserved by us, is represented by lagged *ILLIQ* with an error which increases as the lag is longer.

We find that the negative and significant effect of illiquidity on investment remains even when illiquidity is lagged by two or three years. For a model with $INV_{j,t} = CEx_{j,t}$ we find the following:

(i) Two-year lag: The coefficient of $ILLIQ_{j,t-2}$ is -0.006 with t = -9.10.

(ii) Three-year lag: The coefficient of $ILLIQ_{j,t-3}$ is -0.003 with t = -4.74.

The results are similar for $INV_{j,t} = CExRD_{j,t}$. These results show that even with a greater lag, the coefficient of *ILLIQ* remains negative and highly significant while it declines in absolute value, as expected, because the longer lag exacerbates the errors-in-the-variables problem. Also, the other variables remain in the model with their original one-year lag thus part of the effect of the recent value of *ILLIQ* is subsumed by these variables whose values are correlated with *ILLIQ*.

We replicate this estimation for inventory investment, $dINVTR_{j,t}$ using Model (1) that is augmented by $dSales_{j,t}$. We find the following results:

(i) Two-year lag: The coefficient of $ILLIQ_{j,t-2}$ is -0.003 with t = -7.74.

(ii) Three-year lag: The coefficient of $ILLIQ_{j,t-3}$ is -0.002 with t = -4.73.

In summary, the results show that the negative effect of illiquidity on investment endures over two and three years and is not a reaction to the firm's transitory illiquidity condition.

3. The effect of decimalization

We study the effect on firm investment of an exogenous liquidity-increasing event, the 2001 decimalization of quoted stock prices. Before that, stock prices were quoted in fractions of \$1/16 or \$0.0625; decimalization enabled quoting in increments of \$0.01 and the minimum bid-ask spread to decline from \$0.0625 to \$0.01. Decimalization took place in January 2001 and in April 2001 for NYSE-AMEX and for Nasdaq stocks, respectively. Bessembinder (2003) finds that both quoted and effective bid-ask spreads declined substantially following decimalization.

We expect that following decimalization, more liquid stocks experienced a greater decline in their expected return or in the cost of capital which is an increasing function of illiquidity costs. First, Bessembinder (2003) finds that the decline in the bid-ask spread was proportionately greater for more liquid stocks that initially had narrower spreads.[17] The second reason for a greater decline in the cost of capital of firms with narrower bid-ask spread is based on Amihud and Mendelson's (1986) theory and evidence, cited above. They show that due to the investors' clientele effect by which stocks with lower bid-ask spread are held by frequently-

[17] One reason for that is that decimalization relaxed the lower bound – the minimum tick – of \$0.0625 on the spread.

trading stockholders who value liquidity more, a given decline in the bid-ask spread will induce a greater decline in the required expected return.

In summary, we expect that following decimalization, firms that had narrower bid-ask spread beforehand experienced a greater decline in the cost of capital which induced higher investment. We test this hypothesis by estimating a model based on Model (1):

$$\Delta INV_j = b1*BA_j + b2*\Delta CF_j + b3*\Delta Q_j + b4*\Delta TA_j + b5*\Delta VOL_j + b6*\Delta RET2_j + Ind.\ FE \quad (2)$$

This model follows the methodology suggested in Roberts and Whited (2012, p. 524) and includes industry fixed effects (using Fama and French's 49 industry classification).[18] The prefix Δ means a change in the respective variable, the average annual values over the two post-decimalization years 2002-2003 minus the average annual values over the two pre-decimalization years 1999-2000, skipping the year 2001 when decimalization took place. The sample includes 1428 firms from NYSE, AMEX and Nasdaq.

The key explanatory variable is BA_j, the natural logarithm of the average quoted bid-ask spread during the months January-July of 2000 which precede the SEC's experiment with decimalization in late 2000 with some stocks. The data source for the quoted bid-ask spread is the TAQ database. The mean (median) of BA_j is -1.669 (-1.745) and its standard deviation is 0.50.

INSERT TABLE 6

We hypothesize that $b1 < 0$. That is, the narrower the initial bid-ask spread, the greater the improvement in liquidity and the greater increase in corporate investment. The results, presented in Table 6, support our hypothesis. The coefficient of BA_j is negative and highly significant. For $\Delta INV = \Delta CEx$ or $\Delta CExRD$, the coefficient of BA_j is -0.013 with t = -4.24 and -0.020 with t = -4.99, respectively. The economic significance of these results is illustrated as follows. A decrease of one standard deviation in BA_j induces an increase of 0.65% in capital expenditures (relative to assets). This is a meaningful increase given that the average annual *CEx* was 5.25% over the years 2002-2003.

We replicate the tests for $\Delta INV = \Delta dTA$, the change in total assets.. The coefficient of BA_j is -0.092 with t = -6.03, again highly significant. These results support our proposition that improved stock liquidity induces more investment by firms.

[18] Two industries, Gold and Smoke, have only one firm in our sample.

As a robustness test we re-estimate Model (2) with all explanatory variables' values being their average *level* over the pre-decimalization period, 1999-2000. Thus, their values are not affected by the decimalization. We find again that the coefficient *b1* of BA_j is negative and significant for all four investment variables. For $\Delta INV = \Delta CEx$ and $\Delta CExRD$, the coefficient of BA_j is -0.017 (t = -4.94) and -0.028 (t = -5.93), respectively, and it is also negative and highly significant for $\Delta INV = \Delta TA$.

To further control for differences in characteristics between firms with high and low values of BA_j, we estimate Model (2) using pairs of firms that are matched by their characteristics and differ only in that one firm is above the median of BA_j and one is below it. For each firm with above-median BA_j, we select a matched firm from the same industry whose BA_j value is below the median using propensity score matching that employs $CF_{j,0,}$ $Q_{j,0}$, $TA_{j,0}$, $VOL_{j,0}$, $RET2_{j,0}$ (with replacement). The matched sample includes 714 pairs of above and below median BA_j firms.[19] Panel B of Table 6 and Panel B pf Table A4 present the results of the estimated model. They are similar to those presented in Panel A in that *b1* is negative and significant. This supports our hypothesis that investment increased more in firms whose liquidity benefitted more following decimalization.

As a robustness test, we replace in Model (2) BA_j by $P625_j$, the proportion of bid-ask spread quotes at $0.0625 ($1/16) out of all quotes during the pre-decimalization period, January-July of 2000. The mean (median) of $P625_j$ is 0.248 (0.223), its standard deviation is 0.16, and its range is between 0.001 and 0.951. Naturally, the correlation between $P625_j$ and BA_j is negative, being 0.806. We expect a positive coefficient of $P625_j$ because decimalization benefitted more firms whose bid-ask spread was constrained by the minimum allowed tick size. We find that the coefficient of $P625_j$ is positive and highly significant.

We find that the coefficients of $P625_j$ which replaces BA_j in Model (2), with $\Delta INV = \Delta CEx$ or $\Delta CExRD$, are 0.038 with t = 4.12 and 0.055 with t = 4.30, respectively, both highly significant. In the model where all control variables are their average *levels* in the two years before decimalization, with $\Delta INV = \Delta CEx$ and $\Delta CExRD$, the coefficients of $P625_j$ are 0.065 (t = 5.19) and 0.094 (t = 5.21), respectively. The results mean that firms whose stock was more frequently quoted at the minimum possible bid-ask spread before decimalization increased their

[19] We lose 5 cases for which we cannot find a match in the same industry.

investment by more after their stock could be quoted at a narrower spread following decimalization.

We again examine whether the firm's financial constraint affects the investment-illiquidity relation. We divide the sample of 1,428 firms into two equal groups, above and below the median, by two measures of financial constraint, average Cash Distribution or by the average Whited-Wu measure over the pre-decimalization years 1999-2000. The average values of BA_j are fairly close in magnitude for the firms above and below the medians of these measures.[20] We then estimate Model (2) separately for each group, using $\Delta INV_j = \Delta CEx_j$. We find the following:[21]

(i) Low-constraint (high Cash Distribution) group: $b1 = -0.017$, $t = -3.87$.
High-constraint (low Cash Distribution) group: $b1 = -0.009$, $t = -1.72$.

(ii) Low-constraint (low Whited-Wu) group: $b1 = -0.015$, $t = -3.36$.
High-constraint (high Whited-Wu) group: $b1 = -0.010$, $t = -1.87$.

The results suggest that unconstrained firms benefitted more from reduced illiquidity as a result of decimalization. (The difference is not significant for (ii).) This is consistent with the view that the channel by which illiquidity affects investment is through the firm's cost of capital. Following the decline in illiquidity, stockholders demand lower expected return and consequently firm managers expand investment more in unconstrained firms.

We replicate the analysis for inventory investment. We estimate Model (2) using as dependent variable $\Delta INVTR_j$, the different between average $dINVTR_{j,t}$ over the years 2002-2003 and its average over 1999-2000. We add to the control variables $\Delta dSales_j$, the difference between average $dSales_{j,t}$ over the years 2002-2003 and its average over 1999-2000. We find that the coefficient of BA_j is -0.008 with $t = -2.97$. When estimating this model with $P625_j$ instead of BA_j we find that its coefficient is 0.031 with $t = 3.84$. The results mean that after decimalization, inventory investment increased relatively more in firms whose quoted bid-ask spread was narrower before decimalization.

[20] For Cash Distribution, the average values of BA_j for firms with high (low) constraint are -1.62 (-1.73) and for Whited-Wu, the average values of BA_j for firms with high (low) constraint are -1.53 (-1.81).

[21] The t statistics are calculated using robust standard errors.

4. Illiquidity effect on the firm's production process

We test the effects of stock liquidity on the firm's production process. Since illiquidity lowers firm investment it induces the firm to select production processes which are less capital intensive. We hypothesize that greater stock illiquidity leads to the following results:

1) Higher marginal revenue product of capital, *MRPK*.
2) Higher labor input for a given increase in capital, that is, a higher rate of labor/capital substitution.
3) Lower Operating Leverage (*OL*), the extent of fixed costs in production, which includes fixed costs due to all types of investment, both tangible and intangible.

Test 1: Marginal productivity of capital

A profit-maximizing firm determines the level of capital input such that the marginal revenue productivity of capital, *MRPK*, equals its cost of capital. We estimate the effect of illiquidity on the MRPK in two ways. We derive the expression for *MRPK* using Hsieh and Klenow's (2009) model that allows for friction in the capital market that raises the cost of capital. Assume a Cobb-Douglas production function with constant return to scale, $Y = AL^{\alpha}K^{(1-\alpha)}$, where Y is output, A is a constant and L and K are labor and capital, respectively. The firm's profit function is $\Pi = PY - wL - (1+c_K)rK$, where P is output price, w is the cost of labor, r is the market-wide cost of capital and c_K indicates the firm-specific illiquidity premium required by capital providers – the holders of its capital claims – which is an increasing function of illiquidity. The firm optimally sets $MRPK = (1+c_K)r$. In this model, $MRPK = PY/K$ which measures the output per using of capital, also called "asset turnover." We define $MRPK_{j,t} = Sales_{j,t}/Total\ Assets_{j,t}$ and we hypothesize that *MRPK* increases in *ILLIQ*.

INSERT TABLE 7

We estimate Model (1) with $MRPK_{j,t}$ as the dependent variable and hypothesize that $b1 > 0$. The test results, presented in Panel A of Table 7 support our hypothesis. The coefficient of $ILLIQ_{j,t-1}$ is positive and significant for the entire test period, being 0.026 with $t = 6.13$. It is also positive and significant for each of the two subperiods. As before, volatility too has a positive and significant effect on *MRPK*; the effect is significant for the entire period and for the second subperiod.

We again exploit 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 $\Delta MRPK_j$, the average revenue/assets ratio over 2002-2003 minus the average over 1999-2000. We find that the coefficient of BA_j is 0.032 with t = 2.11 which is significantly different from zero. That is, firms whose stock had narrower bid-ask spread, for which liquidity improved the most (Bessembinder, 2003), increased the capital intensity of production, i.e., they shifted to a lower sales-to-assets ratio.

We also estimate a 2SLS model using $IH_{j,t}$ as instrument (see Section 2.1 above). We estimate Model (1) with $MRPK_{j,t}$ as the dependent variable and $FILLIQ_{j,t-1}$ instead of $ILLIQ_{tj,t-1}$. We find that the coefficient of $FILLIQ_{j,t-1}$ is positive and significant: $b1$ = 0.034 with t = 2.14.

We further use a general model that estimates the effect of illiquidity on the marginal productivity of capital which is the increase in sales relative to changes in capital. The model is:

$$dSales_{j,t} = b1*ILLIQ_{j,t-1} + b2*dTA_{j,t} + \mathbf{b3*ILLIQ_{j,t-1}*dTA_{j,t}} + b4*Q_{j,t-1} + b5*TA_{j,t-1} + b6*VOL_{j,t-1} + b7*RET2_{j,t-1} + firm\ FE + year\ FE\ , \qquad (3)$$

where $dSales_{j,t}$ and $dTA_{j,t}$ are the change is sales and in total assets, respectively, both scaled by lagged assets, and $MRPK_{j,t} = b2 + b3*ILLIQ_{j,t-1}$. Ignoring illiquidity costs, $MRPK_{j,t}$ is measured by $b2$ which is obviously positive. Our proposition that illiquidity induces higher $MRPK_{j,t}$ implies that $b3 > 0$.

The estimation results of Model (3) are presented in Table 7, Panel B. To save space, we report only the coefficients that pertain to *dTA* and *ILLIQ*. We find that $b3$ = 0.043 with t = 8.23. We also find that $b3$ is positive and significant in each of the two subperiods. For robustness, we estimate the model without firm fixed effects. We find that $b3$ = 0.046 with t = 8.00. The results are similar when adding industry fixed effects to the model.

We also estimate the model replacing *dTA* by *CEx*. We find that $b3$ = 0.034 with t = 3.16. However, this model provides a poorer fit: Its R^2 is 34.0% compared with 49.4% for Model (3). This may be because *CEx* does not reflect well changes in capital. It includes investment that replaces depreciated assets, in which case total capital does not change, and it does not reflect changes in capital due to mergers, acquisitions and spinoffs which strongly affect both total assets and sales.

We again estimate Model (3) by 2SLS replacing $ILLIQ_{j,t-1}$ by its instrumented value $FILLIQ_{j,t-1}$ obtained from a first-stage regression. We find that $b3$ = 0.025 with t = 2.42, which is significant.

In summary, the results suggest that illiquidity, which increases the cost of capital, induces firms to select a production process that generates a higher marginal productivity of capital.

Test 2: 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 Hsieh and Klenow's (2009) model, the firm's optimal labor input is given by $L = [\alpha r(1+c_K)/(1-\alpha)w]*K$. Thus $dL/dK = \alpha r/(1-\alpha)w + c_K\alpha r/(1-\alpha)w$. This means that the marginal rate of substitution between labor and capital in production – the increase in labor input that accompanies a given increase in capital – is positively related to the illiquidity premium in the cost of capital for which c_K is a proxy.

We test whether dL/dK, the rate of labor-capital substitution measured by the change in labor relative to change in capital, is increasing in illiquidity. We estimate Model (3) with the dependent variable being $dLabor_j$, the change in the number of employees over the year scaled by lagged total assets and the change in capital is $dTA_{j,t}$. The increase in labor input for a given increase in capital is $b2 + b3*ILLIQ_{j,t-1}$ where $ILLIQ$ is in the role of c_K. Naturally, $b_2 > 0$ since, ignoring illiquidity, the firm maintains a rate of substitution between labor and capital that equals $\alpha r/(1-\alpha)w$. We focus on whether $b3 > 0$ as the model implies, that is, higher illiquidity premium, proxied by c_K, induces firms to accompany their investment with a greater increase in labor input because the higher cost of capital induces them to substitute labor for capital.

INSERT TABLE 8

The estimation results are presented in Table 8. As expected, $b2 > 0$ meaning than labor input generally rises to match an increase in capital. Importantly, we find that $b3 > 0$ which means that the increase in labor input for a given increase in capital is significantly higher when stock illiquidity is higher. We find that $b3$ = 0.120 with t = 7.38. The results are consistent across the two subperiods: $b3$ = 0.15 (t = 7.83) and $b3$ = 0.037 (t = 8.52) in the first and second subperiods, respectively. For robustness, we estimate the model without firm fixed effects. We find that $b3$ = 0.125 with t = 7.26. The results are similar when adding industry fixed effects to the model.

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 $b3 = 0.080$ with and $t = 6.21$.

We again replicate the estimation of the model replacing $dTA_{j,t}$ by $CEx_{j,t}$, which – as discussed in the previous section – does not exactly reflect changes in capital. Indeed, for this model $R^2 = 25.3\%$ compared with $R^2 = 33.6\%$ in the model with $dTA_{j,t}$ representing the change in capital. We find that the coefficient $b3$ of $ILLIQ_{j,t-1}*CEx_{j,t}$ is 0.201 with $t = 7.11$ for the entire period and it is 0.183 ($t = 3.97$) and 0.065 ($t = 4.44$) for the first and second period, respectively. All coefficients are highly significant.

Since production functions differ across industries, we robustness by estimating separately for each of the five one-digit SIC code industries Model (3) with $dLabor_{j,t}$ as dependent variable. Panel B presents the estimation results. We find that $b3$ is positive and significant for all five industries. In conclusion, the evidence robustly shows that firms with illiquid stocks choose a production process which employs less capital and is thus more labor intensive.

We again employ the decimalization in 2001 to test the effect of an exogenous change in illiquidity on labor input. We expect a decline in labor input of firms whose stock became more liquid because they shifted to a production process that is more capital intensive. That is, we expect a positive coefficient of BA_j, Meaning that firms with narrower bid-ask spread, whose illiquidity improved most after the decimalization, reduced their labor-to-capital rate of substitution in production.

We estimate Model (2) with the dependent variable being $\Delta Labor_j$, the (logarithmic) change in the average number of employees from 1999-2000 to 2002-2003. We find that the coefficient of BA_j is 0.108 with $t = 5.10$, highly significant. Notably, the effect of illiquidity on labor is after controlling for the change in firm's scale of capital by the explanatory variable ΔTA_j, whose coefficient is 0.375 with $t = 14.75$. The results show that a rise in stock liquidity which induces greater capital investment also reduces the labor intensity of the firm's production process.

We employ again a 2SLS estimation to account for endogeneity using $IH_{j,t}$ as instrument as in Section 2.1 above. We estimate the model with the instrumented value $FILLIQ_{j,t-1}$ replacing of $ILLIQ_{tj,t-1}$ and find that the coefficient $b3$ of $FILLIQ_{j,t-1}*dTA_{j,t}$ is 0.056 with t = 3.83, highly significant.

Test 3: Operating leverage

We test the effect of stock illiquidity on the firm's operating leverage, *OL*, the extent of fixed costs in the total cost of production. This supplements our analysis on the effect of illiquidity on capital investment. An alternative to investing in assets is leasing them.[22] But if switching from buying to leasing assets is a costly endeavor that is driven by illiquidity, it means that illiquidity imposes higher cost on the firm and inhibits the use of capital assets. This induces the firm to adopt a production process that relies less on fixed costs and more on variable costs. We test this hypothesis below.

In addition, operating leverage that measures costs that are unrelated to current sales may reflect investment in intangible assets, such as expenditures on employee training or research and development projects.

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

$$Cost_{j,t} = b1*ILLIQ_{j,t-1} + b2*Sales_{j,t} + \mathbf{b3*ILLIQ_{j,t-1}*Sales_{j,t}} + b4*Q_{j,t-1} + b5*TA_{j,t-1} + b6*VOL_{j,t-1} + b7*RET2_{j,t-1} + firm\ FE + year\ FE\ , \qquad (4)$$

$Cost_{j,t}$ and $Sales_{j,t}$ are contemporaneous while $ILLIQ_{j,t-1}$ is lagged. $Cost_{j,t}$, defined as $Sales_{j,t}$ - $EBIT_{j,t}$ (*EBIT* is earnings before interest and taxes), includes all costs, both variable and fixed.[23] Its main components are cost of goods sold, selling general and administrative costs, R&D cost 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, we define operating leverage as $OL = 1 - b2 - b3*ILLIQ$ and hypothesize that $b3 > 0$. This means that firms with higher *ILLIQ* have lower operating leverage and smaller reliance on fixed costs.

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[22] Sharpe and Nguyen (1995) find that capital-constrained firms tend to be more engaged in leasing.
[23] See Aboody, Levi, and Weiss (2017) for this definition.

INSERT TABLE 9

The estimation results of Model (4), presented in Table 9, support our hypothesis of positive *b3*. We find that *b3* = 0.003 with *t* = 5.21. The estimated coefficient *b3* is consistent in both subperiods in both magnitude and statistical significance: for the first and second period, it is 0.004 (*t* = 3.76) and 0.003 (*t* = 3.71), respectively.

We also note the positive and significant coefficient of $ILLIQ_{j,t-1}$ which means that for a given level of sales, cost is higher for firms with illiquid stock. This is consistent with Fang et al.'s (2009) proposition that stock illiquidity induces inefficient production, thus lowering firm value.

We again use the decimalization event of 2001 to test the effect of an exogenous change in stock liquidity. We estimate an augmented version of Model (2) with $\Delta Sales_j$, the average $Sales_j$ in the years 2002-2003 minus its average in the years 1999-2000, and we replace BA_j by a dummy variable $LowBA_j$ that equals 1 if BA_j is at the lowest quartile of the bid-ask spread in the pre-decimalization period and 0 otherwise. We expect that stocks with the narrower bid-ask spread, for which liquidity improved the most – increased their operating leverage. The estimated model is:

$$\Delta Cost_j = b1 * LowBA_j + b2 * \Delta Sales_j + \mathbf{b3 * LowBA_j * \Delta Sales_{j,t},} + Controls \quad ,$$

where *Controls* are ΔQ_j, ΔTA_j, ΔVOL_j, $\Delta RET2_j$, and industry fixed effects. We expect that $b3 < 0$ because stocks with narrower bid-ask spread, for which liquidity improved the most, increased their operating leverage which means relying less on variable cost that are a function of sales.

We find that *b3* = -0.039 with *t* = -1.60 which is insignificant, though it is significant at one-tail 10% level. The negative sign of *b3* means that operational leverage increased for firms with the lowest bid-ask spread whose liquidity improved more after decimalization. For such firms, OL=1-$b2$-$b3$ while for the other firms OL=1-$b2$. Given that $b3 < 0$, *OL* is higher for the more liquid firms.

Again, we account for endogeneity by employing 2SLS estimation following the methodology in Section 2.1, using institutional holdings as instrument. We estimate Model (4) with the instrumented value $FILLIQ_{j,t-1}$ replacing $ILLIQ_{tj,t-1}$ and find that *b3* = 0.002 with *t* = 2.80. This supports our conclusion that illiquidity increases the reliance on variable costs and diminishes the reliance on fixed cost in the firm's production process, consistent with our result that illiquidity inhibits capital investment and induces substitution to labor in production.

5. **Concluding remarks**

This paper presents a channel by which Wall Street affects Main Street. We show that stock market liquidity affects corporate investment and production decisions. Because stock illiquidity in the secondary market raises the expected return required by stockholders, it raises the firm's opportunity cost of capital and lowers corporate investment. The negative investment-illiquidity relation holds even for firms that are not financially constrained and have a lesser need to raise capital in the primary market. Because illiquidity curtails capital investment, it induces firms to economize on the use of capital in production. Firms with higher illiquidity produce more output per unit of capital and rely relatively more on labor input in production. Generally, their cost of production consists less of fixed costs and more of variable costs. Our results suggest that it is in the firm's interest to expend resources in reducing their stock illiquidity, which would in turn reduce their cost of capital.

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Table 1: Descriptive statistics

The sample includes data of NYSE and AMEX firms for 1963-2016. We eliminate financial stocks (SIC 6000-6999), utility firms, stocks with share code other than 10 and 11, share price of less than $1, total assets lower than $10 million and firms total assets or sales doubled or were halved from year *t*-1 to year *t*. Investment is either of capital expenditures, *CEx*, or *CExRD*, the sum of *CEx* and *R&D*, investment in research and development. These variables are scaled by lagged total assets. Illiquidity is measured by either *ILLIQ*, the average ratio of daily absolute return to dollar volume, or *SPRD*, the average proportional quoted bid-ask spread. Both variables are in logarithms, and the average is over a year. Data for these variables are from CRSP; for *SPRD*, data are available since 1993. *CF* is cash flow, defined as net income (before extraordinary items) plus depreciation and amortization divided by lagged assets. *MRPK* is the marginal revenue productivity of capital, defined as total sales divided by total assets. $dLabor_j$ is the change in number of employees from the beginning to the end of the year, scaled by lagged total assets. *Q* (an estimate of Tobin's *q*) is total firm's market value divided by its book value. *TA* is total assets in logarithm. *REV* is the logarithm of total revenues divided by total assets. *VOL* is equity volatility, the standard deviation of the weekly stock return during last year, and *RET2* is the cumulative stock return over the last two years.

Variable	*N*	*Mean*	*Std. Dev.*	*Q1*	*Median*	*Q3*
CEx_t	62,102	0.077	0.074	0.030	0.056	0.097
$CExRD_t$	62,102	0.095	0.085	0.039	0.073	0.122
$ILLIQ_{t-1}$	62,102	-16.81	3.121	-19.11	-16.58	-14.46
$SPRD_{t-1}$	26,242	-5.254	1.732	-6.763	-4.837	-3.887
CF_t	62,102	0.096	0.097	0.060	0.100	0.143
$MRPK_t$	62,102	1.359	0.818	0.842	1.227	1.667
$dLabor_t$	62,102	0.089	0.546	-0.036	0.008	0.123
Q_{t-1}	62,102	1.476	0.935	0.943	1.199	1.666
TA_{t-1}	62,102	5.988	1.894	4.564	5.874	7.305
$RET2_{t-1}$	62,102	0.353	1.021	-0.191	0.181	0.636
VOL_{t-1}	62,102	0.057	0.026	0.038	0.051	0.068

Table 2: Investment as a function of illiquidity

This table presents results for the model:

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

Investment of firm *j* in year *t*, $INV_{j,t}$, is either $CEx_{j,t}$ or $CExRD_{j,t}$. Descriptions of the variables appear in the legend of Table 1. Filters for the data and the variables apply. The estimation includes firm and year fixed effects and errors are clustered by firm and year. The sample includes NYSE and AMEX firms unless otherwise indicated. The regressions with industry fixed effects in Panel E employ Fama and French's 49-industry classification. To save space, we present in Panels B-E only the coefficient of $ILLIQ_{j,t-1}$; the model includes all control variables. The sample includes 62,102 firm-years. *,**, and *** indicate significance level at the 0.10, 0.05, and 0.01, respectively.

Panel A: Estimation over the entire period, 1963-2016

	Dependent Variable	
	$CEx_{j,t}$	$CExRD_{j,t}$
$ILLIQ_{j,t-1}$	-0.008	-0.009
	(-13.05)***	(-12.54)***
$CF_{j,t}$	0.132	0.125
	(11.09)***	(8.69)***
$Q_{j,t-1}$	0.006	0.009
	(5.98)***	(7.27)***
$TA_{j,t-1}$	-0.018	-0.022
	(-13.14)***	(-13.42)***
$VOL_{j,t-1}$	-0.090	-0.096
	(-4.38)***	(-3.98)***
$RET2_{j,t-1}$	0.005	0.006
	(4.84)***	(4.81)***
Firm FE	Yes	Yes
Year FE	Yes	Yes
N	62,102	62,102
R^2	60.2%	61.9%

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

	Dependent Variable: $CEx_{j,t}$				
	One-Digit SIC Industry Code				
	SIC=1	SIC=2	SIC=3	SIC=4	SIC=5
$ILLIQ_{j,t-1}$	-0.014	-0.007	-0.005	-0.013	-0.008
	(-5.78)***	(-6.14)***	(-8.14)***	(-3.68)***	(-7.08)***
Controls	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes
N	5,456	14,152	22,510	3,382	9,129
R^2	67.3%	50.5%	51.7%	54.5%	61.9%

Panel C: Estimation over two subperiods, 1963-1989 and 1990-2016

	1963-1989		*1990-2016*	
	$CEx_{j,t}$	$CExRD_{j,t}$	$CEx_{j,t}$	$CExRD_{j,t}$
$ILLIQ_{j,t-1}$	-0.011	-0.011	-0.007	-0.007
	(-12.87)***	(-11.69)***	(-9.31)***	(-8.52)***
Controls	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
N	30,760	30,760	31,342	31,342
R^2	60.0%	62.8%	67.7%	68.1%

Panel D: Estimation for Nasdaq firms, 1998-2016

	Dependent Variable	
	$CEx_{j,t}$	$CExRD_{j,t}$
$ILLIQ_{j,t-1}$	-0.004	-0.005
	(-9.39)***	(-7.69)***
Controls	Yes	Yes
Firm FE	Yes	Yes
Year FE	Yes	Yes
N	27,273	27,273
R^2	66.0%	78.5%

Panel E: Estimation with industry fixed effects replacing firm fixed effects.

The estimation is by panel regression, with industry and year fixed effects, or by the Fama-Macbeth procedure where we do annual cross-section regressions with industry fixed effects. The table presents the average coefficients. The calculation of the standard errors of the annual coefficients employs 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 (-9.22)***	-0.008 (-10.59)***	-0.005 (-17.18)***	-0.007 (-20.16)***
Controls	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes		
R^2	32.4%	27.7%	16.6%	16.5%

Panel F. Estimation using first difference of all variables

In these panel regressions all 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). The complete results presenting the coefficients of all the variables are in the 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 (-10.53)***	-0.008 (-10.35)***	-0.010 (-12.01)***	-0.010 (-11.75)***
$dINV_{j,t-1}$			-0.219 (-13.91)***	-0.212 (-15.24)***
Controls	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
# OBS	54,668	54,668	54,668	54668
R^2	9.8%	10.0%	13.9%	13.2%

Panel G. Adding Cash and changes in Cash, dCash

This panel presents estimation of Model (1) with the following added variables: $Cash_{j,t-1}$, the sum of cash and cash-equivalent investments scaled by lagged assets, or $dCash_{j,t-1}$, the change in the sum of cash and cash equivalents scaled by lagged assets. To save space we present only the coefficient of $ILLIQ_{j,t-1}$ and those of the added variables. The dependent variable is $CEx_{j,t}$.

Panel G1: *Adding* $Cash_{j,t-1}$ to Model (1)

	1963-2016	1963-1989	1990-2016
$ILLIQ_{j,t-1}$	-0.008	-0.011	-0.007
	(-13.10)***	(-12.82)***	(-9.41)***
$Cash_{j,t-1}$	-0.008	-0.002	-0.006
	(-1.93)*	(-0.25)	(-1.23)
Controls	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
# OBS	62102	30760	31342
R^2	60.2%	60.0%	67.7%

Panel G2: *Adding* $dCash_{j,t-1}$ to Model (1)

	1963-2016	1963-1989	1990-2016
$ILLIQ_{j,t-1}$	-0.008	-0.011	-0.007
	(-13.07)***	(-12.88)***	(-9.41)***
$dCash_{j,t-1}$	-0.015	-0.021	-0.008
	(-3.23)***	(-3.11)***	(-1.44)
Controls	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
# OBS	62086	30751	31335
R^2	60.3%	60.0%	67.7%

Table 3: The effect of illiquidity on inventory investment

The dependent variable is $dINVTR_{j,t}$, the change in inventory scaled by lagged total asset. This table presents results for Model (1), see the legend of Table 2 for details. The model is augmented by $dSales_{j,t}$, the change in sales scaled by lagged total assets.

	Period		
	1963-2016	1963-1989	1990-2016
$ILLIQ_{j,t-1}$	**-0.005**	**-0.007**	**-0.004**
	(-11.12)***	**(-10.09)*****	**(-8.13)*****
$CF_{j,t}$	0.066	0.154	0.043
	(7.77)***	(10.05)***	(5.86)***
$Q_{j,t-1}$	-0.001	-0.002	-0.001
	(-2.18)**	(-1.35)	(-0.78)
$TA_{j,t-1}$	-0.012	-0.018	-0.011
	(-13.41)***	(-10.44)***	(-9.02)***
$VOL_{j,t-1}$	-0.050	-0.068	-0.070
	(-2.36)**	(-2.60)***	(-2.65)***
$RET2_{j,t-1}$	0.003	0.003	0.002
	(5.39)***	(3.56)***	(3.61)***
$dSales_{j,t}$	0.105	0.103	0.097
	(29.92)***	(19.96)***	(20.14)***
Firm FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
#OBS	57,689	29,758	27,931
R^2	41.6%	44.8%	42.1%

Table 4: Investment as a function of *ILLIQ*, controlling for financial constraint

This table presents estimation results for Model (1) (see the legend of Table 2). $INV_{j,t}$ is $CEx_{j,j}$. Variable description appears in Table 1's legend. The sample includes 62,102 firm-years and each subsample includes approximately 20,000 firm-years. Filters for the data and the variables apply. Errors are clustered by firm and year. *,**, and *** indicate significance level at the 0.10, 0.05, and 0.01, respectively.

Table 4.1. Firms are sorted in each year by $ILLIQ_{j,t\text{-}1}$ and by -1**Equity Capitalization*$_{j,t\text{-}1}$ as indicators of financial constraint and are divided into three groups. Model (1) is estimated for each group. To save space, we report only the coefficient of $ILLIQ_{j,t\text{-}1}$ and $CF_{j,t}$. For the complete tables with estimated coefficients for all variables see the Appendix Table A3.

Period	Variable	Low value = **Low constraint**	Medium	High value = **High constraint**
		Panel A: Sorting by $ILLIQ_{j,t\text{-}1}$		
1963-2016	$ILLIQ_{j,t\text{-}1}$	-0.015	-0.010	-0.006
		(-9.43)***	(-9.12)***	(-7.77)***
	$CF_{j,t}$	0.142	0.144	0.102
		(8.26)***	(8.85)***	(10.07)***
1963-1989	$ILLIQ_{j,t\text{-}1}$	-0.016	-0.012	-0.008
		(-7.35)***	(-7.42)***	(-5.48)***
	$CF_{j,t}$	0.266	0.254	0.196
		(9.91)***	(7.16)***	(8.89)***
1990-2016	$ILLIQ_{j,t\text{-}1}$	-0.012	-0.009	-0.006
		(-5.41)***	(-5.69)***	(-5.71)***
	$CF_{j,t}$	0.083	0.097	0.065
		(6.73)***	(6.50)***	(7.99)***
		Panel B: Sorting by -1**Equity Capitalization*$_{j,t\text{-}1}$		
1963-2016	$ILLIQ_{j,t\text{-}1}$	-0.012	-0.007	-0.006
		(-9.52)***	(-7.90)***	(-8.39)***
	$CF_{j,t}$	0.139	0.159	0.097
		(7.25)***	(9.52)***	(9.90)***
1963-1989	$ILLIQ_{j,t\text{-}1}$	-0.015	-0.010	-0.007
		(-8.61)***	(-7.23)***	(-5.77)***
	$CF_{j,t}$	0.262	0.270	0.196
		(8.73)***	(8.15)***	(8.62)***
1990-2016	$ILLIQ_{j,t\text{-}1}$	-0.008	-0.005	-0.006
		(-5.13)***	(-4.49)***	(-6.18)***
	$CF_{j,t}$	0.079	0.107	0.065
		(5.60)***	(8.67)***	(7.66)***

Table 4.2. The effect of financial constraint on the coefficient of $ILLIQ_{j,t-1}$ in Model (1)

Firms are sorted in each year by the lagged values of measures that are indicators of financial constraint and divided into three groups. Then, Model (1) is estimated for each group. The table reports only the coefficients of $ILLIQ_{j,t-1}$ (to save space). The measures of financial constraint are the following. *Cash Distribution* is dividends plus stock purchases divided by market value of equity. *Age* is the number of years from IPO. *Firm Size* is total assets. *Cash Flow* is income before extraordinary items plus depreciation divided by total assets. *Cash Balance* is cash and cash equivalents divided by total assets. *Leverage* is short-term and long-term debt minus cash, divided by total assets. *Whited-Wu* is a weighted average of 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 high constraint.

Measure of constraint by which sorting is done	Low value = **High constraint**	Medium	High value = **Low constraint**
A: $Cash\ Distribution_{j,t-1}$	-0.009 (-10.43)***	-0.007 (-9.13)***	-0.007 (-8.67)***
B: $Age_{j,t-1}$	-0.010 (-10.31)***	-0.009 (-8.79)***	-0.007 (-7.69)***
C: $Firm\ Size_{j,t-1}$	-0.008 (-11.07)***	-0.010 (-10.54)***	-0.011 (-8.62)***
D: $Cash\ Flow_{j,t-1}$	-0.006 (-8.94)***	-0.007 (-8.34)***	-0.007 (-6.85)***
E: $Cash\ Balance_{j,t-1}$	-0.007 (-7.76)***	-0.008 (-9.17)***	-0.007 (-9.61)***
F: $-Leverage_{j,t-1}$	-0.009 (-8.38)***	-0.006 (-7.48)***	-0.006 (-8.11)***
G: $-1*Whited\text{-}Wu_{j,t-1}$	-0.009 (-10.96)***	-0.008 (-9.85)***	-0.010 (-9.47)***

Table 4.3. Inventory investment: The effect of financial constraint on the coefficient of $ILLIQ_{j,t-1}$ in an augmented Model (1)

The dependent variable is $dINVTR_{j,t}$, the change in inventory scaled by lagged total assets. The estimation model in Model (1) augmented by $dSales_{j,t}$, the change in sales scaled by total assets. The estimation procedure is as in Table 4.2. For sake of parsimony we present only results for classification by characteristics A-C and G in Table 4.2.

Measure of constraint by which sorting is done	Variable	Low value = **High constraint**	Medium	High value = **Low constraint**
A: *Cash Distribution*$_{j,t-1}$	$ILLIQ_{j,t-1}$	-0.005	-0.005	-0.005
		(-6.99)***	(-6.52)***	(-7.00)***
	$CF_{j,t}$	0.067	0.072	0.067
		(6.20)***	(5.83)***	(5.26)***
B: *Age*$_{j,t-1}$	$ILLIQ_{j,t-1}$	-0.005	-0.007	-0.004
		(-7.13)***	(-9.12)***	(-5.52)***
	$CF_{j,t}$	0.085	0.085	0.044
		(6.42)***	(6.34)***	(4.08)***
C: *Firm Size*$_{j,t-1}$	$ILLIQ_{j,t-1}$	-0.006	-0.006	-0.003
		(-8.26)***	(-8.24)***	(-4.93)***
	$CF_{j,t}$	0.085	0.077	0.043
		(7.06)***	(6.59)***	(3.43)***
G: -1**Whited-Wu*$_{j,t-1}$	$ILLIQ_{j,t-1}$	-0.006	-0.005	-0.003
		(-8.50)***	(-7.40)***	(-4.59)***
	$CF_{j,t}$	0.082	0.065	0.078
		(7.29)***	(5.07)***	(5.92)***

Table 5: Instrumental variable estimation (2SLS)

This table presents results for the 2SLS model:

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

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

The instrumental variable is Institutional Holdings, $IH_{j,t}$, the percent ownership by institutional investors. 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 estimation includes firm and year fixed effects and errors are clustered by firm and year. The sample includes 29,740 firm-years between 1981 and 2016. *,**, and *** indicate significance level at the 0.10, 0.05, and 0.01, respectively.

	Dependent Variable		
	Stage 1	***Stage 2***	
	$ILLIQ_{j,t-1}$	$CEx_{j,t}$	$CExRD_{j,t}$.
	(1)	(2)	(3)
$\mathbf{FILLIQ_{j,t-1}}$		**-0.010**	**-0.011**
		(-4.29)***	**(-4.09)*****
$CF_{j,t}$	-0.993	0.104	0.094
	(-6.45)***	(9.99)***	(7.05)***
$Q_{j,t-1}$	-0.481	0.005	0.009
	(-11.03)***	(2.88)***	(3.97)***
$TA_{j,t-1}$	-1.295	-0.027	-0.034
	(-41.55)***	(-6.95)***	(-7.75)***
$VOL_{j,t-1}$	6.394	-0.072	-0.082
	(6.38)***	(-2.46)**	(-2.35)**
$RET2_{j,t-1}$	-0.068	0.004	0.003
	(-3.44)***	(3.04)***	(2.68)***
$\mathbf{IH_{j,t-1}}$	**-1.452**		
	(-12.17)***		
Firm FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
N	29,740	29,740	29,740
R^2	95.4%	65.0%	67.4%

Table 6: Decimalization and the effect of illiquidity on investment

This table presents results for the model:

$$\Delta INV_j = b1*BA_j + b2*\Delta CF_j + b3*\Delta Q_j + b4*\Delta TA_j + b5*\Delta VOL_j + b6*\Delta RET2_j + Ind.\ FE \qquad (2)$$

BA is the natural logarithm of the average quoted bid-ask spreads for the firm's stock during the months January-July of 2000 (source: TAQ). The change (Δ) of a variable is the average value of the variable in the two post-decimalization years 2002-2003 minus the average value over the two pre-decimalization years 1999-2000, skipping the year of decimalization, 2001. INV_t is *CEx* or *CExRD*. The variables are described in Table 1. The model includes industry fixed effects, using Fama and French's 49 industry classification. The t-statistics employ robust standard errors. *, **, and *** indicate significance level at the 0.10, 0.05, and 0.01, respectively.

Panel A presents the results for the entire sample of 1,428 NYSE, AMEX, and NASDAQ firms. Panel B presents results for firms with above-median BA_j and a matched sample of firms from the same industry with below-median BA_j using a matching propensity score that is based on $Q_{j,t-1}$, $TA_{j,t-1}$, $CF_{j,t-1}$, $VOL_{j,t-1}$, $RET2_{j,t-1}$. This sample includes 1428 firms. To save space, we present only the coefficient *b1* of BA_j; the model includes all control variables.

Panel A: Tests using the entire sample

	Dependent Variable	
	ΔCEx_j	$\Delta CExRD_j$
$\boldsymbol{BA_j}$	**-0.013**	**-0.020**
	(-3.83)***	**(-4.46)*****
ΔCF_j	0.041	0.036
	(2.43)**	(1.41)
ΔQ_j	0.010	0.018
	(5.68)***	(6.97)***
ΔTA_j	-0.001	-0.006
	(-0.26)	(-0.78)
ΔVOL_j	-0.096	-0.048
	(-1.79)*	(-0.62)
$\Delta RET2_j$	0.003	0.009
	(2.12)**	(4.08)***
N	1,428	1,428
R^2	17.7%	25.0%

Panel B: Results for matched samples

	Dependent Variable	
	ΔCEx_j	*$\Delta CExRD_j$*
BA_j	**-0.013**	**-0.024**
	(-2.92)***	**(-3.53)*****
Control variables	Yes	Yes
R^2	19.6%	29.2%

Table 7: Effect of illiquidity on the marginal revenue productivity of capital

Panel A: The effect of illiquidity on the ratio of sales to capital

We estimate Model (1) with the dependent variable being *MRPK*, the marginal revenue productivity of capital defined as the ratio of the firm's sales to its capital or total assets. See Table 1 for variable definitions. The estimation is over the entire period, 1963-2016, and over two subperiods, 1963-1989 and 1990-2016. The *t*-statistics (in parentheses) are based on standard errors that are clustered by firm and year. *,**, and *** indicate significance level at the 0.10, 0.05, and 0.01, respectively.

	Dependent Variable: $MRPK_{j,t}$,		
		Subsample	
	1963-2016	1963-1989	1990-2016
$ILLIQ_{j,t-1}$	0.026	0.030	0.017
	(6.13)***	(5.82)***	(3.54)***
$CF_{i,t}$	0.296	0.594	0.180
	(5.27)***	(4.82)***	(3.42)***
$Q_{j,t-1}$	0.024	0.023	0.026
	(4.08)***	(2.73)***	(4.15)***
$TA_{j,t-1}$	-0.105	-0.105	-0.122
	(-8.67)***	(-6.58)***	(-8.84)***
$VOL_{j,t-1}$	0.386	0.105	0.603
	(2.41)**	(0.50)	(3.31)***
$RET2_{j,t-1}$	0.012	0.015	0.006
	(4.13)***	(3.58)***	(2.47)**
Firm FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
N	62,102	30,760	31,342
R^2	85.7%	90.2%	87.0%

Panel B: The effect of illiquidity on sales growth relative to investment

This table presents results for the model:

$$dSales_{j,t} = b1*ILLIQ_{j,t-1} + b2*dTA_{j,t} + \mathbf{b3*ILLIQ_{j,t-1}*dTA_{j,t}} + b4*Q_{j,t-1} + b5*TA_{j,t-1} + b6*VOL_{j,t-1} + b7*RET2_{j,t-1} + firm\ FE + year\ FE, \quad (3)$$

$dSales_{j,t}$ is the change in sales (from the preceding year) scaled by lagged total assets and $dTA_{j,t}$ is the change in assets scaled by lagged total assets. See Table 1 for details on the variables. To save space, we report only the coefficients that relate to *ILLIQ* and *dTA*. In all panels, *t*-statistics (in parentheses) are based on standard errors clustered by firm and year. *,**, and *** indicate significance level at the 0.10, 0.05, and 0.01, respectively.

	Entire period	Subperiods	
	1963-2016	1963-1989	1990-2016
$ILLIQ_{j,t-1}$	0.014	0.021	0.016
	(6.62)***	(5.35)***	(5.64)***
$dTA_{j,t}$	1.273	1.684	0.833
	(12.48)***	(12.83)***	(10.57)***
$\mathbf{ILLIQ_{j,t-1}*dTA_{j,t}}$	**0.043**	**0.063**	**0.022**
	(8.23)***	**(9.45)*****	**(5.06)*****
Control variables	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
R^2	49.4%	53.6%	49.4%

Table 8: The effect of illiquidity on labor input relative to investment

This table presents results for Model (3) (See Table 7, Panel B) with the dependent variable being $dLabor_{j,t}$, the change in number of employees over the year (from the preceding year) scaled by lagged total assets. In both panels below, *t*-statistics (in parentheses) based on standard errors clustered by firm and year. *, **, and *** indicate significance level at the 0.10, 0.05, and 0.01, respectively.

Panel A: Estimations of Model (3) with $dLabor_{j,t}$ as dependent variable *for the entire sample*

	1963-2016	*1963-1989*	*1990-2016*
$ILLIQ_{j,t-1}$	-0.012	-0.005	-0.002
	(-3.29)***	(-0.73)	(-0.98)
$dTA_{j,t}$	2.788	3.799	1.030
	(8.08)***	(9.73)***	(11.44)***
$\boldsymbol{ILLIQ_{j,t-1}*dTA_{j,t}}$	**0.120**	**0.150**	**0.037**
	(7.38)***	**(7.83)*****	**(8.52)*****
$Q_{j,t-1}$	0.015	0.044	0.006
	(1.86)*	(3.01)***	(2.09)**
$TA_{j,t-1}$	-0.069	-0.163	-0.014
	(-6.33)***	(-6.89)***	(-2.49)**
$VOL_{j,t-1}$	0.100	0.620	-0.208
	(0.64)	(1.85)*	(-2.01)**
$RET2_{j,t-1}$	0.015	0.022	0.008
	(3.57)***	(2.19)**	(2.84)***
Firm FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
N	62,102	30,760	31,342
R^2	33.6%	38.6%	42.9%

Panel B: Estimation of Model (3) with $dLabor_{j,t}$ as dependent variable *by industry*

	One-Digit SIC Industry Code				
	SIC=1	SIC=2	SIC=3	SIC=4	SIC=5
$ILLIQ_{j,t-1}$	-0.002	-0.018	-0.005	-0.006	-0.024
	(-0.37)	(-1.96)**	(-0.70)	(-0.83)	(-2.58)***
$CEx_{j,t}$	0.977	3.707	3.259	1.301	3.090
	(4.98)***	(6.48)***	(7.50)***	(4.16)***	(6.50)***
$\boldsymbol{ILLIQ_{j,t-1}*dTA_{j,t}}$	**0.042**	**0.168**	**0.137**	**0.054**	**0.125**
	(4.37)* **	**(6.16)*** **	**(6.92)*** **	**(3.54)*** **	**(5.17)*** **
Controls	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes
N	5,456	14,152	22,510	3,382	9,129
R^2	21.6%	30.7%	37.9%	37.9%	39.0%

Table 9: The effect of illiquidity on operating leverage

This table presents results for the model:

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

$Sales_{j,t}$ 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 model is estimated for the entire period, 1963-2016, and for the two subperiods, 1963-1989 and 1990-2016, and *t*-statistics (in parentheses) are based on standard errors clustered by firm and year. *,**, and *** indicate significance level at the 0.10, 0.05, and 0.01, respectively.

		Subsamples	
	1963-2016	*1963-1989*	*1990-2016*
$ILLIQ_{j,t-1}$	0.004	0.002	0.001
	(3.01)***	(1.37)	(0.85)
$Sales_{j,t}$	0.949	0.949	0.936
	(106.6)***	(63.27)***	(69.37)***
$\mathbf{ILLIQ_{j,t-1}*Sales_{j,t}}$	**0.001**	**0.002**	**0.002**
	(2.82)***	**(2.18)****	**(2.17)****
Controls	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
N	62,102	30,760	31,342
R^2	99.5%	99.7%	99.4%

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 and 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-D only the coefficient of $SPRD_{j,t-1}$; the models include all control variables. *,**, and *** indicate significance level at the 0.10, 0.05, and 0.01, respectively.

Panel A: Estimations over the entire period, 1994-2016

	1994-2016	
	Dependent Variable	
	$CEx_{j,t}$	$CExRD_{j,t}$
$SPRD_{j,t-1}$	-0.008	-0.009
	(-6.64)***	(-5.29)***
$CF_{j,t}$	0.080	0.062
	(10.19)***	(5.60)***
$Q_{j,t-1}$	0.010	0.015
	(8.87)***	(10.54)***
$TA_{j,t-1}$	-0.015	-0.023
	(-7.86)***	(-8.97)***
$VOL_{j,t-1}$	-0.098	-0.106
	(-4.06)***	(-3.57)***
$RET2_{j,t-1}$	0.003	0.002
	(2.57)***	(2.25)**
Firm FE	Yes	Yes
Year FE	Yes	Yes
N	26,242	26,242
R^2	70.1%	69.9%

Panel B: Estimations for Nasdaq firms, 1998-2016

	Dependent Variable	
	$CEx_{j,t}$	$CExRD_{j,t}$
$SPRD_{j,t-1}$	-0.007	-0.009
	(-6.14)***	(-6.35)***
Controls	Yes	Yes
Firm FE	Yes	Yes
Year FE	Yes	Yes
N	27,273	27,273
R^2	65.9%	78.5%

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

	Panel Regressions		*Fama-Macbeth Regressions*	
	$CEx_{j,t}$	$CExRD_{j,t}$	$CEx_{j,t}$	$CExRD_{j,t}$
$SPRD_{j,t-1}$	-0.006	-0.007	-0.006	-0.008
	(-5.14)***	(-3.83)***	(-10.54)***	(-6.97)***
Controls	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes		
R^2	38.6%	30.8%	12.4%	11.8%

Table A2: Changes in investment as a function changes in 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 variables are the first difference in each year, indicated by the prefix *d*, of the variables used in Panel A of Table 2. The *t*-statistics employ standard errors that are clustered by firm and year.

	Dependent Variable			
	$dCEx_{j,t}$	$dCExRD_{j,t}$	$dCEx_{j,t}$	$dCExRD_{j,t}$
$dILLIQ_{j,t-1}$	-0.008	-0.008	-0.010	-0.010
	(-10.53)***	(-10.35)***	(-12.01)***	(-11.75)***
$dCF_{j,t}$	0.065	0.049	0.062	0.047
	(7.65)***	(4.09)***	(7.47)***	(4.02)***
$dQ_{j,t-1}$	0.008	0.011	0.009	0.011
	(6.59)***	(7.45)***	(6.67)***	(7.57)***
$dTA_{j,t-1}$	-0.067	-0.082	-0.054	-0.068
	(-14.04)***	(-17.80)***	(-13.37)***	(-16.78)***
$dVOL_{j,t-1}$	-0.089	-0.102	-0.089	-0.102
	(-2.98)***	(-3.08)***	(-2.91)***	(-3.01)***
$dRET2_{j,t-1}$	0.003	0.003	0.003	0.003
	(4.09)***	(3.81)***	(4.22)***	(3.97)***
$dINV_{j,t-1}$			-0.219	-0.212
			(-13.91)***	(-15.24)***
Year FE	Yes	Yes	Yes	Yes
N	54,668	54,668	54,668	54668
R^2	9.8%	10.0%	13.9%	13.2%

Table A3: Complete results for Model (1) to accompany Table 4.1

This table presents the complete estimation of Model (1) for each of the three three groups of firms sorted on in each year by $ILLIQ_{j,t\text{-}1}$ and by -1*$Equity\ Capitalization_{j,t\text{-}1}$ as indicators of financial constraint. Table 4.1 presents only the coefficients of $ILLIQ_{j,t\text{-}1}$ and of $CF_{j,t}$. The estimations are for the entire period, 1963-2016. The *t*-statistics employ standard errors clustered by firms and years.

	Sorting on $ILLIQ_{j,t\text{-}1}$			Sorting on -1*$Equity\ Capitalization_{t\text{-}1}$		
	Low value= Low constraint	Medium	High value= High constraint	Low value= Low constraint	Medium	High value= High constraint
$ILLIQ_{j,t\text{-}1}$	-0.015	-0.010	-0.006	-0.012	-0.007	-0.006
	(-9.43)***	(-9.12)***	(-7.77)***	(-9.52)***	(-7.90)***	(-8.39)***
$CF_{j,t}$	0.142	0.144	0.102	0.139	0.159	0.097
	(8.26)***	(8.85)***	(10.07)***	(7.25)***	(9.52)***	(9.90)***
$Q_{j,t\text{-}1}$	0.004	0.007	0.006	0.004	0.007	0.006
	(2.99)***	(4.27)***	(3.51)***	(3.03)***	(3.33)***	(3.46)***
$TA_{j,t\text{-}1}$	-0.021	-0.020	-0.020	-0.020	-0.024	-0.020
	(-9.07)***	(-8.94)***	(-11.22)***	(-8.68)***	(-8.66)***	(-11.69)***
$VOL_{j,t\text{-}1}$	-0.064	-0.182	-0.097	-0.039	-0.091	-0.099
	(-1.41)	(-4.99)***	(-4.07)***	(-0.87)	(-2.58)***	(-4.34)***
$RET2_{j,t\text{-}1}$	0.007	0.004	0.005	0.007	0.003	0.005
	(5.15) ***	(2.82)***	(6.57)***	(4.47)***	(2.48)**	(5.76)***
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
N	20680	20719	20703	20703	20720	20679
R^2	68.2%	67.8%	59.8%	69.3%	66.9%	57.9%