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

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Abstract

This paper links stock market liquidity with corporate investment and production decisions. We propose that investment is declining in illiquidity which raises the firm's cost of capital. The negative illiquidity-investment relation holds even for firms that are not financially constrained. Consequently, higher illiquidity induces firms to select a production process that is less capital intensive: they have higher output per unit of capital or higher marginal productivity of capital, lower capital/labor ratio, and lower operating leverage that means less reliance on fixed costs that represent broad forms of investments. The negative illiquidity-investment relation holds for an exogenous liquidity event – the 2001 decimalization – and remains after accounting for endogeneity by instrumental variable estimation.

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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 the employment of capital in the firm's production process. This is because illiquidity raises the expected return required by investors as compensation for higher transaction costs as proposed by Amihud and Mendelson (1986).[1] 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 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 raining the firm's cost of capital. We present evidence that stock illiquidity has negative and significant effect on corporate investment in panel regressions with firm fixed effects and show that this relation holds over time and across industries. Our results remain qualitatively unchanged after we account for potential endogeneity by employing instrumental variable regressions. We also test the effect on investment of an exogenous liquidity-increasing event, the 2001 decimalization, and find that firms whose stock liquidity benefitted most from decimalization invested significantly more.

The negative effect of stock illiquidity on investment, like the negative effect of risk, holds 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. Given the stock illiquidity and risk, corporate managers select investment projects which generate sufficiently high return to satisfy stockholders' required return even if they have the necessary funds. We test that by dividing firms into groups by measures of financial constraint and estimating the investment-illiquidity relation for each group. We find that the negative effect of illiquidity on investment is about equally strong for all groups including that of unconstrained firms.

[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.

We next propose that higher illiquidity affects the production process selected by firms by making it less capital intensive. Firms with illiquid stocks have higher marginal productivity of capital: they have higher output-to-capital ratio and they increase output by more for a given increase in capital. Firms with illiquid stocks have greater increase in labor input for a given increase in capital with this result holding across industries. And, we find that stock illiquidity lowers the firm's operating leverage meaning that the firm's production relies less on fixed costs which reflects broader definition of investment. The effect of stock illiquidity on the firm's production process also holds as predicted around the 2001 decimalization and when we employ instrumental variables estimation.

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. The results are consistent for all measures of investment and of stock 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, Hubbard and Petersen (1988) we include current cash flow scaled by assets and lagged values of *Q* (the ratio of market value to book value of assets). The control variables also include lagged total assets, return volatility and past two-year stock return. The models are estimated over a period of 54 years, 1963 through 2016 and as a robustness test we replicate the estimations for two equal subperiods of 27 years, 1963-1989 and 1990-2016.[3] The results are consistent for both subperiods. Our results remain the same when we do cross-section estimations with industry fixed effects in a panel or in the Fama and Macbeth (1973) 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.

[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.

Having lagged *Q* as an explanatory variable of investment may make it unnecessary to include other explanatory variables – illiquidity, cash flow, total assets, return volatility, and past stock return – given Hayashi's (1982) proposition that corporate investment can be sufficiently explained by marginal *Q*. We find, however, that all these explanatory variables have significant effect on investment in addition to that of *Q*. This may be because we use the standard average *Q* instead of marginal *Q* which the model demands. Hennessy, Levi and Whited (2007) propose that the two are equal when financing is frictionless and profits are linear in capital. But frictionless financing is clearly inconsistent with illiquidity, which is the focus of our analysis. Another reason why *Q* is insufficient to explain investment is that it is measured with error since we use the assets' book value instead of their replacement value. As a partial remedy for that we conduct a robustness test where we replace the standard measure of *Q* by Peters and Taylor's (2017) "total *Q*" whose calculation takes into account intangible assets, such as capitalized research and development expenditures and part of selling, general and administrative expenditures. Our results on the negative effect of illiquidity on investment remain practically unchanged.

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). Morck, Shleifer and Vishny (1990) and Bond, Edmans and Goldstein (2012) propose that the secondary market affects real activity through its effect on the issuance of new securities, which is more important for financially constrained firms. Our analysis suggests an additional channel by which stock illiquidity affects investment: The positive effect of illiquidity on the firm's cost of capital which should hold for all firms regardless of their financial constraint. We test this by estimating the investment-illiquidity relations across firms with different level of financial constraint. We sort firms by nine commonly used measures of financial constraint – equity size, firm asset size, stock illiquidity, cash distribution, cash flow, cash balance, age, leverage, and Whited-Wu's (2006) measure – and divide them into three groups. Estimating our model for each group we find that the negative and highly significant effect of illiquidity on investment holds for all groups. By some measures of financial constraint, the effect of stock illiquidity on investment is even more negative for unconstrained firms. This supports our view that the negative investment-illiquidity relation is because of the effect of illiquidity on the cost of capital. Higher illiquidity induces managers to select investment projects that generate higher expected return in order to accommodate their stockholders who dislike stock illiquidity just as they are averse to risk and demand to be compensated for both.

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 which 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, we estimate the effect of illiquidity 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). This reduces the likelihood of contemporaneous shocks affecting both investment and illiquidity. We find that the negative and significant effect of illiquidity on investment persists even when illiquidity is lagged by more than one year.

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

The next body of tests examines the effect of illiquidity on the firm's production process. Since illiquidity negatively affects capital investment, it induces firms to employ 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 for a unit increase of capital.

(ii) Illiquidity raises labor input for a given capital investment, meaning that it induces a lower capital/labor ratio in production.

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

[4] Bessembinder (2003) finds that liquidity improved most for the most liquid stocks, and Amihud and Mendelson (1986) prove that a given decline in trading costs reduces expected return more for stocks that are more liquid.

These results are consistent with the findings that illiquidity reduces firm value, presented by Fang Noe and Tice (2009) who propose that illiquidity reduce the information provided by stock prices. . We add a channel by which illiquidity impairs firm value: it depresses investment and induces firms to adopt production processes that deviate from those selected by their liquid counterparts.

Our microeconomic 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.

[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.

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 SEOs. This is why firms prefer to do SEOs after their stock liquidity has improved, see Corwin (2003) and 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 the FHP 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, and Hasbrouck (2009) and Goyenlo et al. (2009) show that it is the most highly correlated low-frequency measure of illiquidity with Kyle's (1985) 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. For robustness, we also test the model replacing $ILLIQ_{j,t}$ by another measure of illiquidity denoted $SPRD_{j,t}$, 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 1983 and thus the sample size is smaller.) The results for estimations that use $SPRD_{j,t}$ are presented in the appendix.

The control variables include contemporaneous cash flow, *CF*, following Myers and Majluf (1984) and FHP 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 measures the firm's total size. *VOL* is the standard deviation of weekly stock return calculated over the year, which measures the firm's risk, which may negatively affect investment. *RET2* is the two-year cumulative stock return which captures recent market expectations about investment opportunity and may also positively affect investment. 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. Then, their omission may erroneously attribute their effects to that of illiquidity. *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* that include 29,296 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 $INV_{j,t}$ = $CEx_{j,t}$ 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 relative quoted bid-ask spread. The results are qualitatively similar to those when illiquidity

[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.

is measured by *ILLIQ*. In all regressions, the bid-ask spread has negative and significant effect on corporate investment.

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* (cash flow) and *Q* have positive and significant effects on investment as found by FHP. Investment is lower for larger firms (those with higher *TA*), it is higher for firms with better past performance (higher *RET2*) and lower for firms with higher return volatility (*VOL*). The significant effect on investment of the last three variables, which are also correlated with *ILLIQ*, highlight the importance of not omitting them from a model that focuses on the effect of *ILLIQ*.

### 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, 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.

[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.

### 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,[9] a shorter estimation period makes this assumption more reasonable. We 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.

### 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 effect of *ILLIQ* on subsequent investment is negative and highly significant. In the Appendix Table A1, Panel B, we present the results with *SPRD*.

### 2.1.4. Replacing firm fixed effects by industry fixed effects

In Panel E we replicate the estimation of Panel A with *industry* fixed effects instead of *firm* fixed effects, using Fama and French's 49-industry classification. The estimation is done either by panel regressions or by annual cross-section Fama-Macbeth regressions, reporting the average of the annual coefficients over the 54 years.[10] We find that the coefficients of *ILLIQ* are similar to those in Panel A in both magnitude and statistical significance. For example, for the panel regression here with *CExRD* as dependent variable, the coefficient of *ILLIQ* is -0.008 ($t$ = -

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[9]See Roberts and Whited (2013).

[10] 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.

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. In the Fama-MacBeth estimation procedure we find again 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.

### 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 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 $ILLIQ_{j,t-1}$ 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 replace all variables from levels to changes. We convert all variables in Model (1) to their first difference and estimate the model without firm fixed effect, which is a useful alternative to the panel regression with firm fixed effects when the residuals are potentially correlated. 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 and when $dCEx_{j,t-1}$ is added to the model the coefficient of $dILLIQ_{j,t-1}$ is -0.010 with $t$ = -12.01. The coefficient of $dCEx_{j,t-1}$ has high statistical significance and it considerably raises the model's $R^2$, which is lower here than in Panel A of Table 2 which includes firm fixed effects. This is consistent with Eberly et al.'s (2012) suggestion.[11] The negative coefficient of $dINV_{j,t-1}$ indicates partial reversals in investment which is often bulky and changes intermittently in large increments. Yet the coefficients of $dILLIQ_{j,t-1}$ as well as those of all other variables retain their sign and significance as in Panel A of Table 2 after including lagged investment changes in the model.

### 2.1.7. Using other measures of investment: change in inventory and in total assets

We extended the tests to include two other measures of investment, the change in total assets, *dTA*, and the change in inventory, *dINVTR*, both scaled by lagged total assets. The variable *dTA* reflects changes in all the firm's assets due to capital expenditures and investment in inventory or acquisitions of companies. However, *dTA* may also include accounting revaluation of assets which raises asset value without the firm making an investment. More importantly, for 27% of the firm years in our sample we have $dTA < 0$. This reflects both voluntary and involuntary declines in total assets. Voluntary decline in total assets includes spinoffs and split-offs, which are driven by economic considerations that are unrelated to illiquidity. Or, a firm may sell assets and distribute the proceeds to stockholders through dividend and stock repurchase. Total assets may also decline because of involuntary impairment

[11] We also estimate Model (1) adding lagged investment without firm fixed effect. We find that the coefficient of $ILLIQ_{j,t-1}$ is negative and highly significant.

of value and capital losses. Changes in inventory, *dINVTR*, may be considered an investment that is affected by stock illiquidity given that part of inventory carrying cost is the cost of capital. However, here too, *dINVTR* may be negative due to losses that reflect impairment of value of inventory or it may fall due to an involuntary depletion of inventory caused by an unexpected surge in sales. For completeness, we analyze the effect of illiquidity on these two variables, which partially reflect voluntary investment.

We estimate Model (1) with $INV_{j,t} = dTA_{j,t}$ or $dINVTR_{j,t}$ and find that the results are similar to those reported in Table 2, that is, illiquidity reduces investment. The coefficients of $ILLIQ_{j,t-1}$ for $INV_{j,t} = dTA_{j,t}$ or $dINVTR_{j,t}$ are, respectively, -0.024 ($t$ = -11.83) and -0.004 ($t$ = -7.46), both highly significant. The negative effect of illiquidity is consistent over time: The coefficients of $ILLIQ_{j,t-1}$ are similar in magnitude and significance for both subperiods.[12] In the cross-section regressions using the Fama-Macbeth procedure (as we do in Panel E) with industry fixed effects, the coefficients of $ILLIQ_{j,t-1}$ for $INV_{j,t} = dTA_{j,t}$ or $dINVTR_{j,t}$ are -0.011 ($t$ = -10.11) and -0.002 ($t$ = -4.09), respectively, both highly significant. The coefficients of $ILLIQ_{j,t-1}$ are negative and significant for the sample of Nasdaq firms. When using $SPRD_{j,t-1}$ as a measure of illiquidity with $INV_{j,t} = dTA_{j,t}$ or $dINVTR_{j,t}$, the coefficients are -0.041 ($t$ = 8.36) and -0.005 ($t$ = 4.55), both 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 $b1$ = -0.018 with $t$ = -8.88, which is highly significant.

### 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

[12] For subperiods I and II, the coefficients of $ILLIQ_{j,t-1}$ for $INV_{j,t} = dTA_{j,t}$ are, respectively, -0.029 ($t$ = 11.57) and -0.025 ($t$ = 8.13). For $INV_{j,t} = dINVTR_{j,t}$, these coefficients are -0.005 ($t$ = 6.38) and -0.003 ($t$ = 4.45).

on investment could be that illiquidity indicates a financial constraint.[13] Then, by Fazzari, Hubbard and Petersen (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.

(i) If the negative investment-illiquidity relation is due financial constraint indicated by to illiquidity, the coefficient *b1* of $ILLIQ_{j,t-1}$ should be more negative for firms with higher *ILLIQ* or -1**Equity Capitalization* (smaller size), and *b1* should be close to zero for unconstrained firms. However, if illiquidity lowers investment because it raises the corporate cost of capital, *b1* should be negative and significant for unconstrained firms.

(ii) The coefficient *b2* of $CF_{j,t}$ should be higher for constrained firms as suggested by Fazzari et al. (1988).

INSERT TABLE 3

We find that the negative investment-illiquidity relation is not driven by financial constraint. The results are presented in Table 3.1; 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

[13] In seasoned equity offerings (SEOs), investment banking fees increase in the firm's stock illiquidity especially for large equity issues (Butler, Grullon and Weston, 2005, and Gao and Ritter, 2010) and illiquidity induces a greater price discount (Asem, Chung, Cui and Tian, 2016). Firms prefer doing SEOs after their stock liquidity has improved, see Corwin (2003) and Lin and Wu (2013). Higher bond illiquidity 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).

subperiods, 1973-1989 and 1990-2016. In the Appendix Table A3 we present the complete results with coefficients for all the variables.

Regarding (i), we find that *b1* is negative and significant for all three groups including for the least constraint group, that with the lowest illiquidity and largest size. In fact, for this group *b1* is more negative than for the constrained group indicating that for unconstrained firms that can readily invest there is an important role for illiquidity that affects the cost of capital which in turn affects investment. The coefficient of *ILLIQ* for the most and least constrained firms in Panel A is $b1$ = -0.006 ($t$ = -7.77) and $b1$ = -0.015 ($t$ = -9.43), respectively, and in Panel B it is $b1$ = -0.006 ($t$ = -8.39) and $b1$ = -0.012 ($t$ = -9.52), respectively.[14] Results are similar for the two subperiods showing consistency over time.

Regarding (ii), we do not find a systematic relation between illiquidity and the investment-cash flow sensitivity. This is consistent with Kaplan and Zingales's (1997, 2000) claim that this sensitivity is not a valid measure of financing constraint.

We further test item (i) – whether the negative investment-illiquidity relation is affected by financial constraint – by using six measures of financial constraint and estimating Model (1) for firms classified by these measures.  Following FHP 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

[14] Morck et al. (1990) propose that an improved sentiment about a constrained firm, reflected in a rise in its stock price, can lead to increased investment.  We control for the effect of a lagged change in stock price by using $RET2_{j,t-1}$ whose coefficient is positive and significant. However, the magnitude of this coefficient does not vary meaningfully between firms with the highest or lowest measure of constraint.

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 3.2 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. For the constraint measures in Panels A, B and F, *b1* is significantly more negative for the most financially constrained firms. However, in Panel C, where constraint is measured by firm size (total assets), we observe the opposite, namely that the effect of *ILLIQ* on investment is more negative for unconstrained 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.

In summary, even unconstrained firms exhibit a significantly negative investment-illiquidity relation. 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). Endogeneity may result from favorable economic shocks that enhance stock liquidity and at the same time induce firm investment. 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 preference for liquid stocks is motivated by the size of their investments and their incentive to use information in trading. We too find that illiquidity is strongly and negatively related to $IH_{j,t}$. Yet $IH_{j,t-1}$ has insignificant effect on investment. When adding this variable to Model (1) with $INV_{j,t} = CEx_{j,t}$, its coefficient is positive with $t$ = 1.62, insignificant.

$IH_{j,t}$ is measured as the percent of ownership by institutional investors. The data are based on 13F reporting; the source is Thomson Reuters Institutional Holdings. We use in each year the last quarter's 13F filings, add all the shares that institutions own and divide by the number of shares outstanding. When 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.

This is a two-stage least squared analysis. In the first stage, we 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 4. The coefficient of $IH_{j,t-1}$ is negative and highly significant as expected. Good news such as higher cash flow (*CF*), *Q* and lagged returns (*RET2*) lower illiquidity while higher volatility raises it and larger firm size is associated with lower illiquidity.

INSERT TABLE 4

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 4, columns (2) and (3). In the first-stage regression (column (1)) we find that $IH_{j,t}$ has negative and highly significant effect on $ILLIQ_{j,t}$, consistent with findings in earlier studies. The coefficients of the other variables are also as expected. Illiquidity is lower for large firms, increasing in return volatility and is a decreasing function of the firm's performance, indicated by negative coefficients of past return, cash flow and *Q* value.[15]

In the second-stage regression we find that $FILLIQ_{j,t-1}$, the fitted or instrumented value of $ILLIQ_{j,t-1}$, has a negative and significant effect on investment. For $INV_{j,t}$ measured by $CEx_{j,t}$ and $CExRD_{j,t}$, the coefficients of $FILLIQ_{j,t-1}$ are -0.010 with $t$ = -4.29 and -0.011 with $t$ = -4.09, respectively. These results show that the negative effect of illiquidity on investment is quite robust.

### 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

[15] 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*.

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 Cash Flow). Because illiquidity is a persistent characteristic of a stock, 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 with a greater lag, the coefficient of *ILLIQ* declines in absolute value but it remains highly significant. As expected, the absolute magnitude of the coefficient is smaller than in Table 2 because of a greater errors-in-the-variables problem when the lag is longer. Also, given that the other variables remain in the model with their original one-year lag, part of the effect of the recent value of *ILLIQ* is subsumed by the effects of these variables whose values are correlated with *ILLIQ*.

## 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.[16] 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. They show that a given decline in the bid-ask spread leads to greater decline in expected return for stocks with lower bid-ask spread because such stocks are held in equilibrium by frequently-trading stockholders who price illiquidity cost more dearly.[17]

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):

$$\Delta INV_j = b1*BA_j + b2*\Delta CF_j + b3*\Delta Q_j + b4*\Delta TA_j + b5*\Delta VOL_j + b6*\Delta RET2_j + Ind.\ FE \quad (2.1)$$

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 $\Delta$ 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

[16] One reason for that is that decimalization relaxed the lower bound – the minimum tick – of $0.0625 on the spread.
[17] Amihud and Mendelson (1986, Table 6) 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.
[18] Two industries, Gold and Smoke, have only one firm in our sample.

the TAQ database. The mean (median) of $BA_j$ is -1.669 (-1.745) and its standard deviation is 0.50.

INSERT TABLE 5

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 5, 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 ($t$ = -4.24) and -0.020 ($t$ = -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 $\Delta INV = \Delta dTA$ and $\Delta dINVTR$. The coefficient of $BA_j$ is, respectively, -0.092 ($t$ = -6.03) and -0.011 ($t$ = -3.34), again highly significant. These results support our proposition that improved stock liquidity induces more investment by firms.

We conduct a robustness test where Model (2.1) is estimated with all explanatory variables' values being their average *level* over the pre-decimalization period, 1999-2000, indicated by the subscript 0. This attends to the possibility that changes in some explanatory variables were instigated by decimalizion. When all explanatory variables are lagged relative to the change in the dependent variable that followed the decimalization, their values are not affected by the decimalization. We estimate the following model:

$$\Delta INV_j = b1*BA_j + b2*CF_{j,0} + b3*Q_{j,0} + b4*TA_{j,0} + b5*VOL_{j,0} + b6*RET2_{j,0} + Ind.\ FE \quad (2.2)$$

The results are presented in the Appendix Table A4. 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 $\Delta INV = \Delta TA$ and $\Delta INVTR$.

To further control for differences in characteristics between firms with high and low values of $BA_j$, we estimate Model (2.1) 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 5 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 Models (2.1) and (2.2) $BA_j$ 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. In Model (2.1) for $\Delta INV = \Delta CEx$ or $\Delta CExRD$, the coefficient of $P625_j$ is 0.038 ($t$ = 4.02) and 0.055 ($t$ = 4.38), respectively, both highly significant. And, in Model (2.2) for $\Delta INV = \Delta CEx$ and $\Delta CExRD$, the coefficient of $P625_j$ is 0.065 ($t$ = 5.18) and 0.094 ($t$ = 5.59), respectively.

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:

(i) Low-constraint (high Cash Distribution) group: *b1* = -0.017, $t$ = -4.81.
High-constraint (low Cash Distribution) group: *b1* = -0.009, $t$ = -1.77.

(ii) Low-constraint (low Whited-Wu) group: *b1* = -0.015, $t$ = -3.68.
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.

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

Following the decline in illiquidity, stockholders demand lower expected return and consequently firm managers expand investment more in unconstrained firms.

Finally, we estimate a third version of the model following Fang et al.'s (2009) model that estimates the effect of decimalization:

$$\Delta INV_j = b1*\Delta ILLIQ_j + b2*\Delta CF_j + b3*\Delta Q_j + b4*\Delta TA_j + b5*\Delta VOL_j + b6*\Delta RET2_j + Ind.\ FE \quad (2.3)$$

We find that *b1* = -0.0030 with *t* = 2.06, which is consistent with our findings on the negative effect of illiquidity on investment. Firms which benefitted more from decimalization – those with lower (more negative) $\Delta ILLIQ_j$ – realized greater increase in investment.

## 4. Illiquidity effect on the firm's production process

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

1) Higher marginal revenue product of capital, *MRPK*, estimated by sales-to-capital ratio.
2) Higher labor input associated with capital investment, which informs about the firm's production function.
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

We derive the expression for the marginal revenue productivity of capital, denoted *MRPK*, following Hsieh and Klenow (2009). 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 and r are the market-wide cost of labor and capital, respectively, and $c_k$ is the firm-specific illiquidity premium required by providers of capital to the firm, being an increasing function of the firm's stock illiquidity. The firm sets the capital input such that it equates *MRPK* with its illiquidity-adjusted cost of capital r(1+ck), where *MRPK* is proportional to PY/K. That is, the revenue-capital ratio is increasing in *ck*, which we proxy by *ILLIQ*. This is consistent with our earlier result higher *ILLIQ* reduces the firm's investment.

We hypothesize that higher stock illiquidity raises the firm's *MRPK* = PY/K, defined as $MRPK_{j,t} = Sales_{j,t}/Total\ Assets_{j,t}$, which measures the extent of use of capital to produce a given output.[21] We hypothesize that *MRPK* increases in *ILLIQ*.

INSERT TABLE 6

We estimate Model (1) with $MRPK_{j,t}$ as the dependent variable and hypothesize that $b1 > 0$. The test results, presented in Table 6, Panel A support our hypothesis. The coefficient of $ILLIQ_{j,t-1}$ is positive and significant for the entire test period as well as for each of the two subperiods.

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 $t$ = 2.22 which is significantly different from zero. That is, firms whose stock had narrower bid-ask spread and 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 estimate a general model of the effect of illiquidity on marginal revenue productivity of capital which is not tied to a specific production function:

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

where $dSales_{j,t}$ is the change is sales scaled by lagged assets which estimates the firm's output. Here, $MRPK_{j,t}$ which is the increase in output relative to an increase in capital is estimated as ($b2 + b3*ILLIQ_{j,t-1}$. We use for $INV_{j,t}$ both $CEx_{j,t}$ and $dTA_{j,t}$, the change in total assets scaled by lagged assets, in order to provide a more general measure of expansion in capital. If illiquidity induces higher $MRPK_{j,t}$ we expect $b3 > 0$.

The estimation results of Model (3) are presented in Table 6, Panel B. To save space, we report only the coefficients that pertain to *INV* and *ILLIQ*. For *INV* = *CEx*, we find that $b3$ = 0.034 with $t$ = 3.16, and for *INV* = *dTA* we find that $b3$ = 0.043 with $t$ = 8.23. Both estimates are

[21] In finance and accounting literature, this variable is also called "asset turnover."

positive and highly significant suggesting that illiquidity, which increases the cost of capital, induces firms to select a production process that generates a higher marginal productivity of capital.

**<u>Test 2</u>: Labor input relative to investment**

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 $L = [\alpha r(1+c_k)/(1-\alpha)w]*K$ and $dL/dK = \alpha r/(1-\alpha)w + c_k\alpha r/(1-\alpha)w$. That is, the change in labor relative to an increase in capital is increasing in $c_k$ which we measure by *ILLIQ*. This reflects that substitution between labor and capital in production.

We test whether the change in labor relative to change in capital is increasing in illiquidity by the following model:

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

where $dLabor_j$ is the change in the number of employees over the year scaled by lagged total assets and the change in capital is investment in capital assets, *INV*, with its effect being conditional on stock liquidity. The increase in labor input for a given investment is $b2 + b3*ILLIQ_{j,t-1}$ where *ILLIQ* is in the role of $c_k$. Naturally, $b_2 > 0$. We focus on whether $b3 > 0$ as the model implies, that is, higher illiquidity 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 7

The estimation results of Model (4) are presented in Table 7. As expected, $b2 > 0$ meaning than labor input generally rises with investment. Importantly, we find that $b3 > 0$ which means that the increase in labor input for a given capital investment is significantly higher when stock illiquidity is higher. We find that $b3 = 0.201$ ($t = 7.11$) and 0.181 ($t = 6.98$) for *INV* = *CEx* and *CExRD*, respectively. The result of $b3 > 0$ is consistent for the two subperiods, using *INV* = *CEx* (it is similar when for *INV* = *CExRD*).

We re-do the analysis employing annual cross-section Fama-Macbeth regressions with industry fixed effects, using Fama and French's 49 industry classification. We find again that the coefficient *b3* is positive and significant. For example, for *INV* = *CEx* we find that *b3* = 0.092 with and $t$ = 4.20.

The expansion in the firm's labor input can be associated with expansion in capital not only through capital expenditures but also from acquisitions. We therefore re-estimate model (4) replacing $INV_{j,t}$ by $dTA_{j,t}$, the change in total assets scaled by lagged assets. This allows for a broader test of the effect of illiquidity on labor input as the capital assets of the firm increase. Again, we expect that the coefficient *b3* of $ILLIQ_{j,t-1}*dTA_{j,t}$ is positive. We find that *b3* = 0.120 with $t$ = 7.38, highly significant. The estimated coefficient *b3* is positive and significant in each of the two subperiods. Because $dTA_{j,t}$ more broadly captures the expansion in the firm's capital stock, we find in this model that $R^2$ = 33.6% which is higher than the $R^2$ = 25.3% when $INV_{j,t}$ = $CEx_{j,t}$.

Since production functions differ across industries, we test the robustness of our results by estimating Model (4) separately for each of the five one-digit SIC code industries. Panel B presents the estimation results. To save space we present results only for *INV* = *CEx* and for the coefficients that are related to *ILLIQ* and *INV*. We find that *b3* is positive for all five industries, being significant for all industries but the mining and construction industry (SIC code = 1). 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 $BA_j$, the logarithm of quoted bid-ask spread. These firms' liquidity improved most after the decimalization and we have shown that these firms increased their capital investment.

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 $t$ = 5.42, highly significant. Notably, the effect of illiquidity on labor is after controlling for the change in firm's scale by the explanatory variable $\Delta TA_j$, 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 Model (4) with the instrumented value $FILLIQ_{j,t-1}$ replacing of $ILLIQ_{tj,t-1}$ and $INV = CEx$. We find that $b3 = 0.053$ with $t = 1.77$ which is marginally 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:

$$Cost_{j,t} = b1*ILLIQ_{j,t-1} + b2*Sales_{j,t} + \mathbf{b3*ILLIQ_{j,t-1}*Sales_{j,t}} + firm\ FE + year\ FE \quad (5)$$

$Cost_{j,t}$ 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] $Sales_{j.t}$ and $EBIT_{j,t}$, and consequently $Cost_{j,t}$, are scaled by lagged assets. Operating leverage is defined as $OL = 1\text{-}b2$, following Lev (1974). We define operating leverage as $OL = 1\text{-}b2\text{-}b3*ILLIQ$ and hypothesize that $b3 > 0$. This means that firms with higher *ILLIQ* have lower operating leverage and smaller reliance on fixed costs.

INSERT TABLE 8

[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.

The estimation results of Model (5), presented in Table 8, 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 a model similar to Model (5), replacing $ILLIQ_{j,t-1}$ by $LowBA_j$, an indicator variable that equals 1 for firms in the bottom quartile of $BA_j$ 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:

$$\Delta Cost_j = b1 * LowBA_j + b2 * \Delta Sales_j + \mathbf{b3 * LowBA_j * \Delta Sales_{j,t}}, \quad (5')$$

where $\Delta Cost_j$ is the average $Cost_j$ in the years 2002-2003 minus its average in the years 1999-2000, $\Delta Sales_j$ is similarly calculated. The model includes industry fixed effects. We find that *b3* = -0.033 with *t* = -8.83 which is significant. This implies that operational leverage increased for firms with whose liquidity improved the most 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.

We again account for endogeneity by employing 2SLS estimation using institutional holdings as instrument as in Section 2.1. We estimate Model (5) with $FILLIQ_{j,t-1}$ replacing $ILLIQ_{tj,t-1}$ and find *b3* = 0.005 with *t* = 4.53. This supports our conclusion that illiquidity lowers the reliance on fixed cost in the firm's production process and is consistent with our result that illiquidity reduces capital investment and increases the use of 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 1984. *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 |
| $SPRD_{t-1}$ | 29,296 | -5.098 | 1.719 | -6.609 | -4.629 | -3.773 |
| $CF_t$ | 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 |
| $ILLIQ_{j,t\text{-}1}$ | -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* | |
|---|---|---|---|---|
| | $CEx_{j,t}$ | $CExRD_{j,t}$ | $CEx_{j,t}$ | $CExRD_{j,t}$ |
| $ILLIQ_{j,t\text{-}1}$ | -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* | |
|---|---|---|
| | $CEx_{j,t}$ | $CExRD_{j,t}$ |
| $ILLIQ_{j,t\text{-}1}$ | -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 | -0.008 | -0.005 | -0.007 |
| | (-9.22)*** | (-10.59)*** | (-17.18)*** | (-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. Robustness tests, 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 presented 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 | -0.008 | -0.010 | -0.010 |
| | (-10.53)*** | (-10.35)*** | (-12.01)*** | (-11.75)*** |
| $dINV_{j,t-1}$ | | | -0.219 | -0.212 |
| | | | (-13.91)*** | (-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% |

**Table 3: 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 3.1.** Firms are sorted in each year by $ILLIQ_{j,t-1}$ and by -1*$Equity\ Capitalization_{j,t-1}$ 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 $ILLIQ_{j,t-1}$ and $CF_{j,t}$. The complete tables for the entire period, 1963-2016, are in the Appendix Table A3.

| Period | Variable | Low value = **Low constraint** | Medium | High value = **High constraint** |
|---|---|---|---|---|
| | | Panel A: Sorting by $ILLIQ_{j,t-1}$ | | |
| 1963-2016 | $ILLIQ_{j,t-1}$ | -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 | $ILLIQ_{j,t-1}$ | -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 | $ILLIQ_{j,t-1}$ | -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*$Equity\ Capitalization_{j,t-1}$ | | |
| 1963-2016 | $ILLIQ_{j,t-1}$ | -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 | $ILLIQ_{j,t-1}$ | -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 | $ILLIQ_{j,t-1}$ | -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 3.2.** 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<br>(-10.43)*** | -0.007<br>(-9.13)*** | -0.007<br>(-8.67)*** |
| B: $Age_{j,t-1}$ | -0.010<br>(-10.31)*** | -0.009<br>(-8.79)*** | -0.007<br>(-7.69)*** |
| C: $Firm\ Size_{j,t-1}$ | -0.008<br>(-11.07)*** | -0.010<br>(-10.54)*** | -0.011<br>(-8.62)*** |
| D: $Cash\ Flow_{j,t-1}$ | -0.006<br>(-8.94)*** | -0.007<br>(-8.34)*** | -0.007<br>(-6.85)*** |
| E: $Cash\ Balance_{j,t-1}$ | -0.007<br>(-7.76)*** | -0.008<br>(-9.17)*** | -0.007<br>(-9.61)*** |
| F: $-Leverage_{j,t-1}$ | -0.009<br>(-8.38)*** | -0.006<br>(-7.48)*** | -0.006<br>(-8.11)*** |
| G: $-1*Whited\text{-}Wu_{j,t-1}$ | -0.009<br>(-10.96)*** | -0.008<br>(-9.85)*** | -0.010<br>(-9.47)*** |

**Table 4: 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 5: 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.

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. $^{*}$, $^{**}$, and $^{***}$ indicate significance level at the 0.10, 0.05, and 0.01, respectively.

*Panel A: Tests using the entire sample*

| | *Dependent Variable* | |
|---|---|---|
| | $\Delta CEx_j$ | $\Delta CExRD_j$ |
| $\boldsymbol{BA_j}$ | **-0.013** | **-0.020** |
| | **(-4.24)**$^{***}$ | **(-4.99)**$^{***}$ |
| $\Delta CF_j$ | 0.041 | 0.036 |
| | (3.35)$^{***}$ | (2.25)$^{**}$ |
| $\Delta Q_j$ | 0.010 | 0.018 |
| | (8.32)$^{***}$ | (11.45)$^{***}$ |
| $\Delta TA_j$ | -0.001 | -0.006 |
| | (-0.29) | (-1.11) |
| $\Delta VOL_j$ | -0.096 | -0.048 |
| | (-1.90)$^{*}$ | (-0.71) |
| $\Delta RET2_j$ | 0.003 | 0.009 |
| | (2.38)$^{**}$ | (5.33)$^{***}$ |
| N | 1,428 | 1,428 |
| $R^2$ | 17.7% | 25.0% |

*Panel B: Results for matched samples*

| | *Dependent Variable* | |
| --- | --- | --- |
| | *$\Delta CEx_j$* | *$\Delta CExRD_j$* |
| ***$BA_j$*** | **-0.013** **(-4.25)***** | **-0.024** **(-5.27)***** |
| Control variables | Yes | Yes |
| $R^2$ | 19.6% | 29.2% |

**Table 6: Effect of illiquidity on the marginal revenue productivity of capital**

This table presents results for Model (1) with the dependent variable being *MRPK*, the marginal revenue productivity of capital, defined as the ratio of the firm's sales to capital (total assets). See Table 1 for variable definitions. The models are estimated with firm and year fixed effects. 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.

| Panel A: | *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 the sales growth relative to investment**

This table presents results for the model:

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

$dSales_{j,t}$ is the change in sales (from the preceding year) scaled by lagged total assets. Investment of firm *j* in year *t*, $INV_{j,t}$, is either of $CEx_{j,t}$ or $dTA_{j,t}$. See Table 1 for details on the variables. To save space, we report only the coefficients that relate to *ILLIQ* and *INV*. 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.

| | $INV = CEx_{j,t}$ | $INV = dTA_{j,t}$ |
|---|---|---|
| $ILLIQ_{j,t-1}$ | 0.003 | 0.014 |
| | (1.27) | (6.62)$^{***}$ |
| $INV_{j,t}$ | 1.411 | 1.273 |
| | (7.34)$^{***}$ | (12.48)$^{***}$ |
| $\mathbf{ILLIQ_{j,t-1}*INV_{j,t}}$ | **0.034** | **0.043** |
| | **(3.16)$^{***}$** | **(8.23)$^{***}$** |
| Control variables | Yes | Yes |
| $R^2$ | 34.0% | 49.4% |

**Table 7: The effect of illiquidity on labor input relative to investment**

This table presents results for the model:

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

$dLabor_j$ is the change in number of employees over the year (from the preceding year) scaled by lagged total assets. Investment of firm *j* in year *t*, $INV_{j,t}$, is either of $CEx_{j,t}$ or $CExRD_{j,t}$. See Table 1 for details on the variables. Errors are clustered by firm and year. In Panel A, the model is estimated with firm and year fixed effects for the entire period, 1963-2016 for the two alternative measures of investments. In all panels, 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 using two different definitions of investment,* $INV_{j,t}$

| | $INV = CEx_{j,t}$ 1963-2016 | $INV = CExRD_{j,t}$ 1963-2016 | $INV = CEx_{j,t}$ 1963-1989 | 1990-2016 |
|---|---|---|---|---|
| $ILLIQ_{j,t-1}$ | -0.032 | -0.035 | -0.047 | -0.010 |
| | (-6.47)*** | (-6.69)*** | (-4.64)*** | (-3.78)*** |
| $INV_{j,t}$ | 4.782 | 4.237 | 4.802 | 1.863 |
| | (8.46)*** | (8.05)*** | (6.13)*** | (6.39)*** |
| $\mathbf{ILLIQ_{j,t-1}*INV_{j,t}}$ | **0.201** | **0.181** | **0.183** | **0.065** |
| | **(7.11)*** | **(6.98)*** | **(3.97)*** | **(4.44)*** |
| $Q_{j,t-1}$ | 0.026 | 0.026 | 0.050 | 0.017 |
| | (3.30)*** | (3.26)*** | (2.98)*** | (4.75)*** |
| $TA_{j,t-1}$ | -0.143 | -0.143 | -0.349 | -0.058 |
| | (-8.34)*** | (-8.38)*** | (-7.32)*** | (-5.97)*** |
| $VOL_{j,t-1}$ | -0.392 | -0.428 | -0.299 | -0.459 |
| | (-2.60)*** | (-2.81)*** | (-0.80) | (-3.67)*** |
| $RET2_{j,t-1}$ | 0.030 | 0.031 | 0.054 | 0.013 |
| | (4.52)*** | (4.65)*** | (4.20)*** | (3.53)*** |
| Firm FE | Yes | Yes | Yes | Yes |
| Year FE | Yes | Yes | Yes | Yes |
| N | 62,102 | 62,102 | 30,760 | 31,342 |
| $R^2$ | 25.3% | 25.1% | 28.0% | 31.4% |

*Panel B: Estimation of Model (4) by industry*

| | One-Digit SIC Industry Code | | | | |
|---|---|---|---|---|---|
| | SIC=1 | SIC=2 | SIC=3 | SIC=4 | SIC=5 |
| $ILLIQ_{j,t-1}$ | -0.011 | -0.038 | -0.032 | -0.020 | -0.042 |
| | (-1.50) | (-3.42)*** | (-4.05)*** | (-2.19)** | (-4.31)*** |
| $CEx_{j,t}$ | 0.686 | 6.891 | 6.118 | 3.019 | 9.804 |
| | (2.35)** | (6.49)*** | (6.34)*** | (3.55)*** | (6.56)*** |
| $\boldsymbol{ILLIQ_{j,t-1}CEx_{j,t}}$ | **0.025** | **0.311** | **0.251** | **0.139** | **0.399** |
| | **(1.59)** | **(5.36)*** ** | **(4.87)*** ** | **(2.87)*** ** | **(5.02)*** ** |
| 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 |
| $R^2$ | 16.3% | 20.0% | 26.7% | 32.4% | 35.0% |

**Table 8: The effect of illiquidity on operating leverage**

This table presents results for the model:

$$Cost_{j,t} = b1*ILLIQ_{j,t-1} + b2*Sales_{j,t} + \mathbf{b3*ILLIQ_{j,t-1}*Sales_{j,t}} + firm\ FE + year\ FE, \quad (5)$$

$Sales_{j,t}$ are total revenues and $Cost_{j,t} = Sales_{j,t} - EBIT_{j,t}$ where $EBIT_{j,t}$ is earnings before interest and taxes. These variables are scaled by lagged total assets. *ILLIQ* is illiquidity, defined in Table 1, in logarithm. Operating leverage is $1 - b2 - b3*ILLIQ_{j,t-1}$. The 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* |
| $ILLIQ_{j,t-1}$ | 0.009 | 0.007 | 0.009 |
| | (8.20)$^{***}$ | (3.50)$^{***}$ | (6.12)$^{***}$ |
| $Sales_{j,t}$ | 0.957 | 0.958 | 0.946 |
| | (94.07)$^{***}$ | (59.69)$^{***}$ | (62.29)$^{***}$ |
| $\mathbf{ILLIQ_{j,t-1}*Sales_{j,t}}$ | **0.003** | **0.004** | **0.003** |
| | **(5.21)**$^{***}$ | **(3.76)**$^{***}$ | **(3.71)**$^{***}$ |
| Firm FE | Yes | Yes | Yes |
| Year FE | Yes | Yes | Yes |
| N | 62,102 | 30,760 | 31,342 |
| $R^2$ | 99.4% | 99.6% | 99.3% |

## Appendix

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

This table presents results for the model:

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

$SPRD_{j,t}$ is the (logarithm of the) average daily relative quoted bid-ask spread (the dollar spread divided by the quote's mid-point) in year *t*. Data for *SPRD* are available from CRSP since 1983 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: Estimation over the entire period, 1984-2016*

| | *1984-2016* | |
|---|---|---|
| | *Dependent Variable* | |
| | $CEx_{j,t}$ | $CExRD_{j,t}$ |
| $SPRD_{j,t-1}$ | -0.009 | -0.010 |
| | $(-7.48)^{***}$ | $(-5.91)^{***}$ |
| $CF_{j,t}$ | 0.087 | 0.070 |
| | $(11.03)^{***}$ | $(6.40)^{***}$ |
| $Q_{j,t-1}$ | 0.010 | 0.015 |
| | $(9.56)^{***}$ | $(11.01)^{***}$ |
| $TA_{j,t-1}$ | -0.015 | -0.022 |
| | $(-9.01)^{***}$ | $(-9.86)^{***}$ |
| $VOL_{j,t-1}$ | -0.095 | -0.101 |
| | $(-4.03)^{***}$ | $(-3.51)^{***}$ |
| $RET2_{j,t-1}$ | 0.003 | 0.003 |
| | $(3.16)^{***}$ | $(2.79)^{***}$ |
| Firm FE | Yes | Yes |
| Year FE | Yes | Yes |
| N | 29,296 | 29,296 |
| $R^2$ | 67.8% | 68.3% |

*Panel B: Estimation 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* | |
|---|---|---|---|---|
| | $CEx_{j,t}$ | $CExRD_{j,t}$ | $CEx_{j,t}$ | $CExRD_{j,t}$ |
| $SPRD_{j,t-1}$ | -0.007 | -0.008 | -0.010 | -0.013 |
| | (-5.54)*** | (-4.24)*** | (-9.50)*** | (-6.86)*** |
| Controls | Yes | Yes | Yes | Yes |
| Firm FE | Yes | Yes | Yes | Yes |
| Year FE | Yes | Yes | | |
| $R^2$ | 36.8% | 29.9% | 14.1% | 13.7% |

**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, 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<br>(-10.53)*** | -0.008<br>(-10.35)*** | -0.010<br>(-12.01)*** | -0.010<br>(-11.75)*** |
| $dCF_{j,t}$ | 0.065<br>(7.65)*** | 0.049<br>(4.09)*** | 0.062<br>(7.47)*** | 0.047<br>(4.02)*** |
| $dQ_{j,t-1}$ | 0.008<br>(6.59)*** | 0.011<br>(7.45)*** | 0.009<br>(6.67)*** | 0.011<br>(7.57)*** |
| $dTA_{j,t-1}$ | -0.067<br>(-14.04)*** | -0.082<br>(-17.80)*** | -0.054<br>(-13.37)*** | -0.068<br>(-16.78)*** |
| $dVOL_{j,t-1}$ | -0.089<br>(-2.98)*** | -0.102<br>(-3.08)*** | -0.089<br>(-2.91)*** | -0.102<br>(-3.01)*** |
| $dRET2_{j,t-1}$ | 0.003<br>(4.09)*** | 0.003<br>(3.81)*** | 0.003<br>(4.22)*** | 0.003<br>(3.97)*** |
| $dINV_{j,t-1}$ | | | -0.219<br>(-13.91)*** | -0.212<br>(-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:** Firms are sorted in each year by $ILLIQ_{j,t-1}$ and by -1**Equity Capitalization*$_{j,t-1}$ as indicators of financial constraint and divided into three groups. Model (1) is estimated for each group. To save space, we report only the coefficient of $ILLIQ_{j,t-1}$ and $CF_{j,t-1}$. These estimations are for the entire period, 1963-2016. The *t*-statistics employ standard errors clustered by firms and years.

| | Sorting on $ILLIQ_{j,t-1}$ | | | Sorting on -1**Equity Capitalization*$_{t-1}$ | | |
|---|---|---|---|---|---|---|
| | Low value= Low constraint | Medium | High value= High constraint | Low value= Low constraint | Medium | High value= High constraint |
| $ILLIQ_{j,t-1}$ | -0.015<br>(-9.43)*** | -0.010<br>(-9.12)*** | -0.006<br>(-7.77)*** | -0.012<br>(-9.52)*** | -0.007<br>(-7.90)*** | -0.006<br>(-8.39)*** |
| $CF_{j,t}$ | 0.142<br>(8.26)*** | 0.144<br>(8.85)*** | 0.102<br>(10.07)*** | 0.139<br>(7.25)*** | 0.159<br>(9.52)*** | 0.097<br>(9.90)*** |
| $Q_{j,t-1}$ | 0.004<br>(2.99)*** | 0.007<br>(4.27)*** | 0.006<br>(3.51)*** | 0.004<br>(3.03)*** | 0.007<br>(3.33)*** | 0.006<br>(3.46)*** |
| $TA_{j,t-1}$ | -0.021<br>(-9.07)*** | -0.020<br>(-8.94)*** | -0.020<br>(-11.22)*** | -0.020<br>(-8.68)*** | -0.024<br>(-8.66)*** | -0.020<br>(-11.69)*** |
| $VOL_{j,t-1}$ | -0.064<br>(-1.41) | -0.182<br>(-4.99)*** | -0.097<br>(-4.07)*** | -0.039<br>(-0.87) | -0.091<br>(-2.58)*** | -0.099<br>(-4.34)*** |
| $RET2_{j,t-1}$ | 0.007<br>(5.15) *** | 0.004<br>(2.82)*** | 0.005<br>(6.57)*** | 0.007<br>(4.47)*** | 0.003<br>(2.48)** | 0.005<br>(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% |

**Table A4: Decimalization and investment**

This table presents results for the model:

$$\Delta INV_j = b1*BA_j + b2*CF_{j,0} + b3*Q_{j,0} + b4*TA_{j,0} + b5*VOL_{j,0} + b6*RET2_{j,0} + Ind.\ FE \quad (2.2)$$

The legend is as in Table 5. All control variables are at their pre-decimalization level. The subscript 0 indicates the average value of the variable during the years 1999-2000. $BA_j$ is the natural logarithm of average quoted bid-ask spread for the firm during the period January to July of 2000 (source: TAQ). Panel A presents the estimation that includes data for 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. $^{*}$, $^{**}$, and $^{***}$ indicate significance level at the 0.10, 0.05, and 0.01, respectively. To save space, we report only the coefficient of $BA_j$.

*Panel A: Entire sample*

| | *Dependent Variable* | |
|---|---|---|
| | $\Delta CEx_j$ | $\Delta CExRD_j$ |
| $BA_j$ | -0.017 | -0.028 |
| | (-4.94)$^{***}$ | (-5.93)$^{***}$ |
| *Controls* | Yes | Yes |
| *Industry FE* | Yes | Yes |
| N | 1,428 | 1,428 |
| $R^2$ | 14.1% | 18.4% |

*Panel B: Results for matched samples*

| | *Dependent Variable* | |
|---|---|---|
| | $\Delta CEx_j$ | $\Delta CExRD_j$ |
| $BA_j$ | -0.017 | -0.031 |
| | (-5.39)$^{***}$ | (-6.57)$^{***}$ |
| *Controls* | Yes | Yes |
| *Industry FE* | Yes | Yes |
| N | 1,428 | 1,428 |
| $R^2$ | 15.2% | 21.3% |