Does capital market drive corporate investment efficiency? Evidence from equity lending supply

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Abstract

The increased equity lending supply (ELS) in the equity loan market, available for short sellers to borrow, exposes a firm to greater short selling threats. Considering short sellers' strong incentives to uncover firm-specific information and monitor managers, we hypothesize that short selling threats, proxied by ELS, enhance corporate investment efficiency. We find that ELS significantly reduces managerial tendencies to underinvest (overinvest) especially for firms prone to underinvest (overinvest). The effect of ELS on investment efficiency is stronger for firms with higher information asymmetry and weaker corporate governance, confirming short sellers' role in mitigating information and agency costs. However, short selling risk weakens the effect of ELS. Our evidence is robust to endogeneity checks and suggests that corporate investment can be driven by a particular capital market condition: the amount of lendable shares in the equity loan market.

Keywords: equity lending supply, short selling threats, corporate investment efficiency, financial constraints

JEL Codes: G31, G34, G10, D22

1. Introduction

In a frictionless world (Modigliani and Miller, 1958), managers make optimal investment decisions to maximize shareholders' wealth. While in reality the presence of frictions, namely moral hazard and adverse selection, often leads to firm investment deviating from the optimal level (e.g., Jensen, 1986; 1993; Holmstrom, 1979; Harris and Raviv, 1979; Grossman and Hart, 1983; Bertrand and Mullainathan, 2003). The empirical literature on the determinants of corporate investment efficiency documents that investment efficiency is driven by certain aspects of corporate financial reporting and disclosure[1], for example, financial reporting quality (Biddle et al., 2009; Chen et al., 2011; Jung et al., 2014; Dou et al., 2019), the adoption of IFRS (Chen et al., 2013), accounting conservatism (Lara et al., 2016), and auditor characteristics (Bae et al., 2016). This literature focuses predominantly on the roles of firm characteristics and accounting choices, while much less is known about whether capital market has a real impact on the efficiency of corporate investment. We contribute to the investment efficiency literature by investigating the real effect of an important, yet underexplored, equity loan market condition, namely equity lending supply (i.e. the amount of equity available for short sellers to borrow).

Short sellers could play an influential role in promoting corporate investment efficiency. Short sellers have their own capital at stake and they profit from stock price declines of their target firms, and therefore have strong incentives to both collect and disseminate firm information unavailable to the market (i.e. *information intermediary role*), and scrutinize managerial behavior (i.e. *external governance role*). Specifically, short sellers, who take short positions, would gain if they manage to drive down the price of the target stocks by uncovering negative firm-specific news or managers' misbehavior (e.g., value-destroying investment decisions). Thus, short sellers are highly incentivized to closely

[1] See Roychowdhury, Shroff and Verdi (2019) for a review.

monitor their target firms, imposing discipline on managers. This discipline effect arising from short sellers can be stronger than those from other stakeholders (e.g., financial analysts and institutional investors) whose monitoring incentives might be compromised due to the conflict of interests faced by analysts (e.g., O'Brien et al., 2005; Malmendier and Shanthikumar, 2007; Campbell et al., 2019) and heterogeneous investment strategies of institutional investors (e.g., Chen et al., 2007; Roychowdhury and Srinivasan, 2019). Considering that short sellers are in a good position to mitigate both moral hazard and adverse selection by playing governance and information intermediary roles, and could in turn curb suboptimal investment decisions, we hypothesize that short selling threats increase investment efficiency.

Empirically, we use the detailed equity lending data from Markit database over the period 2006-2018 to investigate the effect of a particular dimension of short selling, namely equity lending supply, as an *ex-ante* proxy for short selling threats.[2] Our analysis focuses on the *ex-ante* "short selling potential", which is observable by managers (Lamont, 2012; Chang et al., 2019) and reflects the "maximum potential impact that short sellers may have" on managerial behavior (Massa et al., 2015a). It is worth noting that, ceteris paribus, the intensity of short selling threats depends on the amount of equity available in the equity loan market for short sellers to borrow (Saffi and Sigurdsson, 2011). For instance, in the absence of lending supply, short sellers would not even be able to initiate short positions, leaving firms unexposed to short selling threats. Thus, equity lending supply (ELS) is a key element of short selling threats, and its effect on corporate investment efficiency is an important empirical question.

Our empirical strategies to test investment efficiency are built upon two alternative empirical frameworks. First, we follow Biddle et al.'s (2009) approach which models

[2] The empirical literature on the effects of short selling focuses on several dimensions of short selling, including market-wide short selling regulations, short-interest, and realized short sales (see Reed (2013) for a review).

investment efficiency as the change in corporate investment conditional on the ex-ante propensity to overinvest and underinvest respectively. Specifically, we find that ELS reduces (increases) investment for firms prone to overinvest (underinvest), meaning that ELS reduces inefficient investment. Second, following the literature (e.g., Biddle et al., 2009; Chen et al., 2013), we use the residuals estimated from a regression of investment on investment opportunities (measured by sales growth) as a proxy for the magnitude of the deviation from the optimal level of investment. We find that ELS increases the probability that a firm's investment is close to the optimal level. Taken together, we find consistent evidence supporting our main hypothesis that equity lending supply enhances investment efficiency.

The main empirical challenge of our study is that the observed positive association between equity lending supply and investment efficiency could be subject to endogeneity problems. Although we include an extensive list of controls in our empirical models, unobserved heterogeneity could still induce the omitted variable bias. To address endogeneity concerns, we perform two tests. We first utilize the Reg SHO[3] as an exogenous shock to the intensity of short selling threats and conduct a difference-in-differences (DiD) test. Our DiD results show that the treated firms (those facing higher short selling threats due to the removed restriction on short selling) have significantly higher investment efficiency.

In addition, we employ an instrumental variable approach. Following the literature (Hirshleifer et al., 2011; Massa et al., 2015a; Chang et al., 2019), we use the ownership of passive institutional investors (Bushee, 2001) as an instrumental variable for equity lending supply. The passive institutional investors (i.e. exchange-traded funds (ETF)) supply lendable shares to the equity loan market but typically do not actively monitor firms, and therefore the passive institutional ownership can be used to extract the exogenous component of equity lending supply (Massa et al., 2015a). We find that the instrumented equity lending supply

[3] The Regulation (Reg) SHO is a regulation governing the short selling of US stocks. From May 2, 2005 to August 6, 2007, one-third of stocks in the Russell 3000 index are randomly chosen to be pilot stocks. The pilot stocks are exempted from short-sale price tests, and are therefore exposed to higher short selling threats.

significantly increases investment efficiency. To sum up, our main findings that equity lending supply enhances investment efficiency survive the endogeneity checks, suggesting a causal link between short selling threats and investment efficiency. Our study suggests that capital market, equity loan market in particular, does drive corporate investment efficiency.

Next, we explore the cross-sectional heterogeneity in the relation between short selling threats and investment efficiency. We expect that short selling threats, associated with equity lending supply, would mitigate both moral hazard and adverse selection, and thus have a more pronounced effect on investment efficiency for firms with weaker governance mechanisms and higher information asymmetry. Consistent with this proposition, we find that short selling threats have a stronger effect on investment efficiency for firms with more co-opted independent directors (i.e. less effective monitoring) and lower takeover threats, and firms with higher analyst forecast error and dispersion.

Furthermore, the effect of equity lending supply on investment efficiency could depend on the magnitude of short selling risk. Given the same level of equity lending supply, the intensity of short selling threats would be weak when potential short sellers face higher risk (Miller, 1977; Diamond and Verrecchia, 1987; Engelberg et al., 2018). Consistent with this conjecture, we find that short selling risk, i.e. the risk of being charged a high lending fee and forced to close the short position prematurely (Engelberg et al., 2018), significantly weakens the positive effect of equity lending supply on investment efficiency, suggesting that the intensity of short selling threats depends on short selling risk.

To shed further light on the mechanisms underlying the positive relation between short selling threats and investment efficiency, we examine the moderating effects of financial constraints on the relation between equity lending supply and investment efficiency. We find that equity lending supply significantly reduces the probability of underinvestment for firms that are ex-ante financially constrained and are therefore prone to underinvestment

(Biddle et al., 2009; Dou et al., 2019). In addition, equity lending supply significantly reduces the probability of overinvestment for firms that are ex-ante financially unconstrained and are therefore prone to overinvestment (Biddle et al., 2009; Chang et al., 2019). These results are consistent with the aforementioned baseline evidence based on Biddle et al.'s (2009) model that short selling threats reduce (increase) investment for firms prone to overinvest (underinvest). These cross-sectional results confirm that financial constraints play a pivotal role in influencing the relation between short selling and investment efficiency, and imply that short selling threats can not only reduce underinvestment by easing financial constraints but also curb overinvestment by playing a governance role.

Finally, we examine the direct effects of short selling threats on the degree of financial constraints faced by firms. It is expected that short selling can alleviate financial constraints and facilitate external financing. We find that equity lending supply significantly reduces the overall financial constraints, as proxied by the text-based measure of financing challenges developed by Hoberg and Maksimovic (2015). Furthermore, to sharpen the analysis, we employ three specific financing constraints measures (Hoberg and Maksimovic, 2015) that separately capture constraints for different forms of external financing. We show that equity lending supply eases both debt financing and private placement constraints, but has an insignificant effect on equity financing constraints. Moreover, we find that equity lending supply facilitates firms' access to long-term debt. The resulting longer debt maturity can enhance investment efficiency by reducing refinancing risk (e.g., Harford et al., 2014; Benmelech et al., 2019). Finally, we find a negative effect of equity lending supply on the likelihood of equity issues, which is in line with Grullon et al. (2015). Overall, these results suggest that an important channel through which short selling threats enhance investment efficiency is the loosened financial constraints in terms of greater access to long-term debt and private placement financing.

To the best of our knowledge, this is the first study that utilizes detailed equity lending supply data to examine the real effect of short selling threats on the efficiency of corporate investment decisions. We contribute to the literature in three ways. First, this study contributes to investment efficiency literature (e.g., Biddle et al., 2009; Chen et al., 2011; Chen et al., 2013; Lara et al., 2016; Chen et al., 2017; Dou et al., 2019). Prior literature on investment efficiency focuses on the roles of firm characteristics and accounting choices (Roychowdhury et al., 2019), while we document that equity lending supply, as an *ex-ante* proxy for short selling threats, is an important determinant of investment efficiency, and reduces managerial tendencies to underinvest and overinvest. This new evidence enhances our understanding of the favorable role of capital market in driving corporate investment efficiency. Our study is related to Grullon et al. (2015) which document that the US short selling deregulation reduces corporate investment of small firms in particular. However, it remains unclear whether short selling increases or decreases investment efficiency. We provide direct evidence that short selling threats enhance investment efficiency, which represents a departure from, and an important complement to, Grullon et al. (2015).

The favorable role played by short sellers is also consistent with Deng et al. (2020) which document that the US short selling deregulation can reduce stock price crash risk by curbing firm overinvestment. In their setting, investment efficiency is used as a moderating variable, while we examine the direct effect of equity lending supply on investment efficiency. In addition, several studies that exploit the Chinese short selling deregulations provide mixed evidence related to investment efficiency.[4] Hu et al. (2019) document that short selling reduces cost of equity and increases investment efficiency. In contrast, Ni and Yin (2020) show that short selling reduces firm value by inducing firms to cut capital expenditures and R&D investment and Ding et al. (2020) find that short selling decreases

[4] A potential caveat of the Chinese short selling experiment is that the selection of shortable shares made by the China Securities Regulatory Commission (CSRC) is not random (Hu et al., 2019; Ding et al., 2020).

labor investment efficiency. Unlike Hu et al.'s (2019) study that focuses on the cost of equity implications of short selling deregulation in China, we delve into the impact of ex-ante short selling threats on investment efficiency and find that access to equity financing is not the channel through which short selling threats enhance investment efficiency of U.S. firms.

Second, our study contributes to the literature on the real effects of short selling. Recent studies show the impacts of short selling deregulation on various corporate decisions, including earnings management (Fang et al., 2016), innovation (He and Tian, 2016), corporate internal resource allocation (Albertus et al., 2019) and managerial incentive compensation (Lin et al., 2019), while we are the first to document the real effect of an underexplored dimension of short selling, namely *equity lending supply*, on investment efficiency. Our study contributes to a burgeoning literature on the real effect of equity lending supply on corporate decisions, such as earnings management (Massa et al., 2015a) and mergers and acquisitions (Chang et al., 2019). In particular, we provide direct and comprehensive evidence on the efficiency of a range of corporate investments, based on a different empirical approach (i.e. an "accounting-based framework" (Biddle et al., 2009; Richardson, 2006)). Our evidence suggests that equity lending supply allows potential short sellers to play information intermediary and external governance roles, which in turn enhances investment efficiency. Our study therefore adds to the debate on the roles of various gatekeepers in capital markets (Roychowdhury and Srinivasan, 2019), and supports the view that the threats of selling shares discipline managers (e.g., Admati and Pfleiderer, 2009).

Third, this study is related to a strand of literature on the relation between short selling and investment frictions (in the form of financial constraints) in different institutional environments. In theory, short selling threats could either ease or tighten financial constraints (Meng et al., 2020). Meng et al. (2020) test the competing hypotheses using data on Chinese firms, and find that short selling deregulations tighten financial constraints by reducing firms'

ability to raise external financing.[5] Similarly, we find a negative effect of short selling threats on the likelihood of equity issues of U.S. firms, which is probably because increased short selling leads to stock price declines (Grullon et al., 2015). More importantly, we are the first to show that short selling threats ease financial constraints by facilitating access to long-term debt financing and private placements. This new evidence is largely in line with the notion that short selling threats mitigate various managerial agency problems (e.g., empire building, short-termism) (Massa et al., 2015a; Massa et al., 2015b; Chang et al., 2019; Deng et al., 2020). Overall, our study, together with the aforementioned studies (Meng et al., 2020; Ni and Yin, 2020), suggests that the real effects of short selling on corporate financing and investment may differ across different capital markets.

The paper proceeds as follows. Section 2 develops hypotheses. Section 3 describes data and research design. Section 4 presents the baseline results. Section 5 addresses endogeneity concerns. Section 6 performs cross-sectional analyses. Section 7 conducts further analyses and robustness tests, and section 8 concludes.

2. Related Literature and Hypotheses

2.1 Frictions and corporate investment efficiency

Making optimal corporate investment decisions is essential for maximizing shareholder value. In a frictionless world, the Modigliani and Miller (1958) theorem prescribe that managers make value-enhancing investment decisions by taking projects with positive net present values, and aim to achieve an optimal level of investment where the marginal benefit of investment is equal to its marginal cost. In reality, investment distortions (inefficiencies) do exist due to the presence of various frictions. Two primary types of frictions that could induce suboptimal investment decisions are adverse selection and moral hazard (e.g., Jensen, 1986;

[5] Importantly, consistent with their empirical findings, Meng et al. (2020) also provide interview evidence that "short sales in China have not yet posed enough threat to managers, nor do they play an effective role in monitoring managers' opportunistic behaviour".

1993; Holmstrom, 1979; Harris and Raviv, 1979; Grossman and Hart, 1983; Bertrand and Mullainathan, 2003). Both frictions are closely associated with information asymmetry between managers and outside investors.

Specifically, the adverse selection and moral hazard problems could induce managers to either underinvest or overinvest. The adverse selection problem arises from the information asymmetry between managers and investors (i.e. shareholders, creditors). Managers have superior information about firm value and have the incentive to engage in market timing by issuing overpriced stocks to the market, which benefits the existing shareholders at the expense of the new shareholders (e.g., Baker and Wurgler, 2002). In anticipation of this, the potential new shareholders would ration capital or require a higher return from the equity investment. However, the managers are reluctant to issue new equities at a discounted price. Consequently, managers may have to forego good investment opportunities, and thus underinvest relative to the first best (Myers and Majluf, 1984). Similarly, firms could face credit rationing in the loan market due to adverse selection (Stiglitz and Weiss, 1981), which also leads to underinvestment. The underinvestment problem is more prevalent especially when a firm has insufficient internal funds and is financially constrained.

Moral hazard problems arise when the interests of managers are not perfectly aligned with those of shareholders, and managers pursue their own interests at the expense of shareholders (Jensen and Meckling, 1976). Specifically, self-interested managers tend to make suboptimal (inefficient) investment in accordance with their own preferences. Two such preferences are empire building (Jensen, 1986; 1993; Richardson, 2006) and "quiet life" (Holmstrom, 1979; Harris and Raviv, 1979; Bertrand and Mullainathan, 2003). Managers with the empire-building preference are tempted to build excessively large corporate empires by overinvesting, especially when a firm has substantial free cash flow (Jensen, 1986). In

contrast, managers who prefer a "quiet life" may exert limited effort in enhancing firm value due to managerial effort aversion.

Building upon the theoretical relation between the problems of moral hazard and adverse selection and corporate investment, prior empirical literature on the determinants of investment efficiency establishes the roles of financial reporting and disclosure (Biddle et al., 2009; Chen et al., 2011; Chen et al., 2013; Lara et al., 2016). Various stakeholders, such as financial analysts (Chen et al., 2017), also have significant impacts on investment efficiency. However, the role of capital market conditions in shaping corporate investment decisions is much underexplored. We contribute to the literature by examining the effect of short selling threats, measured by equity lending supply, on investment efficiency. The mechanisms through which short sellers could influence investment efficiency are elaborated in the subsequent section.

2.2 Short selling threats and corporate investment efficiency

Short sellers are sophisticated investors who profit from stock price declines. Given this special business model, short sellers have strong incentives to collect and disseminate information about their target firms, and closely monitor the corporate decisions and performance, and thus could play an important role not only in capital markets but also in shaping managerial decisions in corporations. Specifically, it is well documented that short sellers facilitate price discovery (Dechow et al., 2001; Diether et al., 2009; Drake et al. 2011; Engelberg et al. 2012; Chi et al. 2013; Boehmer and Wu, 2013). Besides, the literature suggests that short selling regulation (i.e. Reg SHO) has real impacts on the economy by influencing a variety of corporate decisions.[6] Adding to this event-based short selling

[6] The literature shows that Reg SHO has significant impacts on earnings management (Fang et al., 2016), financing and capital expenditures (Grullon et al., 2015), innovation (He and Tian, 2016), cash holding (Wang, 2018), managers' voluntary disclosure choices (Li and Zhang, 2015), and managerial incentive compensation (Lin et al., 2019), among others.

literature, an emerging literature takes advantage of the detailed equity loan market data[7] and shows that equity lending supply, as an *ex-ante* proxy for short selling threats, affects earnings management (Massa et al., 2015a) and market reactions to M&A announcements (Chang et al., 2019). Complementing this strand of literature, we examine whether *ex-ante* short selling potential makes corporate investment decisions more optimal. Specifically, we shed light on the effect of short selling threats on the efficiency of corporate investment. We provide direct evidence as to whether the real effect of short selling on corporations is favorable and value-enhancing, which is of particular interest to capital market participants and regulators.

Potential short sellers of a firm's stocks could curb suboptimal investment decisions through two mechanisms. On the one hand, short sellers play an *external governance role* by disciplining self-interested managers. This discipline effect is supported by the evidence that equity lending supply, as a proxy for short selling threats, mitigates value-destroying M&As (Chang et al., 2019). On the other hand, short sellers play an *information intermediary role* by uncovering bad news about their target firms and thus reduce firms' information asymmetry. In brief, short sellers are highly motivated and are able to closely monitor firms, uncover firm-specific hidden information, and force managers to immediately bear the consequences of their misbehavior by triggering price declines.

Short sellers are in a particularly strong position to perform both governance and information roles, compared with other capital market gatekeepers (e.g., financial analysts, institutional investors). It is well established that the information produced by the financial analysts can be biased due to conflicts of interest (e.g., Francis et al., 1997; Mikhail et al., 2004; O'Brien et al., 2005; Malmendier and Shanthikumar, 2007; Jin et al., 2021). In contrast, short sellers are not subject to such bias, and have strong incentives to uncover new

[7] The wide coverage of the equity lending supply data (in the Markit database) ensures a broad market representation and enhances the external validity of the empirical results.

information about the firm because their own capital is at stake. In addition, short sellers can complement the information role of analysts by disclosing negative information about firms.

Regarding institutional investors, despite having a financial stake in the firm, their governance and information intermediary roles can be limited due to their heterogeneous investment strategies.[8] In particular, institutional investors may be reluctant to sell the shares of underperforming firms, for example, to maintain a well-diversified portfolio (Monks and Minow, 1991) or to track a benchmark index (Denes et al., 2017). Consequently, institutional investors tend not to immediately disclose negative firm information to the market. This weakened information role means that managers will only bear the consequence of their suboptimal decisions with a delay, which in turn weakens the discipline effect arising from institutional investors.

Having compared the incentives of short sellers with those of financial analysts and institutional investors, it becomes even clearer that short sellers represent a strong capital market force that can curb both moral hazard and adverse selection, which in turn enhances corporate investment efficiency. We thus propose our main hypothesis (H1) regarding the effect of equity lending supply, as a proxy for short selling threats, on investment efficiency as follows:

H1: Equity lending supply increases corporate investment efficiency.

However, a higher level of equity lending supply in the equity loan market would not necessarily attract more short selling activities. Short sellers' decision to initiate short positions would largely depend on the expected short selling risk. The unique risk faced by short sellers is associated with the uncertainty about the future lending fees and the availability of lendable shares (D'Avolio, 2002; Engelberg et al., 2018). In particular, if the

[8] See Roychowdhury and Srinivasan (2019) for a review on the roles of various gatekeepers in capital markets.

lending fees are highly volatile[9], short sellers, who pay the lending fee on a daily basis until the short position is closed, are more likely to be charged a higher fee in the future; if the share availability is highly volatile, short sellers are more likely to be forced to close their position prematurely due to limited availability of shares[10] (Engelberg et al., 2018). These two forms of short selling risk are "not independent" but are manifestations of the "underlying uncertainty about lending market conditions" (Engelberg et al., 2018) that make the expected profit from short selling highly uncertain.

It has long been recognized that high short selling risk can become a significant impediment to short selling (Miller, 1977; Diamond and Verrecchia, 1987). Indeed, Engelberg et al. (2018) document that stocks with higher short selling risk have less short selling, lower stock price efficiency, and lower future returns. Therefore, the expected short selling risk of being charged a high lending fee and forced to close the short position prematurely could make potential short sellers reluctant to initiate short positions even when equity lending supply is high. We thus expect that short selling risk has a negative moderating effect on the relation between equity lending supply and investment efficiency (H2):

H2: The positive relation between equity lending supply and investment efficiency is less pronounced in the presence of higher short selling risk.

3. Data and Research Design

3.1 Data and sample

We use the level of equity lending supply as a proxy for short selling threats. The equity lending data is provided by Markit (formerly DataExplorer). The Markit data are collected from more than 100 institutional lenders who are major participants in the equity loan

[9] In theory, the variance of loan fees is an important impediment to short selling (D'Avolio, 2002; Duffie et al., 2002).
[10] This is because the lenders have the right to cancel (i.e. recall) the loans at any time.

market.[11] The coverage of Markit represents 90% of the market capitalization of the Centre for Research in Security Price (CRSP) firms (Beneish et al., 2015). Following Massa et al. (2015a), our sample period starts from 2006 due to the relatively limited coverage of the Markit data before 2006. Following the literature (Saffi and Sigurdsson, 2011; Aggarwal et al., 2015; Massa et al., 2015a), we first compute the ratio of the value of a firm's shares available for short sellers to borrow over the market capitalization of the firm on a daily basis. We then define the time-series average of this ratio over a year as the annual equity lending supply (ELS) which is the measure for short selling threats in this study. Our sample includes equity loans of U.S. firms and we drop firms with fewer than 50 non-missing days in a year recorded (Engelberg et al., 2018).

We next merge the equity lending data at the annual frequency with the accounting and financial data from Compustat and CRSP. We exclude firms in the financial industry (SIC codes 6000-6999) as these firms' financial ratios are not comparable with non-financial firms. We also exclude firms in the utility industry (SIC codes 4900-4999) as these firms' investment decisions are regulated. In addition, we also use institutional ownership data from Thomson Reuters 13-F, analyst forecast data from the Institutional Brokers Earnings System (IBES), and governance-related variables from Institutional Shareholder Services (ISS) (formerly RiskMetrics). Appendix A provides the detailed definitions and data sources of all the variables used in our empirical analyses. To mitigate the influence of outliers, we winsorize all continuous variables at the top and bottom 1%. Our final sample consists of 3,246 firms and 21,021 firm-year observations over the period 2006-2018.

3.2 Research design

[11] More detailed information can be found in Saffi and Sigurdsson (2011) who are the first to use the Markit equity lending data.

We test our central hypothesis (H1) that equity lending supply (ELS) enhances corporate investment efficiency using two established approaches for modelling investment efficiency. First, we examine the relation between ELS and the level of investment conditional on whether firms are more likely to over- or underinvest. This conditional test of investment efficiency is proposed by Biddle et al. (2009). Specifically, we follow Biddle et al. (2009) and Cheng et al. (2013) and use two variables, namely cash holdings and leverage, to empirically capture the ex-ante likelihood of over- and underinvestment. The rationale is that firms with more cash and lower leverage face more severe agency problems and are more likely to overinvest (Jensen, 1986), while firms with limited cash and high leverage tend to be financially constrained and consequently are more likely to underinvest (Myers and Majluf, 1984). Thus, a firm's level of cash holdings and leverage could indicate its likelihood of over- and underinvestment.

To implement Biddle et al.'s (2009) conditional test of investment efficiency, we first rank firms in terms of cash holdings and negative leverage (i.e. we multiply leverage by negative one), respectively, into deciles in each year. The two decile rankings are then rescaled between zero and one.[12] Based on these rankings, we construct a composite score, namely *OverFirm*, as the average of the two rankings. A higher score of *OverFirm* indicates a higher likelihood of overinvestment, while a lower score indicates a higher likelihood of underinvestment. To test the effect of ELS on over- and underinvestment, we augment Biddle et al.'s (2009) model by including *ELS* and its interaction with *OverFirm* as follows.

$$Investment_{i,t+1} = \beta_0 + \beta_1 ELS_{i,t} + \beta_2 ELS_{i,t} \times OverFirm_{i,t} + \beta_3 OverFirm_{i,t} + \gamma X_{i,t} + \varepsilon_{i,t+1} \quad (1)$$

[12] To rescale, the raw ranking is subtracted by one and then divided by nine.

where, *Investment* is the level of total investment defined as the sum of capital expenditure, research and development, and acquisition expenditure less the cash receipts from the sales of property, plant, and equipment (PPE) and scaled by lagged total assets (Biddle et al., 2009). *ELS* is the equity lending supply. *OverFirm* measures a firm's likelihood of overinvestment or underinvestment (described above). *X* is a vector of corporate governance proxies and firm-specific control variables, as well as several interaction terms between *OverFirm* and other determinants of investment efficiency used in the literature (Biddle et al., 2009; Cheng et al., 2013). The regression model also includes industry/firm and year fixed effects. The robust standard errors are clustered by firm.

In Eq (1), β_1 measures the relation between ELS and investment for firms with the lowest amount of cash and the highest level of leverage (i.e. *OverFirm*=0). The sum of the two coefficients ($\beta_1 + \beta_2$) measures the relation between ELS and investment for firms with the highest amount of cash and the lowest level of debt (i.e. *OverFirm*=1). As our central hypothesis predicts that a higher level of ELS reduces under- and overinvestment, we expect β_1 to be positive and ($\beta_1 + \beta_2$) to be negative.

Our second approach is to model the optimal level of investment based on growth opportunities, and test whether ELS is positively associated with the closeness between the optimal and the actual level of investment. In this setting, the deviation of the actual level of investment from the optimal level of investment can be used as proxies for over- and underinvestment. Specifically, we use the residuals from an investment model to gauge the magnitude of overinvestment and underinvestment. Similar to Biddle et al. (2009) and Chen et al. (2013), we first estimate an investment model where the actual investment is a function of growth opportunities proxied by sales growth. [13]

[13] Our results are qualitatively similar using Tobin's Q as an alternative proxy for growth opportunities.

$$Investment_{i,t+1} = \beta_0 + \beta_1 Sales\ Gowth_{i,t} + \varepsilon_{i,t+1} \quad (2)$$

where *Investment* is the level of total investment. *Sales Growth* is the percentage change in sales from year t-1 to t. Eq (2) is estimated for each industry-year. The industry classification is based on Fama and French (1997) 48 industries and each industry-year must have at least 20 observations. Positive (negative) residuals capture the extent to which the actual investment is above (below) the optimal level, and thus measure overinvestment (underinvestment). As our main hypothesis (H1) posits that ELS enhances investment efficiency, ELS is expected to reduce the absolute values of the investment residuals from Eq (2). This means that a high level of ELS reduces the deviation of the actual level of investment from the optimal level of investment. To test this conjecture, we estimate a probit model as follows:

$$Eff\_Invest_{i,t+1} = \beta_0 + \beta_1 ELS_{i,t} + \gamma X_{i,t} + \varepsilon_{i,t+1} \quad (3)$$

where *Eff_Invest* takes the value of one if the absolute value of the residuals in Eq (2) is below the median in each year, and zero otherwise. A firm's investment is considered to be efficient if the deviation from the optimal level of investment is relatively low (i.e. *Eff_Invest*=1) (Goodman et al., 2013; Chen et al., 2013). *X* is a vector of corporate governance proxies and firm-specific control variables. The model also includes industry and year fixed effects. The robust standard errors are clustered by firm. We expect that β_1 is positive in Eq (3), meaning that ELS is positively associated with the probability of efficient investment.

To sum up, our empirical analyses are based on two empirical frameworks: (i) a conditional test that examines the effects of ELS on under- and overinvestment respectively,

and (ii) an unconditional test that examines the effect of ELS on the likelihood of efficient investment.

3.3 Summary statistics

Table 1 Panel A reports the summary statistics of the main variables in our empirical analysis. The mean of our main dependent variable, Investment, (in percentage) is 15.675, with a standard deviation of 19.041. The mean of our main explanatory variable, ELS, is 0.150, with a standard deviation of 0.163. These values are comparable to prior literature (Biddle et al., 2009; Chang et al., 2019). In Table 1 Panel B, we present the means of positive, negative, and the absolute values of residuals (estimated from Eq (2)), respectively, across ELS quintiles. By construction, ELS increases across the quintiles shown in the first row of Panel B. The positive residuals (i.e. overinvestment) decrease monotonically from the first quintile to the fifth quintile of ELS. In contrast, the negative residuals (i.e. underinvestment) increase in a monotonic pattern with respect to ELS. The absolute value of residuals (i.e. the aggregate deviation from the optimal level) decreases monotonically across the ELS quintiles. In brief, these univariate results show a clear pattern (see Figure 1) that ELS reduces the magnitude of both overinvestment and underinvestment, indicating that investment efficiency is positively associated with ELS.

[Insert Table 1 and Figure 1 here]

4. Baseline Results

In this section, we first present the baseline results on the relation between equity lending supply (ELS) and investment efficiency (H1), which are based on two empirical frameworks described in Section 3.2.

4.1 Conditional test: ELS and over- and underinvestment

Table 2 shows the results from the conditional test of investment efficiency developed by Biddle et al. (2009). This test (see Eq (1)) allows us to examine the effects of ELS on both underinvestment and overinvestment. Inferences can be made based on the coefficients on ELS and the interaction term, ELS×OverFirm. We control for industry and year fixed effects in Columns (1) and (3), and firm and year fixed effects in Columns (2) and (4). The benefit of controlling for firm fixed effects is that it addresses the concern that the results could be biased due to time-invariant and firm-specific omitted variables.[14]

In Columns (1) and (2), the coefficients on ELS are 9.493 and 18.588 respectively and are significant at 1% level. The positive coefficient on ELS in this particular test suggests that, when firms are more likely to underinvest (OverFirm=0), a higher level of ELS is associated with a higher level of future investment. This means that equity lending supply can reduce underinvestment for firms prone to underinvest. In addition, the coefficients on ELS×OverFirm are -18.374 and -22.589 respectively and are significant at 1% or 5% level. The effect of ELS on firms that are more likely to overinvest can be captured by the sum of β_1 and β_2 in Eq (1), which are the coefficients on ELS and ELS×OverFirm respectively. The sum of these two coefficients are -8.881 and -4.001 in Columns (1) and (2) respectively, and the F-test rejects the null hypothesis that both coefficients are jointly equal to zero.[15] This negative sum of the coefficients on ELS and ELS×OverFirm suggests that, when firms are more likely to overinvest (OverFirm=1), a higher level of ELS is associated with a lower level of future investment. This means that equity lending supply can reduce overinvestment for firms prone to overinvest.

[14] For instance, time-invarient manager heterogeneity (e.g., time preference) may drive corporate investment (Chi et al., 2020).

[15] Following Biddle et al. (2009), we conduct an F-test to examine the joint significance of β1 and β2 in Eq (1). As described in our research design section (section 3.2), a negative sum of β1 and β2 suggests that ELS reduces overinvestment for firms prone to overinvest.

In Columns (3) and (4), we further control for accounting quality and governance variables, and their interactions with OverFirm (Biddle et al., 2009). We obtain consistent results after including these additional control variables. In the full regression model in Column (4), the coefficient on ELS is 21.493 and remains significant at 1% level. Given that the standard deviation of ELS is 0.16, one standard deviation increase in ELS gives rise to a 3.44% increase in investment for firms that are more likely to underinvest. This effect represents an increase of 21.98% relative to the mean of Investment (15.65%). Furthermore, the sum of the coefficients on ELS and ELS×OverFirm is significantly negative at 1% level. In terms of economic significance, one standard deviation increase in ELS decreases investment by 0.48% for firms that are more likely to overinvest. This effect represents a decrease of 3.09% relative to the mean of investment. These findings suggest that ELS reduces both underinvestment and overinvestment, and provide consistent support for H1. Overall, our results based on the conditional test reveal that equity lending supply improves investment efficiency especially for firms prone to underinvest and overinvest.

[Insert Table 2 here]

4.2 Unconditional test: ELS and the probability of efficient investment

Table 3 shows the results from the unconditional test of investment efficiency. This test (see Eq (3)) examines whether a high level of ELS increases the propensity that a firm's actual investment is relatively close to the optimal investment level. Specifically, we use a probit model to estimate the effect of ELS on the likelihood of efficient investment. In Column (1), the results show that ELS has a significant and positive coefficient, suggesting that a high level of ELS increases the propensity of making efficient investment that is close to the optimal level of investment. In Column (2), we further control for accounting quality and governance variables, and the coefficient on ELS is still positive and significant. These

findings are consistent with our central hypothesis that equity lending supply enhances investment efficiency after controlling for other conventional governance mechanisms.

To sum up, both the conditional and unconditional tests of investment efficiency provide supporting evidence that equity lending supply is positively associated with investment efficiency, which is consistent with our H1. Given the difficulties in empirically modelling investment efficiency, it is comforting that the results based on these two alternative approaches are consistent. In our subsequent analyses, we present the results from both approaches.

[Insert Table 3 here]

5. Mitigating Endogeneity

The observed positive relation between ELS and investment efficiency could be subject to endogeneity concerns. In particular, such a relation could be driven by omitted variables. For example, when institutional investors have good knowledge of managers (e.g., about a specific managerial trait) who tend to make efficient investment decisions, these institutional investors are willing to lend out their shares for lending fees. Then, the specific managerial trait could drive both ELS and investment efficiency, making the OLS estimation biased. In addition, it is not clear whether higher ELS enhances investment efficiency, or investment efficiency drives the supply of equity lending. To deal with potential endogeneity issues, we conduct two tests in the following subsections.

5.1 Difference-in-differences estimation

We use the Regulation SHO Pilot Program to test whether regulatory exogenous shocks to short selling restrictions affect investment efficiency. In 2004, the U.S. Securities and Exchange Commission (SEC) announced a pilot program to exempt one-third of the Russell

3000 stocks from price restrictions related to short selling (i.e. short sales could not be placed when stock prices are declining). In particular, approximately 1,000 stocks are randomly selected by the SEC, and short selling these stocks is not subject to uptick rules over the period from May 2, 2005 to August 6, 2007 (e.g., Diether et al., 2009; Grullon et al., 2015; Massa et al., 2015a; Fang et al., 2016). By exploiting this randomized experiment, we attempt to establish a causal relation between short selling threats and investment efficiency by performing difference-in-differences (DiD) tests. [16] Specifically, we first conduct a conditional test of investment efficiency (see Eq (1)) in a DiD framework as follows.

$$Investment_{i,t+1} = \beta_0 + \beta_1 SHO_i + \beta_2 OverFirm_{it} + \beta_3 Post \times OverFirm_{it} + \beta_4 SHO_i \times OverFirm_{it} + \beta_5 Post \times SHO_i + \beta_6 Post \times SHO_i \times OverFirm_{it} + \beta_7 X_{it} + \varepsilon_{it+1} \quad (4)$$

where SHO is an indicator of the treatment group and takes the value of one if a firm is in the pilot group and zero otherwise. Post is an indicator of the post-treatment period and takes the value of one over the SHO period (2005-2007), and zero over the pre-treatment period (2002-2004). OverFirm is the cash and leverage based ranking defined in Eq (1). X is a list of control variables. Similar to the interpretation of the baseline model in Eq (1), β_5 measures the treatment effect when ex-ante probability of underinvestment is high. $(\beta_5 + \beta_6)$ measures the treatment effect when ex-ante probability of overinvestment is high. We expect that β_5 is positive and the sum of β_5 and β_6 is negative, meaning that SHO mitigates underinvestment and overinvestment respectively. Table 4 reports the DiD results. We include industry and year fixed effects in Column (1) and firm and year fixed effects in Column (2). Both Columns (1) and (2) show that the coefficient on Post×SHO is significantly positive, while

[16] Previous studies also employ the SHO pilot program to investigate the treatment effect of short selling on firms' earnings management (Fang et al., 2016; Massa et al., 2015a), price efficiency (Grullon et al., 2015), mergers and acquisitions (Chang et al., 2019), and managerial contracts (De Angelis et al., 2017; Lin et al., 2019).

the coefficient on Post×SHO×OverFirm is significantly negative. The joint significance test suggests that the sum of β_5 and β_6 is significantly negative at 5% or 10% level. These results suggest that SHO significantly reduces underinvestment and overinvestment for firms prone to underinvest and overinvest respectively.

In addition, we conduct an unconditional test of investment efficiency (see Eq (3)) in a DiD framework as follows.

$$Eff\_Invest_{i,t+1} = \beta_0 + \beta_1 SHO_i + \beta_2 Post + \beta_3 Post \times SHO_i + \beta_4 X_{it} + \varepsilon_{it+1} \quad (5)$$

where β_3 measures the treatment effect of SHO on the probability of efficient investment. We expect that β_3 is positive, meaning that SHO increases the probability of making efficient investment decisions. Consistent with this expectation, in Column (2) of Table 4 we find that the coefficient on Post×SHO is significantly positive, suggesting that SHO significantly increases the probability of efficient investment. Overall, our results based on an exogenous regulatory change of short selling restrictions suggest that the heightened short shelling threats, due to the lifted short selling restriction (i.e. SHO), lead to higher investment efficiency.

[Insert Table 4 here]

5.2 Instrumental variable approach

We use the instrumental variable approach to further alleviate the potential endogeneity concern. An ideal instrumental variable should directly correlate with ELS but indirectly correlate with investment efficiency. In the spirit of Hirshleifer et al. (2011), we use the ownership of passive institutional investors ("quasi-indexers") as an instrumental variable of ELS. Passive institutional investors often lend out shares in their portfolios to short sellers.

Thus, changes in the ownership of a firm's stock held by passive institutional investors can lead to changes in the supply of lendable shares. It is worth noting that the changes in the ownership of passive institutional investors are driven by the changes in the benchmark characteristics rather than the information of a specific firm, and thus are reasonably exogenous (Massa et al., 2015a; Chang et al., 2019).[17] Therefore, the ownership of passive institutional investors could satisfy both the inclusion condition (i.e. correlated with ELS) and the exclusion condition (i.e. not directly correlated with investment efficiency other than through ELS).

Following Fang et al. (2016) and Asker et al. (2015), we construct the instrumental variable (denoted as PassiveIO) as the ownership of passive institutional investors classified by Bushee (2001). We undertake a two-stage least squares (2SLS) regression. Considering that both ELS and its interaction term with OverFirm can be endogenous, we use PassiveIO and PassiveIO×OverFirm as instruments for ELS and ELS×OverFirm.[18] Our instrumental variable (IV) estimation thus contains two first-stage regressions and one second-stage regression.[19]

We report the results of the IV regressions in Table 5. Columns (1)-(6) show the results of the conditional test of investment efficiency. We control for industry and year fixed effects in Columns (1)-(3) and firm and year fixed effects in Columns (4)-(6). In the first-stage regression in Columns (1)-(2), the F-statistics are 56.35 and 77.89 respectively, which are far beyond the critical value of 20 for weak exogeneity (Staiger and Stock, 1997),

[17] The portfolios of passive institutional investors, such as ETFs, are managed primarily to replicate their underlying benchmarks. When the composition of the underlying benchmarks changes, passive institutional investors rebalance their portfolios. The purpose of this rebalancing is to minimize tracking errors relative to the benchmarks, rather than to exercise control rights on the firm managers.

[18] See the literature (e.g., Aghion et al., 2005) for a similar instrumental variable analysis where an endogenous variable and its interaction with an exogenous variable are instrumented using an IV and the interaction between the IV and the exogenous variable.

[19] Prior studies (Asker et al., 2015; Fang et al., 2016; Chang et al., 2019) find that stock volatility, momentum, illiquidity, and institutional ownership concentration are correlated with *PassiveIO*. If these variables are also correlated with investment efficiency, controlling for them would make our instrument more exogenous (Larcker and Rusticus, 2010). Our IV results are robust to the inclusion of these four variables as additional controls.

suggesting that the IVs are not weak. Column (3) shows the second-stage results. The instrumented ELS, ELS_INST, is significantly positive, while the instrumented interaction term, (ELS×OverFirm)_INST, is significantly negative. Furthermore, the net effect of ELS_INST and (ELS×OverFirm)_INST is significantly negative, consistent with our hypothesis that ELS reduces both over- and underinvestment. The results still hold in Columns (4)-(6) where we control for firm fixed effects.

In Columns (7)-(8), we estimate the instrumental variable probit model where the dependent variable is Eff_Invest. The first-stage result in Column (7) shows that PassiveIO has a significantly positive effect on ELS, and the F-statistic (96.16) indicates that the IV is not weak. In Column (8), ELS_INST is significantly positive, meaning that equity lending supply increases the probability of efficient investment. Overall, the IV results are consistent with our baseline results, confirming that equity lending supply enhances investment efficiency.

[Insert Table 5 here]

6. Cross-sectional Analyses

Recall the two roles, namely information intermediary and external governance, played by potential short sellers in shaping corporate investment efficiency, one would expect the effect of equity lending supply on investment efficiency to be more pronounced for firms with higher information asymmetry and weaker corporate governance. In addition, according to H2, short selling risk can weaken the effect of equity lending supply. We empirically test the cross-sectional heterogeneity in this section.

6.1 Information asymmetry

Short sellers can reduce the information asymmetry between firms and the market and mitigate adverse selection, and thus enhance investment efficiency. We test this information role of short sellers by examining whether ELS has a more pronounced effect on investment efficiency for firms with higher information asymmetry problems. Following the literature (e.g., Chemmanur et al., 2009; Leary and Roberts, 2010), we use analyst forecast error and analyst forecast dispersion as proxies for information asymmetry.[20] Analyst forecast error is defined as the absolute value of the difference between the actual EPS for year t and the most recent mean analyst EPS forecast that is available before the actual EPS announcement, scaled by stock price as of the end of year t–1. Analyst forecast dispersion is defined as the standard deviation of the most recent analyst EPS forecast for year t scaled by the firms' stock price as of the end of year t−1. High errors and dispersion of analyst forecasts reflect an opaque information environment and high information asymmetry between the firm and investors.

To test information asymmetry as a potential channel through which short selling drives investment efficiency, we partition the full sample into two subsamples of firms with high vs. low information asymmetry. We expect that the information intermediary role of short sellers would be stronger for firms with higher information asymmetry. In Table 6 Panel A, Columns (1) and (3) are based on the subsample with high (above-median) analyst forecast error, while Columns (2) and (4) are based on the subsample with low (below-median) analyst forecast error in each year. In Panel B, Columns (1) and (3) are based on the subsample with high (above-median) analyst forecast dispersion, while Columns (2) and (4) are based on the subsample with low (below-median) analyst forecast dispersion in each year. Using these subsamples, we re-estimate the models specified in Eq (1) and Eq (3).

[20] The results are qualitatively similar when we use analyst coverage as a proxy for information asymmetry.

In Column (1) of Panel A, the coefficient on ELS is significantly positive and the coefficient on ELS×OverFirm is significantly negative. In contrast, although the coefficient on ELS in Column (2) is still significantly positive, the coefficient on ELS×OverFirm becomes insignificant. The results based on these two subsamples suggest that ELS significantly reduces overinvestment for firms prone to overinvest only when analyst forecast error is high. In Column (3), the coefficient on ELS is positive and significant for firms with high analyst forecast error. However, in Column (4) the coefficient on ELS becomes insignificant for firms with low analyst forecast error. This finding suggests that ELS significantly increases the probability of efficient investment only when analyst forecast error is high. In Panel B of Table 6, we obtain consistent results when using analyst forecast dispersion as an alternative proxy for information asymmetry. Taken together, the cross-sectional analyses show that ELS plays a more significant role in enhancing investment efficiency for firms facing high information asymmetry, consistent with short sellers' information intermediary role.

[Insert Table 6 here]

6.2 Corporate governance quality

Short sellers can curb moral hazard, and thus enhance investment efficiency. We test this external governance role of short sellers by examining whether ELS has a more pronounced effect on investment efficiency for firms that are subject to lower quality corporate governance. We first use the co-opted board independence (CBI) as a measure of the quality of internal governance (Coles et al., 2014). The CBI is defined as co-opted independent directors, who are appointed after the CEO assumed office and therefore may not be effective monitors, as a fraction of the total board. The CBI thus better reflects the effectiveness of monitoring from independent directors than the conventional measure of board independence.

High CBI indicates weaker internal governance. In addition, we use the takeover index developed by Cain et al. (2017) as a proxy for the quality of external governance from the takeover market. The takeover index is a firm-level index of the threats of hostile takeovers constructed based on largely exogenous changes in takeover laws. A higher takeover index indicates higher takeover threats and stronger external governance.

To test external governance as a potential channel through which short selling drives investment efficiency, we partition the full sample into two subsamples of firms with high vs. low governance quality. We expect that the external governance role of short sellers would be stronger for firms with weaker alternative internal and external governance mechanisms. In Table 6 Panel C, Columns (1) and (3) are based on the subsample with high (above-median) CBI, while Columns (2) and (4) are based on the subsample with low (below-median) CBI in each year. In Panel D, Columns (1) and (3) are based on the subsample with low (below-median) takeover index, while Columns (2) and (4) are based on the subsample with high (above-median) takeover index in each year. Using these subsamples, we re-estimate the models specified in Eq (1) and Eq (3).

In Column (1) of Panel C, the coefficient on ELS is significantly positive and the coefficient on ELS×OverFirm is significantly negative. In contrast, in Column (2), the coefficient on ELS and the coefficient on ELS×OverFirm become insignificant. The results based on these two subsamples suggest that ELS significantly reduces underinvestment and overinvestment only when CBI is high. In Column (3), the coefficient on ELS is positive and significant for firms with high CBI. However, in Column (4) the coefficient on ELS becomes statistically insignificant for firms with low CBI. This finding suggests that ELS significantly increases the probability of efficient investment only when CBI is high. In Panel D of Table 6, we obtain consistent results when using takeover index as an alternative proxy for governance quality. Taken together, the cross-sectional analyses show that ELS plays a more

significant role in enhancing investment efficiency for firms with lower governance quality, consistent with short sellers' external governance role.

6.3 Short selling risk

The positive effect of equity lending supply on investment efficiency can be weakened by the short selling risk faced by short sellers (H2). Following Engelberg et al. (2018), we use two alternative measures of short selling risk, both of which captures "the same underlying uncertainty about lending market conditions". Our first proxy for short selling risk is $ShortRisk_{Fee}$, defined as the variance of the daily loan fees for each firm over the past 12 months. Our second proxy for short selling risk is $ShortRisk_{Utilization}$, defined as the variance of the daily utilization (i.e. the ratio of the number of shares loaned out to the number of lendable shares) for each firm over the past 12 months. We then partition the sample into low and high short selling risk subsamples. We expect that the role of short sellers in enhancing investment efficiency is more pronounced in the subsample with low short selling risk.

Panels E and F of Table 6 report the results. In Column (1) of Panel E, we use $ShortRisk_{Fee}$ as a proxy for short selling risk, and show that ELS has a positive coefficient and the coefficient on ELS×OverFirm is significantly negative. Thus, the evidence suggests that the positive relation between ELS and investment efficiency remains significant in the subsample with low short selling risk. However, Column (2) of Panel E shows that ELS is significantly positive but the interaction with OverFirm is insignificant, suggesting the effect of ELS is relatively weak in the subsample with high short selling risk. Columns (3) and (4) of Panel E show the results when we use the probit model to estimate the propensity of investment efficiency. Once again, ELS is highly significant in the subsample of low short selling risk but is insignificant in those with high short selling risk. In Panel F, we use $ShortRisk_{Utilization}$ as an alternative proxy for short selling risk, and find largely consistent

results. Overall, the results imply that short selling risk prevents short sellers from curbing managers' suboptimal investment decisions, and thus weakens the positive relation between equity lending supply and investment efficiency.

7. Further Analyses and Robustness

7.1 Financial constraints and the relation between ELS and inefficient investment

To shed further light on how short selling threats drive corporate investment efficiency, we investigate how a key investment friction, namely financial constraints, affects the relation between short selling and investment efficiency.[21] Conceptually, firms in a frictionless world can improve investment efficiency by avoiding both underinvestment (i.e., forgoing positive NPV projects) and overinvestment (i.e., taking negative NPV projects) (Biddle et al., 2009). However, financially constrained firms are limited in their ability to raise external capital and consequently pass up good investment opportunities with positive NPV, leading to underinvestment.[22] In contrast, firms that are financially unconstrained can easily raise external financing and have excessive funds at the disposal of managers, making firms prone to overinvestment. Considering that the underlying mechanisms of the moderating effects of financial constraints may depend on the type of investment inefficiency, we examine underinvestment and overinvestment separately in this section.

7.1.1 How financial constraints affect the relation between ELS and underinvestment

[21] We thank the referees for this valuable suggestion.

[22] In our setting, a firm is defined as investing efficiently if it undertakes any projects with positive NPV (Biddle et al., 2009), and financial constraints are expected to cause underinvestment which is a form of investment inefficiency. A related but different strand of literature shows that financial constraints may improve the quality of project selection (which is beyond the scope of this paper). For instance, Hovakimian (2011) documents that financial constraints increase the efficiency of the internal allocation of corporate resources because limited financial flexibility forces managers to fund more valuable investment opportunities by allocating more capital to relatively high growth segments. Similarly, Almeida et al. (2013) show that financial constraints improve the efficiency of corporate innovation (i.e., maximizing innovation output per unit of input), supporting the view that financial constraints raise the standards for the selection of R&D projects.

On the one hand, we conjecture that short selling threats alleviate the underinvestment problem especially for firms with high ex-ante financial constraints. To the extent that high financial constraints lead to underinvestment (i.e., forgoing positive NPV projects), short selling threats can reduce underinvestment problems by easing financial constraints. In particular, the information role of short selling mitigates adverse selection problems and capital rationing (Myers and Majluf, 1984; Krasker, 1986; Stiglitz and Weiss, 1981), and makes firms less financially constrained.

Panel A of Table 7 presents the results of probit regressions where the dependent variables are Underinvest_D. Underinvest_D is a dummy variable that takes the value of one if the residual from Eq (2) is negative and below the median of the negative residuals, and zero otherwise. Consistent with H1, Column (1) shows that ELS significantly reduces the probability of underinvestment. In Columns (2)-(5), we re-estimate the model in Column (1) based on the subsamples of firm-year observations with high financial constraints in Columns (2) and (4) and low financial constraints in Columns (3) and (5). Using KZ-Index (Kaplan and Zingales, 1997) and WW-Index (Whited and Wu, 2006) to measure financial constraints, we classify firms in the top (bottom) tercile of these three indices into the high (low) financial constraints group. These subsample analyses show that ELS significantly reduces the probability of underinvestment only for firms with high financial constraints because these firms are prone to underinvestment. This evidence suggests that short selling threats can mitigate financial constraints and in turn reduce underinvestment.

[Insert Table 7 here]

7.1.2 How financial constraints affect the relation between ELS and overinvestment

On the other hand, we conjecture that short selling threats alleviate the overinvestment problem especially for firms with low ex-ante financial constraints. Low financial constraints

and the resulting excessive funds make firms prone to overinvestment (i.e., taking negative NPV projects) due to agency problems (Jensen and Meckling, 1976; Jensen, 1986). When short selling threats play a governance role in scrutinizing managers' behaviors (Massa et al., 2015a; Chang et al., 2019), overinvestment would be reduced especially for firms that are susceptible to moral hazard (e.g., empire building).

Panel B of Table 7 presents the results of probit regressions where the dependent variables are Overinvest_D. Overinvest_D is a dummy variable that takes the value of one if the residual from Eq (2) is positive and above the median of the positive residuals, and zero otherwise. Consistent with H1, Column (1) shows that ELS significantly reduces the probability of overinvestment. In Columns (2)-(5), we re-estimate the model in Column (1) based on the subsamples of firm-year observations with high financial constraints in Columns (2) and (4) and low financial constraints in Columns (3) and (5). Similar to Panel A, we classify firms into the high and low financial constraints groups. These subsample analyses show that ELS significantly reduces the probability of overinvestment only for firms with low financial constraints because these firms are prone to overinvestment.

These cross-sectional results are consistent with Chang et al. (2019) which document that a significantly positive association between equity lending supply and market reaction to M&A announcement only exists for less financially constrained firms. They argue that the governance effect of short selling threats on value-destroying acquisitions is stronger for less financially constrained firms where the availability of free cash flow enables self-interested managers to engage in empire building. Our evidence complements Chang et al. (2019) and suggests that the governance role of short selling is more pronounced for firms that are ex-ante financially unconstrained and prone to overinvestment.

In summary, financial constraints play a pivotal role in influencing the relation between short selling and investment efficiency, suggesting that short selling threats can

reduce both underinvestment and overinvestment by playing information and governance roles. These results are in line with our baseline evidence from the Biddle et al. (2009) model (see Eq (1)) which shows that short selling threats significantly increase (reduce) the level of corporate investment for firms that are prone to underinvestment (overinvestment). In a similar vein, the analyses in this section show that short selling threats significantly reduce the probability of underinvestment (overinvestment) when financial constraints are high (low). These results, together with the findings based on the Biddle et al. (2009) model, substantiate the argument that short selling threats can reduce inefficient investment by curbing information and agency problems.

7.2 The direct effects of ELS on investment frictions

The evidence from the previous section implies that loosened financial constraints (thus better access to finance) could be a channel through which ELS reduces underinvestment and improves investment efficiency. To provide further evidence on this mechanism, we explore the direct effects of ELS on financial constraints and financing choices. We first test the effect of ELS on the degree of financial constraints that capture the difficulties faced by firms in accessing external financing. We use the text-based financial constraints measures developed by Hoberg and Maksimovic (2015), including overall constraints, debt constraints, equity constraints and private placement constraints. These measures are constructed directly based on the textual analysis of managerial disclosures in the 10-K files about their own firms' liquidity issues and financing needs.[23] Specifically, the measures capture delayed investment by searching delay related words (e.g., delay, abandon, postpone) around the investment-type words (e.g., construction). Higher overall constraints indicate that a firm is more likely to

[23] This type of discussions are part of the Management Discussion and Analysis (MD&A) section in 10-K file. The text-based financial constraints measures are downloadable from the Hoberg-Maksimovic Financial Constraints Repository (http://faculty.marshall.usc.edu/Gerard-Hoberg/MaxDataSite/index.html). The data is available up to 2015.

delay investment due to financing challenges as disclosed by the managers. In Column (1) of Table 8 Panel A, we regress overall constraints on ELS, controlling for a range of firm characteristics. We find that ELS significantly reduces overall constraints, suggesting that short selling threats mitigate financial constraints.[24]

To sharpen the analysis on financing challenges, we examine and compare the effects of ELS on constraints for different forms of external financing (debt, equity, and private placements). In Columns (2)-(4) of Panel A, we use the three aforementioned measures constructed by Hoberg and Maksimovic (2015) that capture *separately* the constraints in debt, equity, and private placements markets respectively. For instance, a high value of debt constraints indicates that a firm intends to access the debt market but is highly likely to have difficulties in raising debt financing. In Columns (2)-(4), we show that firms with high ELS have significantly lower debt financing constraints and private placement constraints, while the effect of ELS on equity financing constraints is insignificant. These findings suggest that firms with high ELS are significantly less likely to delay investments due to liquidity challenges pertaining to debt and private placement financing.[25] Overall, the evidence in Panel A suggests that ELS decreases financial constraints in general and mitigates the constraints in debt and private placements markets in particular.

A related study (Meng et al., 2020) documents that higher short selling threats following short selling deregulations tighten financial constraints of Chinese firms. The discrepancy between this finding and our results can be largely attributed to the different

[24] We obtain consistent results when using KZ-Index and WW-Index as proxies for overall financial constraints.
[25] There is ample evidence in the literature to suggest that access to debt financing has a considerable impact on corporate investments (e.g., Duchin et al., 2010; Almeida et al., 2011; Amore et al., 2013). However, Hoberg and Maksimovic (2015) do not find evidence that debt-constrained firms significantly curtail investments after negative shocks. This is perhaps due to two potential caveats of the Hoberg-Maksinovic text-based constraints measures. First, the Regulation S-K requires a firm to disclose its investment delay due to financial constraints "only when the firm fails to act on a previously announced investment commitment" (Fazzari et al., 2000, p700). Second, the Hoberg-Maksinovic measures are based entirely on the Liquidity and Capitalization Resource subsection of the MD&A sections, whereas liquidity issues could often be presented in other sections of the 10-K (e.g., the risk factors section) (Bodnaruk et al., 2015). Consequently, as pointed out by Bodnaruk et al. (2015), the Hoberg-Maksinovic approach may be too restrictive in fully revealing the whole picture of financial constraints.

roles short sellers play in the Chinese and US capital markets. A notable difference as highlighted by Meng et al.'s (2020) interview evidence is that Chinese managers often do not consider short selling threats when making decisions and "short sales in China have not yet posed enough threat to managers, nor do they play an effective role in monitoring managers' opportunistic behaviour".[26]

To substantiate our finding that short selling threats make firms generally less financially constrained, we further investigate the effects of ELS on external financing choices in Panel B of Table 8. Specifically, in Columns (1) and (2), we test the effects of ELS on the likelihood of short-term and long-term debt issues respectively, and find that ELS significantly increases long-term debt issues. Consistent with this evidence, in Columns (3) and (4), we find that ELS significantly increases debt maturity, suggesting that short selling threats facilitate firms' access to long-term debt.[27] Longer debt maturity is associated with lower refinancing risk, which in turn allows firms to maintain and enhance investment efficiency (e.g., Harford et al., 2014; Benmelech et al., 2019). Finally, in Column (5), we find that ELS significantly reduces the likelihood of equity issues, perhaps due to the negative impact of short selling on stock prices (Grullon et al., 2015). However, our evidence suggests that firms with high ELS have greater access to long-term debt and private placements, and do not have to rely on equity financing. Taken together, equity lending supply generally mitigates financial constraints, which is an important channel through which equity lending supply improves investment efficiency.

[26] Based on both empirical and interview evidence, Meng et al. (2020) conclude that in Chinese A-share market the monitoring effect of short selling may exist but is "very limited compared to the negative information effect".

[27] Regarding the origins of debt constraints, Hoberg and Maksimovic (2015) provide suggestive evidence that "information is likely not a key factor" and acknowledge that the evidence is inconclusive. In their setting, it is indeed empirically challenging to provide causal evidence because of the endogenous nature of the relationship between information disclosure and debt constraints. Despite the lack of conclusive evidence on the origins of debt constraints, it is relatively well established in the debt maturity literature that long term debt financing can be highly sensitive to information asymmetry (e.g., Flannery, 1986; Barclay and Smith, 1995; Custódio et al., 2013). In particular, using institutional ownership, analyst coverage and Amihud illiquidity as proxies for information asymmetry, Custódio et al. (2013) document that information asymmetry is significantly negatively associated with corporate debt maturity. Therefore, the information role of short selling can facilitate long term debt financing by reducing information asymmetry.

[Insert Table 8 here]

7.3 Robustness tests

To examine the robustness of our evidence to alternative measures of ELS and investment and alternative model specifications, we conduct five additional tests.

7.3.1 Alternative measures of equity lending supply

We use two alternative measures of ELS as a robustness check. The first measure captures the quantity of equity lending supply (ELSQ), defined as the annual average of the daily quantity of lendable shares in the equity loan market divided by the number of outstanding shares of the firm (Engelberg et al., 2018). ELS and ELSQ are similar in the sense that they are based on respectively the value and the quantity of lendable shares. The second measure captures the slack in equity lending supply proposed by Beneish et al. (2015). The level of "supply slack" (SupplySlack) reflects the extent to which the shares of a firm are "easily available to short" in the equity loan market (Beneish et al., 2015). SupplySlack is defined as a dummy variable that takes the value of one if the annual average of the daily cost of borrowing scores (DCBS from Markit) is equal to or below two, and zero otherwise. In Table 9, we find that the results based on these two alternative ELS measures are consistent with the baseline results in Tables 2 and 3.

[Insert Table 9 here]

7.3.2 Capex vs. non-Capex investment

We investigate the effects of ELS on two components of corporate investment: capital expenditure (Capex) and non-capital expenditure (Non-Capex) investment. In particular, we use Capex (defined as capital expenditures scaled by lagged property, plant, and equipment),

and Non-Capex (defined as the sum of R&D and acquisitions scaled by lagged total assets) as dependent variables in Eq (1). In Columns (1)-(2) of Table 10 Panel A, we find that short selling threats have a significantly positive effect on the efficiency of both capital expenditures and non-capital expenditures. In Columns (3)-(4), probit regression results show that ELS significantly increases the likelihood that both Capex and Non-Capex are close to their respective optimal levels, confirming a positive association between ELS and investment efficiency.

7.3.3 Partitions at the aggregate and industry levels

Following Biddle et al. (2009), we use the aggregate investment at the industry and economy levels, respectively, to construct ex-ante measures of the likelihood to over- and underinvest. The benefit of this approach is that investment aggregated at the industry or economy level is less likely to be correlated with the ELS of a particular firm. To measure the industry-level overinvestment probability, we first estimate the investment model (see Eq (2)) using the industry average investment and sales growth for each year. The residuals from this regression are then ranked into deciles and rescaled from zero to one. This rescaled rank is used to measure aggregate industry-year overinvestment, OverIndustry. Similarly, we construct an aggregate overinvestment measure for the whole economy in each year, OverAggregate. We use OverIndustry and OverAggregate respectively to replace OverFirm in the baseline regression (see Eq (1)), and find consistent results in Table 10 Panel B.

7.3.4 Magnitude of underinvestment and overinvestment

We test the effects of ELS on the magnitude of underinvestment and overinvestment respectively. We use the absolute value of the positive (negative) residuals from investment model (see Eq (2)) as a measure of overinvestment (underinvestment). Consistent with our

baseline evidence that equity lending supply increases the probability of efficient investment, we find that ELS significantly decreases the magnitude of both underinvestment and overinvestment in Panel C of Table 10.

7.3.5 Financial crisis

Finally, we examine the effect of financial crisis on the relation between equity lending supply and investment efficiency. Since our sample period starts from 2006, we compare the effects of equity lending supply during (2007-2009) and after (2010-2012) the financial crisis. The financial crisis substantially reduces the supply of external finance for our sample firms. Facing this credit supply shock, a considerable number of firms are financially constrained and have to forego investment opportunities or cut investment (Campello et al., 2010), while those firms with higher equity lending supply (and thus better governance and lower information asymmetry) may have relatively easier access to finance and invest more efficiently. Consistent with this expectation, in Panel D of Table 10 we find that the effect of equity lending supply on investment efficiency is stronger during the crisis period. This evidence suggests that the favorable role of short sellers is more pronounced when firms have difficulties in raising external finance.

[Insert Table 10 here]

8. Conclusion

Does capital market drive corporate investment decisions and thereby have a real effect on the economy? This study sheds light on this important, yet underexplored, question by examining the effect of a particular capital market gatekeeper, namely short sellers, on the efficiency of corporate investment. Understanding the drivers of investment efficiency is important for shareholder value maximization because in the presence of moral hazard and

adverse selection corporate investments (e.g., capital expenditures, R&D, M&As) often deviate from the optimal level and could even be value-destroying. Short sellers, who only profit from share price declines of their target firms, are strongly motivated to uncover hidden firm information (information intermediary role) and closely monitor managers (external governance role). We hypothesize that short sellers are able to enhance investment efficiency, by playing information and governance roles which curb adverse selection and moral hazard.

Empirically, we use the data on an equity market condition, namely equity lending supply (ELS), as a proxy for short selling threats. The increased supply of equity lending exposes a firm to greater short selling threats, which in turn enhances investment efficiency. We find supporting evidence that ELS significantly reduces both corporate underinvestment and overinvestment. This effect is more pronounced for firms subject to higher information asymmetry and weaker corporate governance, consistent with short sellers' information and governance roles. In addition, the effect of equity lending supply is weaker when short selling risk is high. Furthermore, in line with our baseline evidence, we show that equity lending supply significantly reduces the probability of underinvestment (overinvestment) for financially constrained (unconstrained) firms that are prone to underinvestment (overinvestment). An important implication of this study is that corporate investment behavior can be driven by capital market forces in general and equity lending supply in particular. Our study thus suggests that capital market has a real and favorable impact on corporate investment decisions.

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Appendix A Variable definitions

This table presents the definitions and data sources of the main variables.

Variable	Definition	Source
Dependent variables		
Investment	The sum of R&D (item 46), capital expenditure (item 128), and acquisition expenditure (item 129) less cash receipts from sale of property, plant, and equipment (item 107) multiplied by 100 and scaled by lagged total assets (item 6)	Compustat
Eff_Invest	The indicator variable, which is equal to one if the absolute value of residuals estimated by regressing investment on sales growth in each industry-year (see Eq (2)) is below the median and zero otherwise.	Compustat
Capex	Capital expenditure (item 128) multiplied by 100 and scaled by lagged PPE (item 8)	Compustat
Non-capex	The sum of R&D expenditure (item 46) and acquisition expenditure (item 129) multiplied by 100 and scaled by lagged total assets (item 6)	Compustat
Overinvest_D	A dummy variable that takes the value of one if residual estimated by regressing investment on sales growth in each industry-year (see Eq (2)) is positive and above its sample median, and zero otherwise.	Compustat
Underinvest_D	A dummy variable that takes the value of one if residual estimated by regressing investment on sales growth in each industry-year (see Eq (2)) is negative and below its sample median, and zero otherwise.	Compustat
Overinvestment	The absolute value of positive residuals estimated by regressing investment on sales growth in each industry-year (see Eq (2)).	Compustat
Underinvestment	The absolute value of negative residuals estimated by regressing investment on sales growth in each industry-year (see Eq (2)).	Compustat
KZ-Index	An index of financial constraints developed by Kaplan and Zingales (1997). See Farre-Mensa and Ljungqvist (2016) for the data items used to calculate this index.	Compustat
WW-Index	An index of financial constraints developed by Whited and Wu (2006). See Farre-Mensa and Ljungqvist (2016) for the data items used to calculate this index.	Compustat
Overall constraints	A text-based measure of financial constraints. If this value is high, it indicates that a firm is at risk of delaying investments due to liquidity issues.	Hoberg and Maksimovic (2015)
Debt constraints	A text-based measure of debt financing constraints. If this value is high, it indicates that (1) a firm is at risk of delaying investments due to liquidity issues and (2) the firm plans to issue debt.	Hoberg and Maksimovic (2015)
Equity constraints	A text-based measure of equity financing constraints. If this value is high, it indicates that (1) a firm is at risk of delaying investments due to liquidity issues and (2) the firm plans to issue equity.	Hoberg and Maksimovic (2015)
Private placement constraints	A text-based measure of private placement constraints. If this value is high, it indicates that (1) a firm is at risk of delaying investments due to liquidity issues and (2) the firm plans to issue private placements.	Hoberg and Maksimovic (2015)
STD issues	An indicator variable, which is equal to one if debt in current liabilities (item 34) increased by more than 5% of total assets (item 6) in a year and zero otherwise (Hovakimian et al., 2001).	Compustat
LTD issues	An indicator variable, which is equal to one if long-term debt (item 9) increased by more than 5% of total assets (item 6) in a year and zero otherwise (Hovakimian et al., 2001).	Compustat
LTD1_TD	The ratio of long-term debt due in more than one year (item 9) to total debt (item 9+item 34).	Compustat
LTD3_TD	The ratio of long-term debt due in more than three year (item 9-item 91-item 92) to total debt (item 9+item 34).	Compustat
Equity issues	An indicator variable, which is equal to one if net equity issued for cash divided by the book value of assets ((item 108-item 115)/item 6) exceeded 5% and zero otherwise (Hovakimian et al., 2001).	Compustat
Key independent variables		
ELS	The equity lending supply, which is the average ratio of the equity loan amount available to be lent out to short sellers over the market	Markit; CRSP

	capitalization during a year (Saffi and Sigurdsson, 2011).	
ELSQ	The annual average of the daily quantity of lendable shares in the equity loan market divided by the number of outstanding shares of the firm (Engelberg et al., 2018).	Markit; CRSP
SupplySlack	A dummy variable that takes the value of one if the annual average of the daily cost of borrowing the shares (DCBS) is equal to or below two, and zero otherwise. DCBS is a number from 1 to 10 indicating the cost of borrowing this security based on Data Explorers proprietary benchmark rate, where 1 is cheapest and 10 is most expensive (Beneish et al., 2015).	Markit
$ShortRisk_{Fee}$	The variance of the daily loan fees for each stock over the past 12 months (Engelberg et al., 2018).	Markit
$ShortRisk_{Utilization}$	The variance of the daily utilization (i.e. the ratio of the number of shares loaned out to the number of lendable shares) for each firm over the past 12 months (Engelberg et al., 2018).	Markit
OverFirm	A ranked variable based on the average of a ranked (deciles) measure of cash and leverage. Leverage is multiplied by minus one before ranking so that both variables are increasing in the likelihood of overinvestment. The average rankings of the two variables are rescaled from zero to one.	Compustat
OverIndustry	A ranked variable based on the unexplained industry-year investment. Specifically, in each industry-year we measure aggregate investment and regress industry-year investment on industry-year sales growth. We then rank the residuals from this model into deciles and rescale from zero to one.	Compustat
OverAggregate	A ranked variable based on unexplained aggregate (economy-year investment. Specifically, in each year we measure aggregate investment of the whole economy and regress aggregate investment on aggregate sales growth. We then rank the residuals from this model into deciles and rescale from zero to one.	Compustat
Other variables and controls		
AQ	The standard deviation of the firm level residuals from the Dechow and Dichev model during the years t-5 to t-1 and multiplied by negative one. The model is a regression of working capital accruals on lagged, current, and future cash flows plus the change in revenue and PPE. All variables are scaled by average total assets. The model is estimated cross-sectionally for each industry with at least 20 observations in a given year based on the Fama and French (1997) 48 industry classification.	Compustat
IO	Institutional holdings, which is the average percentage of shares held by institutional investors over the past four quarters.	Thomson Reuters 13-F
Analyst	The number of analysts following a firm over a year.	IBES
E-index	The entrenchment index measures a firm's anti-takeover protection and captures six anti-takeover provisions, namely staggered boards, limitation on amending by laws, poison pill, golden parachute, supermajority to approve a merger, and limitation on amending the charter. We multiply negative one on the index so that the governance quality increases with the index.	ISS
Emissing	An indicator variable, which is equal to one if the E-score is missing and zero otherwise.	ISS
LogAsset	The log of total assets (item 6)	Compustat
MTB	The ratio of market value of total assets (item 6+(item 25*item 199)-item 60-item 74) to book value of total assets (item 6).	Compustat
σ(CFO)	Standard deviation of the cash flows from operations deflated by average total assets from years t-5 to t-1	Compustat
σ(Sale)	Standard deviation of the sales deflated by average assets from years t-5 to t-1.	Compustat
σ(Investment)	Standard deviation of investment (Investment, Capex and Non-capex) from year t-5 to t-1.	Compustat
Z-score	3.3(item 170)+(item 12)+0.25(item 36)+0.5((item 4-item 5)/item 6)	Compustat
Tangibility	The ratio of PPE (item 8) to total assets (item 6)	Compustat

IndLeverage	The mean leverage for firms in the same industry	Compustat
CFOsale	The ratio of cash flows from operations to sales (item 12)	Compustat
Cash	The ratio of cash (item 1) to total assets(item 6)	Compustat
Dividend	An indicator variable that takes the value of one if the firm paid a dividend (i.e. if item 21>0 or item 127>0) and zero otherwise.	Compustat
Age	The difference between the first year when the firm appears in CRSP and the current year.	CRSP
OperatingCycle	The log of receivables to sales (item2/item 12) plus inventory to COGS (item 3/item 41) multiplied by 360.	Compustat
Loss	An indicator variable that is equal to one if net income before extraordinary item (item 18) is negative, and zero otherwise.	Compustat
Leverage	The ratio of long-term debt (item 9) to the sum of long term debt to the market value of equity (item 9 +item 25* item 199).	Compustat
Volatility	The standard deviation of daily returns over the past 12 months	CRSP
Past returns	The cumulative return over the past 12 months	CRSP
Illiquidity	The Amihud (2002) illiquidity measure, which is the ratio of the absolute value of daily returns over dollar trading volume. We take the average of these daily ratios over the past 12 months.	CRSP
IO_HHI	The concentration ratio of institutional holdings.	Thomson Reuters 13-F
PassiveIO	The fraction of "quasi-indexers" (Bushee, 2001) holdings.	Thomson Reuters 13-F
Analyst forecast error	The absolute value of the difference between the actual EPS for year t and the most recent mean analyst EPS forecast that is available before the actual EPS announcement, scaled by stock price as of the end of year t–1.	IBES; CRSP
Analyst forecast dispersion	The standard deviation of the most recent analyst EPS forecast for year t scaled by the firms' stock price as of the end of year t−1.	IBES; CRSP
Takeover Index	A firm-level index of the threats of hostile takeovers constructed based on largely exogenous changes in takeover laws (available from Stephen McKeon's website over the period 1964-2014).	Cain et al. (2017)
Co-opted Board Independence (CBI)	CBI is defined as co-opted independent directors, who are appointed after the CEO assumed office and therefore may not be effective monitors, as a fraction of the total board (available from Lalitha Naveen's website over the period 1996-2014).	Coles et al. (2014)

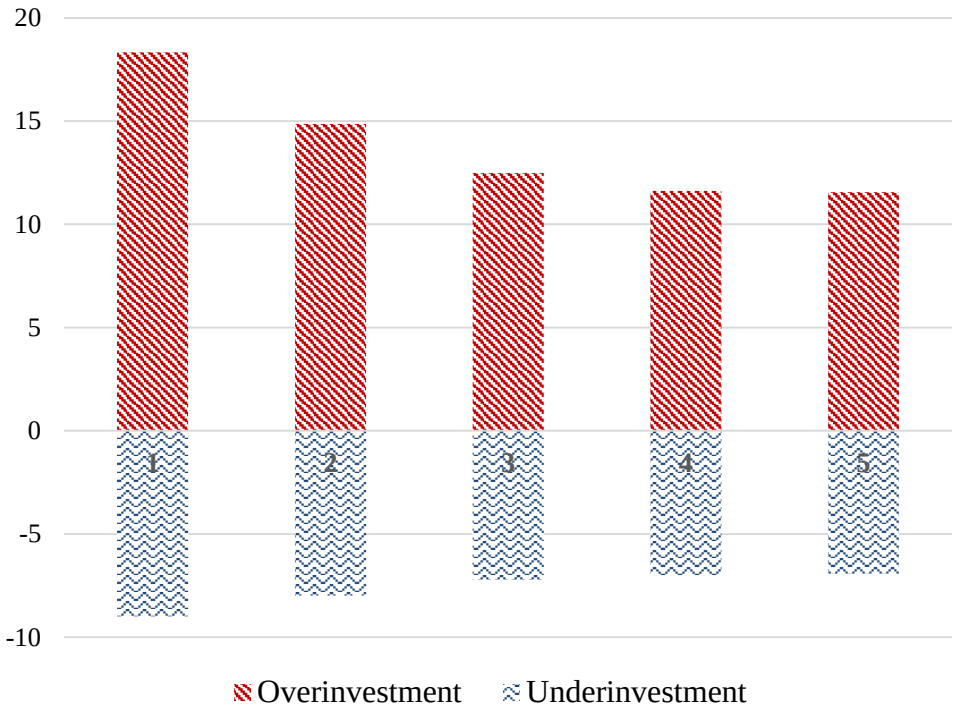

Figure 1 The Magnitude of Overinvestment and Underinvestment across ELS Quintiles

This figure shows the relation between equity lending supply (ELS) and the magnitude of overinvestment and underinvestment respectively. The horizontal axis is the quintiles of ELS, and 1 (5) indicates the bottom (top) quintiles. The vertical axis shows the magnitude of overinvestment (i.e. positive residuals from Eq (2)) and underinvestment (i.e. negative residuals from Eq (2)), respectively.

Table 1 Summary statistics and univariate analysis

This table presents the summary statistics of main dependent and independent variables used in our empirical analyses in Panel A. Panel B reports the univariate analysis on how the averages of overinvestment and underinvestment change across the ELS quintiles. The ELS quintiles are constructed based on the yearly distribution of ELS. Q1 (Q5) indicates the bottom (top) quintile with the lowest (highest) average ELS. Positive residuals and Negative residuals are estimated from Eq (2), and indicate overinvestment and underinvestment respectively. |Residuals| is the absolute value of the residuals from Eq (2). All other variables are defined in Appendix A.

Panel A Summary statistics

Variable	Obs.	Mean	S.D.	25th	Median	75th
Investment (%)	21,021	15.657	19.041	4.226	9.267	19.368
ELS	21,021	0.150	0.163	0.036	0.148	0.244
AQ	21,021	-0.046	0.040	-0.058	-0.033	-0.019
IO	21,021	0.440	4.791	0.095	0.350	0.681
Analyst	21,021	4.963	6.691	0.000	2.000	7.000
E-index	21,021	-0.756	1.535	-4.000	0.000	0.000
Age	21,021	17.781	12.358	8.000	14.000	25.000
LogAsset	21,021	5.362	2.241	3.738	5.226	6.900
MTB	21,021	3.048	5.368	1.088	1.979	3.639
σ(CFO)	21,021	0.228	0.250	0.082	0.146	0.268
σ(Sale)	21,021	0.593	0.640	0.194	0.395	0.751
σ(Investment)	21,021	11.822	37.296	2.269	5.259	11.819
Dividend	21,021	0.406	0.491	0.000	1.000	1.000
Z-score	21,021	0.800	7.737	0.424	1.224	1.910
Tangibility	21,021	0.278	0.241	0.086	0.201	0.408
OperatingCycle	21,021	1.374	11.310	7.115	11.474	17.250
CFOsale	21,021	-3.671	13.831	0.027	0.052	0.124
IndLeverage	21,021	0.180	0.126	0.080	0.154	0.249
Cash	21,021	0.179	0.208	0.028	0.096	0.255
Leverage	21,021	0.181	0.217	0.012	0.102	0.284

Panel B Firm overinvestment and underinvestment across ELS quintiles

	ELS Quintiles				
	Q1 (low)	Q2	Q3	Q4	Q5 (high)
ELS (%)	0.320	3.560	10.325	17.270	25.370
Positive residuals	18.330	14.855	12.485	11.625	11.550
Negative residuals	-8.990	-7.980	-7.225	-6.995	-6.920
|Residuals|	12.670	10.610	9.160	8.585	8.485

Table 2 Baseline evidence: ELS and over- and underinvestment

This table presents the OLS regression results of the effect of equity lending supply (ELS) on investment efficiency. The sample period is 2006-2018. We use the empirical model proposed by Biddle et al. (2009) to examine how ELS drives investment efficiency. The test is based on the following specification (see Eq (1)): $Investment_{i,t+1} = \beta_0 + \beta_1 ELS_{i,t} + \beta_2 ELS_{i,t} \times OverFirm_{i,t} + \beta_3 OverFirm_{i,t} + \gamma X_{i,t} + \varepsilon_{i,t+1}$, where Investment is defined as the sum of R&D, capital expenditure, and acquisition expenditure less cash receipts from sale of PPE multiplied by 100, and scaled by lagged total assets. ELS is a measure of equity lending supply. OverFirm is constructed based on the cash and leverage rankings of each firm. A higher score of OverFirm indicates a higher likelihood of overinvestment, while a lower score indicates a higher likelihood of underinvestment. The main coefficients of interest in the above model are β_1 and $(\beta_1 + \beta_2)$. We expect β_1 to be positive, meaning that ELS reduces underinvestment. We expect $(\beta_1 + \beta_2)$ to be negative, meaning that ELS reduces overinvestment. We report the result of F-test of the joint significance of the coefficients on ELS and ELS×OverFirm, and the F-statistic is reported in square bracket. We control for industry and year fixed effects in Columns (1) and (3), firm and year fixed effects in Columns (2) and (4), and a range of firm and industry-specific characteristics. The detailed definitions of all variables are in Appendix A. Robust t-statistics are reported in parentheses and standard errors are clustered by firm. ***, **, and * indicate significance at 1%, 5%, and 10% level.

Dependent variable	Investment			
	(1)	(2)	(3)	(4)
ELS	9.493***	18.588***	8.396***	21.493***
	(4.34)	(3.20)	(3.04)	(3.58)
ELS×OverFirm	-18.374***	-22.589**	-14.022***	-24.516**
	(-4.31)	(-1.97)	(-3.01)	(-2.15)
Joint significance	-8.881***	-4.001***	-5.626***	-3.023***
	[6.31]	[6.59]	[5.69]	[7.60]
AQ			22.561***	-5.542
			(2.72)	(-0.24)
AQ×OverFirm			-44.990***	15.938
			(-3.76)	(0.37)
Analyst			0.314***	-0.042
			(5.36)	(-0.50)
Analyst×OverFirm			0.043	0.414***
			(1.34)	(2.63)
IO			1.766**	0.934
			(2.52)	(0.53)
IO×OverFirm			-2.553	3.694
			(-1.48)	(1.04)
E-index			-0.405***	0.234
			(-2.60)	(0.68)
E-index×OverFirm			0.224	-0.872*
			(1.04)	(-1.71)
Emissing			1.176**	-0.932
			(2.15)	(-0.78)
OverFirm	10.749***	20.904***	5.716***	20.536***
	(10.45)	(6.14)	(5.37)	(5.63)
Age	-0.049***	0.158*	-0.036***	0.193
	(-6.85)	(1.65)	(-4.84)	(1.39)
LogAsset	-0.457***	-9.194***	-0.903***	-9.221***
	(-6.82)	(-10.10)	(-11.15)	(-9.26)
MTB	0.251***	0.086*	0.210***	0.072

	(9.43)	(1.84)	(11.73)	(1.47)
σ(CFO)	2.655***	-2.065	3.519***	-1.343
	(3.09)	(-1.41)	(7.33)	(-0.81)
σ(Sales)	-0.096	-0.096	-0.329	-0.033
	(-0.25)	(-0.16)	(-1.45)	(-0.05)
σ(Investment)	0.117***	-0.112***	0.101***	-0.120***
	(10.74)	(-3.94)	(14.28)	(-4.00)
Loss	-2.329***	-4.453***	-1.784***	-4.313***
	(-5.51)	(-11.49)	(-8.00)	(-10.89)
Dividend	-1.051***	1.557***	-1.182***	1.607***
	(-4.64)	(2.69)	(-5.67)	(2.76)
Z-score	-1.795***	-1.825***	-1.307***	-1.834***
	(-5.49)	(-6.95)	(-23.80)	(-7.05)
Tangibility	6.477***	3.872	6.596***	2.481
	(9.77)	(0.94)	(10.83)	(0.55)
OperatingCycle	-0.012***	-0.004	-0.011***	-0.005*
	(-10.76)	(-1.47)	(-12.85)	(-1.85)
CFOsale	-0.143***	0.004	-0.118***	0.047
	(-4.10)	(0.08)	(-7.03)	(0.75)
IndLeverage	-10.749***	-11.902***	-8.200***	-11.314***
	(-10.45)	(-5.10)	(-7.85)	(-4.57)
Intercept	11.020**	63.067***	10.262**	63.305***
	(2.36)	(10.78)	(2.31)	(9.16)
Industry and year FE	Y		Y	
Firm and year FE		Y		Y
Observations	21,021	21,021	21,021	21,021
R^2	0.24	0.12	0.28	0.12

Table 3 Baseline evidence: ELS and the probability of efficient investment

This table presents the probit regression result of the effect of ELS on the probability of making efficient investment decisions. The sample period is 2006-2018. The test is based on the following specification (see Eq (3)): $Eff\_Invest_{i,t+1} = \beta_0 + \beta_1 ELS_{i,t} + \gamma X_{i,t} + \varepsilon_{i,t+1}$, where Eff_Invest is a dummy variable that takes the value of one if the absolute value of residuals estimated by regressing investment on sales growth in each industry-year (see Eq (2)) is below the median, and zero otherwise. ELS is a measure of equity lending supply. The main variable of interest is ELS. A positive coefficient on ELS indicates that ELS increases the probability of efficiency investment. We control for both industry and year fixed effects, and a range of firm and industry-specific characteristics. The detailed definitions of all variables are in Appendix A. z-statistics are reported in parentheses and standard errors are clustered by firm. ***, **, and * indicate significance at 1%, 5%, and 10% level.

Dependent variable	Eff_Invest	
	(1)	(2)
ELS	0.500***	0.568***
	(4.68)	(4.05)
AQ		0.612**
		(1.99)
Analyst		0.004
		(0.20)
IO		-0.037
		(-0.88)
E-index		-0.036**
		(-2.66)
Emissing		0.1972
		(1.60)
Age	-0.001	-0.004
	(-0.05)	(-0.55)
LogAsset	0.031***	0.034***
	(4.83)	(3.86)
MTB	-0.013***	-0.014***
	(-6.60)	(-6.41)
σ(CFO)	-0.061	-0.032
	(-1.28)	(-0.56)
σ(Sales)	-0.007***	-0.061**
	(-3.02)	(-2.41)
σ(Investment)	-0.001	-0.001
	(-0.65)	(-0.67)
Loss	0.126***	0.112***
	(5.16)	(4.46)
Dividend	-0.078***	-0.074**
	(-3.65)	(-3.24)
Z-score	0.008	0.007
	(1.46)	(1.16)
Tangibility	0.568***	0.577***
	(8.68)	(8.46)
OperatingCycle	-0.000	-0.000
	(-1.04)	(-0.94)
CFOsale	-0.003	-0.003*
	(-1.62)	(-1.83)
IndLeverage	-0.162	-0.136
	(-1.32)	(-1.09)
Cash	0.067	0.055
	(1.10)	(0.82)
Leverage	0.174**	0.151**
	(2.76)	(2.15)
Intercept	-0.171	-0.331**
	(-1.54)	(-2.44)
Industry and year FE	Y	Y
Observations	21,021	21,021
pesudo-R^2	0.11	0.11

Table 4 Addressing endogeneity: difference-in-differences tests

This table presents the DiD regression results of the treatment effect of SHO (as an exogenous shock to short selling constraints) on investment efficiency. Column (1) shows the conditional test of investment efficiency in a DiD framework (see Eq (4)). Column (2) shows the unconditional test of investment efficiency in a DiD framework (see Eq (5)). In these DiD tests, SHO is an indicator of the treatment group and takes the value of one if a firm is in the pilot group and zero otherwise. Post is an indicator of the post-treatment period and takes the value of one over the SHO period (2005-2007), and zero over the pre-treatment period (2002-2004). In Column (1), we report the result of F-test of the joint significance of the coefficients on Post×SHO and Post×SHO×OverFirm, and the F-statistic is reported in square bracket. Robust t-statistics and z-statistics are reported in parentheses and standard errors are clustered by firm. ***, **, and * indicate significance at 1%, 5%, and 10% level.

Dependent Variable	Investment		Eff_Invest
	(1)	(2)	(3)
SHO	-0.510		-0.056
	(-0.95)		(-1.43)
OverFirm	3.122**	18.715***	
	(2.02)	(13.11)	
Post×OverFirm	-3.924***	-0.124	
	(-3.22)	(-0.11)	
SHO×OverFirm	-2.891**	0.577	
	(-2.05)	(0.23)	
Post×SHO	3.149***	2.482**	0.099*
	(2.85)	(2.28)	(1.76)
Post×SHO×OverFirm	-6.426***	-4.502**	
	(-2.60)	(-2.07)	
Joint significance	-3.277*	-2.020**	
	[2.90]	[4.86]	
Control variables	Y	Y	Y
Industry and year FE	Y		Y
Firm and year FE		Y	
Observations	10,356	10,356	10,356
R^2/pesudo-R^2	0.17	0.17	0.12

Table 5 Addressing endogeneity: instrumental variable approach

This table presents the instrumental variable regression results of the effect of equity lending supply on investment efficiency. We use the "quasi-indexer" ownership (PassiveIO) and PassiveIO×OverFirm as instruments for ELS and ELS×OverFirm in the first-stage regressions in Columns (1)-(2). In Column (4), we use PassiveIO as an instrument for ELS. In the second-stage regressions in Columns (3) and (5), the empirical specifications are the same as Column (2) of Table 2 and Column (2) of Table 3, respectively, except that our main variables of interest are the instrumented ELS (ELS_INST), and the instrumented ELS×OverFirm, ((ELS×OverFirm)_INST). In Column (3), we report the result of F-test of the joint significance of the coefficients on ELS_INST and (ELS×OverFirm)_INST, and the F-statistic is reported in square bracket. Robust t-statistics and z-statistics are reported in parentheses and standard errors are clustered by firm. ***, **, and * indicate significance at 1%, 5%, and 10% level.

Dependent variable	ELS 1st Stage	ELS×OverFirm 1st Stage	Investment 2nd Stage	ELS 1st Stage	ELS×OverFirm 1st Stage	Investment 2nd Stage	ELS 1st Stage	Eff_Invest 2nd Stage
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
PassiveIO	0.071***	-0.007**		0.053***	-0.005		0.063***	
	(10.69)	(-2.08)		(5.13)	(-0.96)		(10.34)	
PassiveIO×OverFirm	-0.021*	0.081***		-0.025*	0.058***			
	(-1.67)	(11.96)		(-1.77)	(5.97)			
ELS_INST			37.241*			96.980***		0.801**
			(1.78)			(2.76)		(2.01)
(ELS×OverFirm)_INST			-85.800***			-122.345**		
			(-2.75)			(-2.30)		
Joint significance			-48.559***			-25.365***		
			[6.25]			[9.89]		
Control variables	Y	Y	Y	Y	Y	Y	Y	Y
Industry and year FE	Y	Y	Y				Y	Y
Firm and year FE				Y	Y	Y		
Observations	21,021	21,021	21,021	21,021	21,021	21,021	21,021	21,021
R^2/pesudo-R^2	0.53	0.71	0.23	0.13	0.25	0.11	0.51	0.14
F-statistics	56.35	77.89		36.67	52.82		96.16	

Table 6 Cross-sectional analysis

This table presents the regression results of the moderating effects of information asymmetry, corporate governance, and short selling risk on the relation between ELS and investment efficiency. Panels A and B compare two subsamples with high information asymmetry in Columns (1) and (3) and low information asymmetry in Columns (2) and (4). Panels A and B use analyst forecast error and dispersion as a proxy for information asymmetry, respectively. Panels C and D compare two subsamples with weak governance in Columns (1) and (3) and strong governance in Columns (2) and (4). Panel C uses co-opted board independence (CBI) as a proxy for internal governance and Panel D uses Takeover Index as a proxy for external governance. Panels E and F compare two subsamples with low short selling risk in Columns (1) and (3) and high short selling risk in Columns (2) and (4). Panel E uses the variance of loan fees ($ShortRisk_{Fee}$) as a proxy for short selling risk and Panel F uses the variance of active utilization ($ShortRisk_{Utilization}$) as a proxy for short selling risk. The empirical specification in Columns (1)-(2) is the same as Column (4) of Table 2. In Columns (1)-(2), we report the result of F-test of the joint significance of the coefficients on ELS and ELS×OverFirm, and the F-statistic is reported in square bracket. The empirical specification in Columns (3)-(4) is the same as Column (2) of Table 3. Robust t-statistics and z-statistics are reported in parentheses and standard errors are clustered by firm. ***, **, and * indicate significance at 1%, 5%, and 10% level.

Panel A Analyst forecast error				
Dependent variable	Investment		Eff_Invest	
	High forecast error	Low forecast error	High forecast error	Low forecast error
	(1)	(2)	(3)	(4)
ELS	27.194***	6.730	0.628**	0.336
	(3.96)	(0.77)	(2.40)	(1.42)
ELS×OverFirm	-36.434**	13.044		
	(-2.50)	(0.72)		
Joint significance	-9.240***	19.774		
	[8.54]	[0.06]		
OverFirm	26.020***	22.617***		
	(5.89)	(3.34)		
Industry and year FE			Y	Y
Firm and year FE	Y	Y		
Observations	8,941	8,941	8,941	8,941
R^2/pesudo-R^2	0.13	0.12	0.13	0.12
Panel B Analyst forecast dispersion				
Dependent variable	Investment		Eff_Invest	
	High forecast dispersion	Low forecast dispersion	High forecast dispersion	Low forecast dispersion
	(1)	(2)	(3)	(4)
ELS	28.475***	5.957	0.629**	0.372
	(3.24)	(0.61)	(2.47)	(1.34)
ELS×OverFirm	-31.225*	4.040		
	(-1.88)	(0.21)		
Joint significance	-2.750**	9.997		
	[3.92]	[0.98]		
OverFirm	31.725***	20.213**		
	(5.60)	(2.56)		
Industry and year FE			Y	Y
Firm and year FE	Y	Y		
Observations	7,025	7,025	7,025	7,025
R^2/pesudo-R^2	0.15	0.10	0.13	0.13
Panel C Co-opted board independence (CBI)				
Dependent variable	Investment		Eff_Invest	
	High CBI	Low CBI	High CBI	Low CBI
	(1)	(2)	(3)	(4)
ELS	53.472***	30.006*	1.363***	0.292
	(3.52)	(1.82)	(4.02)	(0.78)
ELS×OverFirm	-72.233***	-37.024		

	(-2.61)	(-1.21)		
Joint significance	-18.761***	-7.018		
	[9.01]	[2.52]		
OverFirm	-10.826	-16.632		
	(-1.14)	(-1.38)		
Industry and year FE			Y	Y
Firm and year FE	Y	Y		
Observations	3,346	3,346	3,346	3,346
R^2/pesudo-R^2	0.08	0.09	0.24	0.11
Panel D Takeover index				
Dependent variable	Investment		Eff_Invest	
	Low takeover index	High takeover index	Low takeover index	High takeover index
	(1)	(2)	(3)	(4)
ELS	26.873***	10.343	0.569**	0.308
	(2.74)	(1.25)	(1.98)	(1.45)
ELS×OverFirm	-28.585*	2.587		
	(-1.71)	(0.18)		
Joint significance	-1.712**	12.930		
	[4.70]	[0.12]		
OverFirm	16.509***	10.456***		
	(3.58)	(2.69)		
Industry and year FE			Y	Y
Firm and year FE	Y	Y		
Observations	6,566	6,566	6,566	6,566
R^2/pesudo-R^2	0.07	0.05	0.11	0.11
Panel E Volatility of lending fee ($ShortRisk_{Fee}$)				
Dependent variable	Investment		Eff_Invest	
	Low $ShortRisk_{Fee}$	High $ShortRisk_{Fee}$	Low $ShortRisk_{Fee}$	High $ShortRisk_{Fee}$
	(1)	(2)	(3)	(4)
ELS	21.079**	2.168	1.089***	0.242
	(2.39)	(0.29)	(4.65)	(0.74)
ELS×OverFirm	-31.897**	15.384		
	(-1.99)	(0.29)		
Joint significance	-10.818**	17.552		
	[4.65]	[0.33]		
OverFirm	16.987***	14.279***		
	(3.81)	(2.51)		
Industry and year FE			Y	Y
Firm and year FE	Y	Y		
Observations	8,936	9,775	8,936	9,775
R^2/pesudo-R^2	0.14	0.10	0.11	0.11
Panel F Volatility of utilization ($ShortRisk_{Utilization}$)				
Dependent variable	Investment		Eff_Invest	
	Low $ShortRisk_{Utilization}$	High $ShortRisk_{Utilization}$	Low $ShortRisk_{Utilization}$	High $ShortRisk_{Utilization}$
	(1)	(2)	(3)	(4)
ELS	25.209***	8.171	0.743***	0.307
	(2.88)	(0.91)	(3.05)	(1.30)
ELS×OverFirm	-29.420*	-8.456		
	(-1.72)	(-0.52)		
Joint significance	-4.211**	-0.285		
	[5.01]	[0.45]		
OverFirm	26.324***	14.248***		
	(4.52)	(3.13)		
Industry and year FE			Y	Y
Firm and year FE	Y	Y		
Observations	8,886	9,368	8,886	9,368
R^2/pesudo-R^2	0.12	0.09	0.13	0.10

Table 7 Further analysis: Financial constraints and the relation between ELS and inefficient investment

This table presents the regression results of the moderating effects of financial constraints on the relation between ELS and the probability of underinvestment and overinvestment respectively. Panel A and B present the results of probit regressions where the dependent variables are Underinvest_D and Overinvest_D, respectively. Underinvest_D is a dummy variable that takes the value of one if the residual estimated by regressing investment on sales growth in each industry-year (see Eq (2)) is negative and below the median of the negative residuals, and zero otherwise. Overinvest_D is a dummy variable that takes the value of one if the residual estimated by regressing investment on sales growth in each industry-year (see Eq (2)) is positive and above the median of the positive residuals, and zero otherwise. Column (1) is based on the full sample, while in Columns (2)-(5) we split the sample into two subsamples with low financial constraints in Columns (2) and (4) and high financial constraints in Columns (3) and (5). We use KZ-Index (Kaplan and Zingales, 1997) and WW-Index (Whited and Wu, 2006) to measure financial constraints. We classify firms in the top (bottom) tercile of these three indices into the high (low) financial constraints group. We control for industry and year fixed effects and a range of firm and industry-specific control variables used in Column (2) of Table 3. The detailed definitions of all variables are in Appendix A. z-statistics are reported in parentheses and standard errors are clustered by firm. ***, **, and * indicate significance at 1%, 5%, and 10% level.

Panel A The likelihood of underinvestment					
Dependent variable	Underinvest_D				
		KZ-Index		WW-Index	
	Full sample	Low	High	Low	High
	(1)	(2)	(3)	(4)	(5)
ELS	-0.662***	-0.366	-0.806***	-0.151	-1.363***
	(-6.35)	(-1.30)	(-3.29)	(-0.49)	(-5.04)
Control variables	Y	Y	Y	Y	Y
Industry and year FE	Y	Y	Y	Y	Y
Observations	21,021	7,005	7,003	7,006	7,007
pseudo-R^2	0.09	0.09	0.13	0.11	0.14
Panel B The likelihood of overinvestment					
Dependent variable	Overinvest_D				
		KZ-Index		WW-Index	
	Full sample	Low	High	Low	High
	(1)	(2)	(3)	(4)	(5)
ELS	-0.471***	-0.714***	-0.378	-0.780**	-0.070
	(-3.90)	(-2.63)	(-1.45)	(-2.39)	(-0.26)
Control variables	Y	Y	Y	Y	Y
Industry and year FE	Y	Y	Y	Y	Y
Observations	21,021	7,002	7,004	7,006	7,006
pseudo-R^2	0.05	0.08	0.07	0.08	0.10

Table 8 Further analysis: ELS and investment frictions

This table presents the regression results of the effects of equity lending supply (ELS) on financial constraints and external financing. In Panel A, we examine the effects of ELS on various financial constraints. The dependent variable in Columns (1)-(4) are text-based financial constraints measures constructed by Hoberg and Maksimovic (2015), namely overall constraints, debt constraints, equity constraints, and private placement constraints. In Panel B, we examine the effects of external financing choices. In Column (1), the dependent variable is short-term debt issues (STD issues), defined as a dummy variable that takes the value of one if debt in current liabilities increased by more than 5% of the book value of assets in a year (Hovakimian et al., 2001). In Column (2), the dependent variable is long-term debt issues (LTD issues), defined as a dummy variable that takes the value of one if long-term debt increased by more than 5% of the book value of assets in a year (Hovakimian et al., 2001). The dependent variables in Columns (3) and (4) are debt maturity measures. LTD1_TD (LTD3_TD) is defined as the ratio of long-term debt due in more than one (three) years to total debt. The dependent variable in Column (5) is equity issues, defined as a dummy variable that takes the value of one if net equity issued for cash divided by the book value of assets exceeded 5% (Hovakimian et al., 2001). We control for a range of firm characteristics at the beginning of the fiscal year, including LogAsset, MTB, Tangibility, Leverage, Age, AQ, OperatingCycle, CFOsale, σ(CFO), σ(Investment), Analyst, and IO. Robust t-statistics and z-statistics are reported in parentheses and standard errors are clustered by firm. ***, **, and * indicate significance at 1%, 5%, and 10% level.

Panel A Financial constraints

Dependent variable	Overall constraints	Debt constraints	Equity constraints	Private placement constraints
	(1)	(2)	(3)	(4)
ELS	-0.021*	-0.013**	-0.019	-0.023**
	(-1.80)	(-2.17)	(-1.35)	(-2.05)
Control variables	Y	Y	Y	Y
Firm and year FE	Y	Y	Y	Y
Observations	14,711	14,711	14,711	14,711
R^2	0.05	0.05	0.02	0.03

Panel B Access to external financing

Dependent variable	STD issues	LTD issues	LTD1_TD	LTD3_TD	Equity issues
	(1)	(2)	(3)	(4)	(5)
ELS	0.015	0.073**	0.136***	0.153**	-2.378***
	(0.23)	(1.98)	(3.03)	(2.25)	(-10.12)
Control variables	Y	Y	Y	Y	Y
Industry and year FE	Y	Y			Y
Firm and year FE			Y	Y	
Observations	20,978	20,875	19,384	19,384	20,534
R^2/pesudo-R^2	0.11	0.10	0.12	0.07	0.23

Table 9 Alternative measures of equity lending supply

This table presents the regression results of the effects of two alternative measures of equity lending supply (ELS) on investment efficiency. In Columns (1) and (3), the quantity of equity lending supply (ELSQ) is used as an alternative measure of ELS. ELSQ is defined as annual average of the daily quantity of lendable shares in the equity loan market divided by the number of outstanding shares of the firm (Engelberg et al., 2018). In Columns (2) and (4), the level of "supply slack" (SupplySlack), proposed by Beneish et al. (2015), is used as an alternative measure of ELS. SupplySlack is defined as a dummy variable that takes the value of one if the annual average of the daily cost of borrowing the shares is equal to or below two, and zero otherwise. The empirical specification in Columns (1)-(2) is the same as Column (4) of Table 2, except that ELS is replaced with ELSQ. The empirical specification in Columns (3)-(4) is the same as Column (2) of Table 3, except that ELS is replaced with SupplySlack. In Columns (1)-(2), we report the result of F-test of the joint significance of the coefficients on an alternative measure of ELS and its interaction with OverFirm, and the F-statistic is reported in square bracket. Robust t-statistics and z-statistics are reported in parentheses and standard errors are clustered by firm. ***, **, and * indicate significance at 1%, 5%, and 10% level.

Dependent variable	Investment		Eff_Invest	
	(1)	(2)	(3)	(4)
ELSQ	16.893***		0.331**	
	(2.68)		(2.31)	
SupplySlack		7.118***		0.091*
		(3.11)		(1.90)
ELSQ×OverFirm	-19.465*			
	(-1.68)			
SupplySlack×OverFirm		-10.273**		
		(-2.35)		
Joint significance	-2.572**	-3.155***		
	[4.36]	[7.05]		
OverFirm	22.280***	29.890***		
	(5.63)	(4.84)		
Control variables	Y	Y	Y	Y
Industry and year FE			Y	Y
Firm and year FE	Y	Y		
Observations	20,956	19,249	20,956	19,249
R^2/pesudo-R^2	0.23	0.27	0.11	0.11

Table 10 Further robustness tests

This table presents additional evidence on the relation between equity lending supply (ELS) and investment efficiency using alternative specifications. Panel A compares the effects of ELS on two subcomponents of investment, namely capital (Capex) and non-capital expenditures (Non-Capex). Capex is defined as capital expenditures scaled by lagged property, plant, and equipment. Non-Capex is defined as the sum of R&D and acquisitions scaled by lagged total assets. Columns (1)-(2) in Panel A re-estimate Eq (1) using Capex and Non-Capex respectively as dependent variables; Columns (3)-(4) re-estimate Eq (3) using Eff_Cap and Eff_Non-Cap respectively as dependent variables. Eff_Cap (Eff_Non-Cap) is a dummy variable that takes the value of one if the absolute value of residuals estimated by regressing Capex (Non-Capex) on sales growth in each industry-year is below the median, and zero otherwise. Panel B re-estimate Eq (1) using two alternative ex-ante measures of the probability of overinvestment at the industry and aggregate levels respectively (following Biddle et al. (2009)), namely OverIndustry and OverAggregate. Panel C presents the results of OLS regressions where the dependent variables are Underinvestment and Overinvestment respectively. Underinvestment is the absolute value of the negative residuals from Eq (2), and Overinvestment is the absolute value of the positive residuals from Eq (2). Panel D compares the effects of ELS on investment efficiency during and after the financial crisis. The Crisis period is from 2007 to 2009 and the Post-crisis period is from 2010 to 2012. Column (1) re-estimate Eq (1) and Column (2) re-estimate Eq (3), based on the two subperiods. The detailed definitions of all variables are in Appendix A. Robust t-statistics and z-statistics are reported in parentheses and standard errors are clustered by firm. ***, **, and * indicate significance at 1%, 5%, and 10% level.

Panel A Capex vs. non-capex investment				
Dependent variable	Capex	Non-Capex	Eff_Cap	Eff_Non-Cap
	(1)	(2)	(3)	(4)
ELS	17.148**	16.235**	0.567***	0.399**
	(2.31)	(2.00)	(3.26)	(2.15)
ELS×OverFirm	-27.691*	-24.766*		
	(-1.88)	(-1.70)		
Joint significance	-10.543*	-8.531*		
	[3.62]	[3.20]		
OverFirm	11.215**	19.012***		
	(2.07)	(3.58)		
Control variables	Y	Y	Y	Y
Industry and year FE			Y	Y
Firm and year FE	Y	Y		
Observations	21,021	21,021	21,021	21,021
R^2/pesudo-R^2	0.09	0.13	0.15	0.20

Panel B Partitions at the aggregate and industry levels		
Dependent variable	Investment	
	(1)	(2)
ELS	16.807***	29.079***
	(4.01)	(3.73)
ELS×OverIndustry	-20.080***	
	(-3.12)	
ELS×OverAggregate		-37.839***
		(-2.68)
Joint significance	-3.273***	-8.760***
	[14.29]	[9.45]
OverIndustry	4.358***	
	(2.59)	

OverAggregate		5.103
		(0.99)
Control variables	Y	Y
Firm and year FE	Y	Y
Observations	21,021	21,021
R^2	0.12	0.09
Panel C The magnitude of underinvestment and overinvestment		
Dependent variable	Underinvest	Overinvest
	(|Negative residuals|)	(|Positive residuals|)
	(1)	(2)
ELS	-2.229*	-17.949***
	(-1.84)	(-2.67)
Control variables	Y	Y
Firm and year FE	Y	Y
Observations	12,792	8,229
R^2	0.07	0.10

Panel D During and after the financial crisis				
Dependent variable	Investment		Eff_Invest	
	Crisis	Post-crisis	Crisis	Post-crisis
	(1)	(2)	(3)	(4)
ELS	7.273***	20.219***	0.645***	0.390
	(2.72)	(4.68)	(2.64)	(1.60)
ELS×OverFirm	-14.624**	-21.073***		
	(-2.50)	(-2.93)		
Joint significance	-7.351**	-0.854		
	(4.05)	(0.87)		
Control variables	Y	Y	Y	Y
Industry and year FE	Y	Y	Y	Y
Observations	5,837	6,008	5,837	6,008
R^2/pesudo-R^2	0.31	0.30	0.13	0.12